Swarm and Evolutionary Computation 99 (2025) 102130

Contents lists available at ScienceDirect

Swarm and Evolutionary Computation

journal homepage: www.elsevier.com/locate/swevo

# DA2MODE: Dynamic Archive with Adaptive Multi-Operator Differential Evolution for numerical optimization

Mohamed Reda [a,b,*], Ahmed Onsy [a], Amira Y. Haikal [b], Ali Ghanbari [a]

[a] School of Engineering and Computing, University of Lancashire, Preston, PR1 2HE, UK
[b] Computers and Control Systems Engineering Department, Faculty of Engineering, Mansoura University, Mansoura, 35516, Egypt

ARTICLE INFO

Dataset link: https://github.com/MohamedRedaMu/DA2MODE-Algorithm, https://uk.mathworks.com/matlabcentral/fileexchange/182019-da2mode-algorithm

*Keywords:*
Differential Evolution
Evolutionary algorithms
CEC2017 benchmark functions
CEC2020 benchmark functions
CEC2022 benchmark functions
Meta-heuristic optimization

ABSTRACT

This paper presents Dynamic Archive with Adaptive Multi-Operator Differential Evolution (DA2MODE), a new algorithm that aims to boost the performance of meta-heuristic and evolutionary methods in numerical optimization. DA2MODE introduces a Progressive Adaptive Selector with Exponential Smoothing (PASES), which dynamically updates the selection probabilities of both mutation and crossover operators. Unlike prior approaches that emphasize only mutation operators or rely on short-term success within the current generation, PASES adapts based on cumulative operator performance over time, thus favoring the best-performing operators more reliably. DA2MODE employs an Adaptive Non-Elite Archive Update (ANEAU) mechanism that injects a controlled fraction of non-elite solutions into the archive. ANEAU promotes early exploration, which is gradually reduced to strengthen exploitation. Additionally, the control parameters (crossover probability and mutation factor) are automatically tuned in DA2MODE, allowing full adaptivity of both operator selection and parameter control. Extensive experiments on the CEC2017/2018, CEC2020-2022, and 1000-dimensional CEC2013 benchmarks, along with four real-world engineering design problems, confirm that DA2MODE consistently outperforms 33 competitive algorithms, including CEC winners and recent advanced DE variants. It achieves top performance across all statistical tests, demonstrating superior convergence speed and final accuracy. These results establish DA2MODE as a robust, scalable, and reliable algorithm for solving complex numerical optimization problems. The source code of the DA2MODE algorithm is publicly available at: URL https://github.com/MohamedRedaMu/DA2MODE-Algorithm and URL https://uk.mathworks.com/matlabcentral/fileexchange/182019-da2mode-algorithm.

## 1. Introduction

### 1.1. Background

Meta-heuristic and evolutionary algorithms have become essential tools for tackling complex numerical optimization problems in engineering [1], IoT [2], control systems [3], robotics, and machine learning [4]. They serve as general-purpose solvers capable of searching large design spaces without requiring gradient information, thus avoiding the local minima trap for high-dimensional or non-differentiable function [5]. Over the years, these algorithms have diversified into various categories, including evolutionary-based methods, trajectory-based solvers, swarm-based optimizers, and nature-inspired strategies [6].

Recent research has introduced both classical and advanced variants of meta-heuristics. Evolutionary-based algorithms like Genetic Algorithm (GA) [7], Differential Evolution (DE) [8], and Covariance Matrix Adaptation Evolution Strategy (CMA-ES) [9] employ survival-of-the-fittest principles to evolve populations, whereas trajectory-based methods such as Simulated Annealing (SA) [10] refine candidate solutions by sampling neighborhoods.

Swarm-based optimizers, including Particle Swarm Optimization (PSO) [11], Grey Wolf Optimization (GWO) [12], and Artificial Bee Colony (ABC) [13], mimic collective animal behaviors. Meanwhile, nature-inspired algorithms such as Firefly Algorithm (FA) [14], Beetle Antennae Search (BAS) [15], Teaching-Learning-Based Optimization (TLBO) [16], and Moth–Flame Optimization (MFO) [17] draw on natural phenomena.

### 1.2. State-of-the-art DE variants

DE is particularly known for its simplicity and powerful search dynamics based on mutation, crossover, and selection. Its consistent success in major competitions, such as CEC2020-2022 [18], has led to

* Correspondence to: School of Engineering and Computing, University of Lancashire, Preston, PR1 2HE, UK.
*E-mail addresses:* Mohamed.reda.mu@gmail.com, Mohamed.reda@mans.edu.eg (M. Reda).

https://doi.org/10.1016/j.swevo.2025.102130
Received 10 February 2025; Received in revised form 2 August 2025; Accepted 8 August 2025
Available online 19 September 2025

a wide array of advanced variants designed to overcome classical DE's sensitivity to parameter tuning and premature convergence [19].

Recent research has focused extensively on enhancing Differential Evolution (DE) through adaptive and self-adaptive strategies. Mutation, the core operator in DE, generates a mutant vector by perturbing individuals using scaled differences between randomly selected vectors. A prominent trend involves multi-operator mutation frameworks, where several mutation strategies are employed concurrently, and their selection is guided by success rates within the current generation [20,21]. Crossover combines the mutant and target vectors to produce trial solutions. DE primarily adopts two crossover types: binomial crossover, which swaps individual components based on a fixed probability, and exponential crossover, which swaps contiguous segments—particularly effective in problems with correlated variables or structured landscapes [22].

The archive is another critical design component in advanced DE variants. It stores previous individuals to diversify the candidate pool during mutation, thereby enhancing population diversity and reducing the risk of premature convergence. Most existing approaches populate the archive either randomly or with elite individuals [23]. Lastly, adaptive parameter control mechanisms have been introduced to dynamically adjust the mutation factor ($F$) and crossover rate ($CR$) during evolution. Memory-based approaches update parameter memories based on successful offspring, reducing manual tuning [21].

Multiple leading CEC winners are indeed DE variants. For instance, Improved Multi-Operator Differential Evolution (IMODE) achieved first place at CEC2020 [20]. Multiple Adaptation Differential Evolution (MadDE) [24] captured victory in CEC2021, while the Hybrid Sampling Evolution Strategy (HSES) topped CEC2018 [25], and the Evolutionary Algorithm with Eigen Crossover (EA4eig) claimed first place at CEC2022 [26].

### 1.3. Literature gap and motivation

Despite recent progress, many DE variants continue to face critical limitations. First, the selection of mutation operators is often random or based solely on short-term success within the current generation [23], disregarding the cumulative performance of operators across the entire search process [27,28]. Second, crossover mechanisms remain under-explored; binomial crossover is used almost exclusively despite evidence that exponential crossover performs better in problems with contiguous variable dependencies or structured landscapes [27]. Moreover, most existing methods rely on random or fixed crossover selection without learning from past performance [29,30].

Third, archive update strategies commonly store either elite or randomly selected individuals, mirroring the population [31]. This problem reduces population diversity and increases the risk of premature convergence. Lastly, most adaptive parameter schemes—particularly for mutation factor ($F$) and crossover rate ($CR$)—rely on memory updates that occur only after successful offspring are generated [21]. This approach ignores feedback from failed trials and leads to the repeated use of the same parameter values across many individuals. This results in repeated reuse of the same parameter values across many individuals, reducing diversity in parameter space and effectively turning adaptive schemes into static ones.

To overcome these limitations, the proposed DA2MODE algorithm introduces a unified and fully adaptive framework that combines historical performance-based operator selection, feedback-driven crossover adaptation, dynamic archive strategies, and failure-aware parameter control.

### 1.4. Contributions

The main contributions can be summarized as follows:

- **Progressive Adaptive Selector with Exponential Smoothing (PASES).** Unlike previous approaches that rely solely on short-term success rates, a novel operator-selection framework is introduced to adaptively adjust the selection probabilities of both mutation and crossover operators. PASES incorporates a cumulative performance metric based on historical improvement using exponential smoothing. This enables a more informed and stable adaptation process that consistently favors effective operators over time.
- **Adaptive Non-Elite Archive Update (ANEAU).** An innovative archive-management method is proposed, which periodically adds non-elite solutions in a controlled manner. This encourages exploration during early phases and gradually reduces non-elite inclusion as the algorithm converges, mitigating premature convergence while balancing exploration and exploitation.
- **Adaptive Population Size and Control Parameter as Core Features.** DA2MODE employs an automated procedure for critical hyperparameters (e.g., crossover probability and mutation factor). These adaptive mechanisms are tightly coupled with the newly proposed methods (PASES and ANEAU) to minimize manual tuning efforts and maintain high performance under diverse conditions.
- **Comprehensive Benchmark Evaluation.** DA2MODE is validated on CEC2017/2018 (29 functions up to 100D), CEC2020/2021 (10 functions at 10D and 20D), CEC2022 (12 functions at 10D and 20D), and CEC2013 (15 functions up to 1000D). Comparisons against 33 state-of-the-art methods, including top CEC competition winners, reveal that DA2MODE achieves the smallest average errors and highest win rates in Wilcoxon and Friedman tests.
- **Superior Overall Performance.** Using normalized-error scoring, DA2MODE attains a top score of 93.94%, notably higher than the second-ranked ALSHADE at 82.81%. This gap underscores DA2MODE's distinct advantage in both accuracy and robustness for high-dimensional and complex optimization tasks.

### 1.5. Paper organization

The rest of this manuscript is structured as follows: Section 2 discusses the DE variants and related optimization methodologies in the literature. Section 3 then presents the proposed DA2MODE approach, highlighting its newly introduced strategies. Next, Section 4 details the benchmark functions, includes a sensitivity analysis of DA2MODE, and outlines the parameter settings employed for all algorithms in the comparative study. Section 5 presents the performance of DA2MODE on the CEC2020-2022 benchmarks against a group of 20 diverse algorithms, while Section 6 compares its performance with 13 advanced DE variants. Sections 7 and 8 report results on the CEC2017 suite for high-dimensional problems using the same two algorithm groups, respectively. Section 9 evaluates the scalability of DA2MODE on the large-scale CEC2013 functions (1000D) against top-performing methods. Section 10 applies the DA2MODE on constrained engineering optimization problems. Section 11 provides a comprehensive discussion of the experimental results. Finally, Section 12 summarizes the findings and outlines future research directions.

## 2. Literature review and DE principles

This section reviews recent advancements in meta-heuristic optimization, with a focus on Differential Evolution (DE) design principles and algorithmic enhancements relevant to the development of DA2MODE.

### 2.1. State-of-the-art algorithms

This subsection surveys state-of-the-art meta-heuristic algorithms, including competition-winning approaches and recent advanced Differential Evolution variants.

#### 2.1.1. Meta-heuristic optimization algorithms

Meta-heuristic optimization algorithms have emerged as versatile solvers for high-dimensional and complex optimization problems, offering general-purpose strategies inspired by natural and social phenomena. These algorithms are broadly categorized by their underlying design principles into evolutionary-based, trajectory-based, swarm-based, and nature-inspired families.

Evolutionary algorithms operate on a population of solutions, iteratively applying selection, recombination, and mutation to simulate biological evolution. Prominent methods include Genetic Algorithms (GA), Covariance Matrix Adaptation Evolution Strategy (CMA-ES), and Differential Evolution (DE) [3].

Swarm intelligence-based methods simulate decentralized cooperation among simple agents. Representative examples include Artificial Bee Colony (ABC), Particle Swarm Optimization (PSO), and Grey Wolf Optimization (GWO) [32]. Trajectory-based optimizers, such as Simulated Annealing (SA) [33], explore the solution space through guided perturbations.

Nature-inspired designs extend the landscape by emulating physical and ecological processes. Algorithms like Teaching-Learning-Based Optimization (TLBO) [34], Moth–Flame Optimization (MFO) [35], Firefly Algorithm (FA), and Harris Hawks Optimization (HHO) [36] utilize behavior-driven adaptation mechanisms.

#### 2.1.2. CEC winners

Differential Evolution (DE) and its variants have consistently ranked among the top-performing algorithms in the IEEE CEC benchmark competitions, attributed to their balance of simplicity, robustness, and effectiveness [37].

In the CEC 2018 competition, Zhang and Shi proposed the HSES algorithm, a hybridization of the Covariance Matrix Adaptation Evolution Strategy (CMA-ES) and univariate sampling that demonstrated superior robustness and convergence [25]. HS-ES ranked first in the competition.

Later, in CEC 2020, Sallam et al. introduced the IMODE, which employs multiple mutation operators and selects among them based on recent population diversity and success rate [20]. IMODE secured the first place in CEC2020. In the same competition, Mohamed et al. proposed the Adaptive Gaining-Sharing Knowledge (AGSK) algorithm, inspired by knowledge acquisition and transfer among individuals [38], earning second place.

The CEC 2021 competition featured two prominent winners. Biswas et al. introduced the MadDE, which integrates the success-history-based parameter adaptation strategy of SHADE to update the mutation factor ($F$) and crossover rate ($CR$) [24]. Additionally, Mohamed et al. proposed the Adaptive Parameters Gaining-Sharing Knowledge IMODE Hybrid (APGSKIMODE), which merges the strengths of IMODE and AGSK while using an adaptive selection scheme based on population diversity and random crossover switching [23]. Both algorithms ranked first in CEC2021.

In CEC 2022, Bujok and Kolenovský introduced the EA4eig, a suite of four hybrid methods that incorporate eigenvector-based crossover mechanisms to adapt search directions effectively [26]. EA4eig achieved first place in the competition.

#### 2.1.3. Advanced and recent differential evolution variants

Beyond the competition-winning algorithms, numerous DE variants have emerged to address core limitations such as premature convergence, lack of diversity, and fixed control parameters. Civicioglu et al. introduced the *Weighted Differential Evolution* (WDE), which uses fully randomized parameter control to increase unpredictability and global search capability [39]. Moharam et al. proposed the *Equilibrium Optimizer Differential Evolution* (EODE), a hybrid combining DE and Equilibrium Optimizer (EO) to enhance convergence and stability [40]. Karkinli developed the *Multi-Population-Based Differential Evolution* (MDE), incorporating partial elitist mutation and parameter-free crossover [41].

Nadimi-Shahraki et al. presented the Multi-Trial Vector-Based Differential Evolution (MTDE), where diverse mutation strategies are applied to different subpopulations [42]. Civicioglu and Besdok proposed multiple parameter-free DE variants, including the Bernstein Search Differential Evolution (BSD) [43], the Bernstein–Levy Differential Evolution (BDE) with elitist mutation and Bernstein polynomial crossover [44], and the Bezier Search Differential Evolution (BeSD), which introduces Bezier-based search operators [45].

Layeb developed several notable DE variants as well. The mean Differential Evolution (meanDE) employs a population-mean-based strategy with adaptive control parameters, while the mean Differential Evolution with Weibull Distribution (mDEW) uses a Weibull-inspired flight mechanism in the mutation process [27]. Li et al. proposed the Adaptive Success-History Based Differential Evolution (ALSHADE), which introduces a population-mean-based mutation and archives successful historical parameter values for adaptive learning [21].

Haro et al. designed the Quartile-Based Ranked Differential Evolution (QRDE), which partitions the population into quartiles and applies rank-based mutation to favor promising search zones [46]. Zhang and Sanderson introduced the foundational Adaptive Differential Evolution with Optional External Archive (JADE), employing adaptive parameters and external archive-based directional guidance [29]. Building on this, Al Hwaitat and Fakhouri developed the JADE with Geometric Mean Optimizer Hybrid (JADE-GMO), enhancing JADE with elite-guided velocity updates [31].

Yildirim et al. proposed the Dynamic Fitness-Distance Balance SHADE (dFDBLSHADE), which employs a novel dynamic balance between fitness improvement and solution distance to guide mutation, coupled with a linear population size reduction scheme [28].

### 2.2. Differential evolution design trends

This section reviews the operator-level design trends in Differential Evolution (DE), focusing on mutation rules, operator selection, crossover mechanisms, parameter adaptation, and archive strategies. The aim is to highlight the strengths and limitations of various DE enhancements and identify gaps for further innovation.

#### 2.2.1. Mutation operators

Mutation operation is the fundamental update mechanism in differential evolution (DE), and it is responsible for generating new candidate solutions (mutants) by perturbing existing individuals. Mutation strategies in DE can be broadly classified into three categories based on their design principle and search behavior.

The first category relies solely on random individuals for exploration. A representative example is the classical DE/rand/1 mutation strategy proposed by Storn and Price [47], defined in Eq. (1). In this formulation, $x^g_{r1}$, $x^g_{r2}$, and $x^g_{r3}$ are three distinct individuals randomly selected from the current population, and $F$ is the mutation scaling factor.

$$v^g_i = x^g_{r1} + F \cdot (x^g_{r2} - x^g_{r3}) \tag{1}$$

The second category emphasizes exploitation by guiding mutants toward the best-performing individuals. One example is DE/best/1, shown in Eq. (2), which uses the best solution in the current population $x^g_{\text{best}}$ to guide the search [48,49]. However, to reduce greediness and maintain diversity, variants such as DE/pbest/1 (Eq. (3)) select $x^g_{\phi\text{best}}$ randomly from the top $\phi \cdot 100\%$ of the population [50,51].

$$v^g_i = x^g_{\text{best}} + F \cdot (x^g_{r1} - x^g_{r2}) \tag{2}$$

$$v^g_i = x^g_{\phi\text{best}} + F \cdot (x^g_{r1} - x^g_{r2}) \tag{3}$$

The third category incorporates directional guidance using the current individual itself. A notable example is DE/current-to-pbest/1, which balances personal and global guidance (Eq. (4)). Its variant,

DE/current-to-pbest/1 with archive (Eq. (5)), further introduces an archive to diversify the evolutionary process by selecting $\hat{x}^g_{r2}$ from both current and historical solutions [29,52].

$$v^g_i = x^g_i + F \cdot (x^g_{\phi\text{best}} - x^g_i) + F \cdot (x^g_{r1} - x^g_{r2}) \tag{4}$$

$$v^g_i = x^g_i + F \cdot (x^g_{\phi\text{best}} - x^g_i) + F \cdot (x^g_{r1} - \hat{x}^g_{r2}) \tag{5}$$

Other directionally guided strategies include DE/weighted-rand-to-$\phi$best/1, which generates the mutant vector by combining a scaled random individual $x^g_{r1}$ with a directional difference between a top-ranked individual $x^g_{\phi\text{best}}$ and a randomly selected individual $x^g_{r2}$, as shown in Eq. (6). It has been effectively used in high-performing DE variants such as IMODE [20].

$$v^g_i = F \times x^g_{r1} + (x^g_{\phi\text{best}} - x^g_{r2}) \tag{6}$$

### 2.2.2. Multiple operators and selection strategies

Several Differential Evolution (DE) variants employ a single mutation operator throughout the optimization process. Examples include WDE [39], EODE [40], BSD [43], BeSD [45], meanDE [27], QRDE [46], JADE [29], and JADEGMO [31]. However, using a fixed mutation rule limits the algorithm's adaptability because no single operator can perform optimally across different problem landscapes. Consequently, such strategies often fail to generalize to problems with varying modalities and separability.

To address this limitation, various DE variants increasingly adopt multiple mutation operators to combine their complementary strengths [23]. These approaches differ in how they select among the available operators.

One of the simplest strategies is random operator selection, where a mutation rule is randomly assigned to individuals in the population. This method is used in MDE [41], BDE [44], and mDEW [27]. While simple to implement, random assignment is unguided and does not consider the operators' success or the problem type. As a result, it may lead to inefficient search progress or redundant operator use.

Another common strategy is scheduled switching, where the applied operator is changed at predefined stages of the run. For example, dFDBLSHADE [28] applies different mutation strategies in distinct phases of the optimization process. This method can be beneficial for structuring exploration and exploitation across early and late stages. However, since the same operator is applied to the entire population at each iteration, the algorithm behaves as a single-operator DE at each point in time. Thus, it suffers from the same drawbacks: limited generalization and a lack of individual-level adaptation.

More advanced methods adopt adaptive operator selection based on performance metrics. Examples include MadDE [24], ALSHADE [21], MTDE [42], IMODE [20], and APGSKIMODE [23]. These algorithms evaluate operator success based on short-term feedback such as recent fitness improvements or diversity contributions. Although this adaptive mechanism introduces some adaptation capability, it relies only on the current generation's performance. As such, it may fail to capture the long-term effectiveness of each operator, which can result in premature operator elimination or suboptimal reuse patterns.

### 2.2.3. Crossover mechanisms

The crossover operator in Differential Evolution (DE) generates an offspring $u^g_i$ by combining elements from the mutant vector $v^g_i$ and the parent vector $x^g_i$. Two main types are commonly employed: binomial and exponential. In the binomial crossover, each dimension $j$ is independently selected from the mutant vector with a probability $CR_i$, or otherwise from the parent vector, as defined by Eq. (7). This form is computationally efficient and widely used across DE variants due to its simplicity.

$$u^g_{i,j} = \begin{cases} v^g_{i,j} & \text{if rand}_{i,j} \le CR_i \\ x^g_{i,j} & \text{otherwise} \end{cases} \tag{7}$$

In contrast, exponential crossover selects a contiguous block of dimensions from the mutant vector. A random start index $S \in [1, D]$ is chosen, and a block length $L$ is derived based on $CR_i$. The crossover is then applied using Eq. (8). The exponential crossover can better preserve structural relationships between variables, especially in problems where variables are interdependent [22].

$$u^g_{i,j} = \begin{cases} v^g_{i,j} & \text{if } (j \ge S) \text{ and } (j < S + L) \\ x^g_{i,j} & \text{otherwise} \end{cases} \tag{8}$$

Despite the potential of exponential crossover, most DE algorithms in the literature rely exclusively on the binomial version. Examples include dFDBLSHADE [28], WDE [39], JADEGMO, mDEW, JADE [29], MTDE [42], QEDE [46], ALSHADE [21], EODE [40], MDE [41], BSD [43], BDE [44], BeSD [45], and meanDE [27]. While this choice offers implementation simplicity and competitive performance, it may hinder the algorithm in scenarios where the structure or order of variables significantly impacts fitness.

Some recent variants combine both crossover types to combine their complementary strengths. For instance, IMODE [20], MadDE [24], and APGSKIMODE [23] randomly switch between binomial and exponential crossover during execution. Although this hybridization introduces adaptation, the use of random selection again lacks problem awareness. It does not guarantee that the most suitable crossover type is chosen for each individual or stage of the search.

### 2.2.4. Adaptive parameters CR and F

The control parameters, crossover rate (CR) and mutation factor (F), are essential in guiding the search. Several DE variants employ fixed values for these parameters throughout the optimization process. Examples include EODE [40], QRDE [46], meanDE (static CR) [27], and mDEW (static CR) [27]. However, static configurations often lead to imbalanced search behavior. A low CR or F may restrict exploration and cause premature convergence, while a high setting may reduce exploitation and slow convergence.

Some algorithms adopt random parameter assignment, generating CR and F values uniformly within the range [0, 1]. This approach is used in MDE [41], BSD [43], BDE [44], BeSD [45], WDE [39], meanDE (random F) [27], and mDEW (random F) [27]. Although this method increases stochastic diversity, it lacks feedback mechanisms to align parameter settings with problem characteristics or search phases. As a result, the algorithm may unintentionally overemphasize exploration or exploitation at inappropriate times.

A more systematic approach is adaptive parameter control via historical memory. In this design, CR and F values that led to successful offspring are stored in an archive, and future values are sampled from this memory. This mechanism was introduced in JADE [29] and has since been extended in several variants including MadDE [24], IMODE [20], APGSKIMODE [23], ALSHADE [21], MTDE [42], JADEGMO [31], and dFDBLSHADE [28]. These methods use success-driven feedback to guide parameter adaptation. However, when no improvement occurs over multiple generations, the archive of successful parameters remains static. Consequently, the algorithm may reuse ineffective parameter settings, increasing the likelihood of getting trapped in local optima.

### 2.2.5. Archive and its update

In many DE variants, mutation strategies draw individuals solely from the current population. Algorithms such as EODE [40], MDE [41], BSD [43], meanDE [27], QRDE [46], WDE [39], and mDEW [27] relies entirely on current population, typically using strategies like DE/rand/1. However, as the population converges in later generations, diversity diminishes, increasing the risk of premature convergence.

Several DE variants incorporate an archive that stores individuals from previous generations to address this problem. Mutation operators in these algorithms, such as DE/current-to-$\phi$best/1 with archive, sample individuals from both the current population and the archive,

thereby enhancing the diversity of candidate solutions. Notable examples include IMODE [20], APGSKIMODE [23], MadDE [24], BDE, BeSD, JADE [29], JADEGMO [31], and dFDBLSHADE [28]. These variants typically use random insertion and deletion strategies to manage archive size, but such randomness may not ensure sufficient diversity retention in the archive.

Some DE variants adopt elitist update rules. For instance, AL-SHADE [21] and MTDE [42] remove the worst individuals from the archive and replace them with top-performing individuals from the population. While this approach appears to enhance solution quality, it undermines the archive's core purpose. By selecting elite individuals from the population, the archive loses its role as a source of historical diversity and becomes redundant, limiting its ability to counter premature convergence.

#### 2.2.6. Selection process

The selection step in DE follows a greedy strategy where the offspring produced by crossover, $u_i^g$, competes with its parent $x_i^g$. The individual with the better fitness value is passed to the next generation, ensuring that population quality is preserved or improved over time. This mechanism is defined by Eq. (9) [29].

$$x_i^{g+1} = \begin{cases} u_i^g & \text{if } f(u_i^g) \le f(x_i^g) \\ x_i^g & \text{otherwise} \end{cases} \tag{9}$$

#### 2.2.7. Population size

While early DE algorithms typically use a fixed population size, dynamic strategies such as Linear Population Size Reduction (LPSR) have proven their efficiency in the literature [53,54]. LPSR gradually reduces the population from $NP_{\text{init}}$ to $NP_{\min}$ as the number of function evaluations $NFE$ increases until reaching the maximum function evaluations $MaxFEs$, using Eq. (10). This approach has been widely adopted in recent DE variants, including IMODE [20], and is also used in this study.

$$NP = \text{round}\left(\left(\frac{NP_{\min} - NP_{\text{init}}}{\text{MaxFEs}}\right) \cdot \text{NFE} + NP_{\text{init}}\right) \tag{10}$$

#### 2.2.8. Boundary handling

Any solution generated by mutation operators must be checked to ensure all dimensions lie within their respective bounds. A widely adopted and effective method for this purpose in DE algorithms is the midpoint target rule [55]. If a component of a mutant vector $v_{i,j}^g$ violates the lower or upper bound $[x_{\min,j}, x_{\max,j}]$, it is corrected by replacing it with the midpoint between the boundary and the corresponding component in the parent vector $x_{i,j}^g$, as in Eq. (11) [20,29].

$$v_{i,j}^g = \begin{cases} \frac{x_{\min,j} + x_{i,j}^g}{2}, & \text{if } v_{i,j}^g < x_{\min,j} \\ \frac{x_{\max,j} + x_{i,j}^g}{2}, & \text{if } v_{i,j}^g > x_{\max,j} \\ v_{i,j}^g, & \text{otherwise.} \end{cases} \tag{11}$$

A comprehensive summary of the design categories targeted for enhancement in this study is presented in Table 1. Other DE components, such as population size control, selection mechanism, and boundary handling, are adopted as established in prior literature without further modification.

## 3. The proposed DA2MODE algorithm

This section introduces DA2MODE with focused improvements over existing DE methods, including multi-operator selection, adaptive archive updating, dynamic crossover choice, and enhanced control parameter adaptation to address key limitations in the literature.

### 3.1. Progressive Adaptive Selector with Exponential Smoothing (PASES)

As discussed in Section 2.2.2, existing operator selection methods in multi-operator DE algorithms typically rely on recent generation performance, often overlooking an operator's historical performance. To address this limitation, the proposed Progressive Adaptive Selector with Exponential Smoothing (PASES) in DA2MODE evaluates each operator based on both current and accumulated performance across iterations. This dual-evaluation strategy ensures a more informed and stable operator selection process, enhancing the algorithm's adaptability to dynamic search conditions.

Initially, the probability of each operator, $P_{op}$, is equally distributed as $P_{op} = \frac{1}{N_{op}}$, where $N_{op}$ is the number of operators. Operators are assigned using the roulette wheel selection method. The cumulative probability for the $op$-th operator, $PC_{op}$, is calculated using Eq. (12), as the sum of probabilities from $P_1$ to $P_{op}$. The selected operator for the $i$th individual, $op_i$, is determined using Eq. (13), where $rand_i$ is a randomly generated number for the $i$th individual. The operator index $op_i$ is the smallest operator index value satisfying $rand_i \le PC_{op}$.

$$PC_{op} = \sum_{i=1}^{op} P_i, \quad \forall op = 1, \dots, N_{op} \tag{12}$$

$$op_i = \min\left\{op \in \{1, 2, \dots, N_{op}\} : rand_i \le PC_{op}\right\}, \quad \forall i = 1, \dots, NP \tag{13}$$

The selection probability of each operator, $P_{op}$, is updated using the PASES method. Initially, the normalized fitness improvement $\Delta f_{i,op}^g$ for each individual $i$ assigned to operator $op$ is calculated using Eq. (14). If the child's fitness, $f(u_{i,op}^g)$, is worse than the parent's, $f(x_{i,op}^g)$, $\Delta f_{i,op}^g$ is set to zero to ensure positivity. The parameter $\epsilon$ avoids division by zero.

The overall fitness score $S_{op}^g$ of operator $op$ in generation $g$ is then calculated as the average improvement across all individuals using Eq. (15), where $NP_{op}^g$ is the number of individuals assigned to the $op$-th operator in the $g$th generation. This score reflects the operator's impact during the current iteration.

The cumulative performance score $ST_{op}^g$ is calculated using Eq. (16), which combines the current generation score, $S_{op}^g$, with the previous cumulative score, $ST_{op}^{g-1}$. The weighting factor $\alpha_{EMA}$ determines the influence of current and historical scores, with initial value $ST_{op}^0 = 0$. The current generation's score contributes $\alpha_{EMA}\%$, while the prior accumulated score contributes $(1 - \alpha_{EMA})\%$.

Finally, the selection probability of the $op$-th operator for the next generation, $P_{op}^{g+1}$, is computed using a softmax function (Eq. (17)), scaled by a factor $c = 1000$ to magnify the small value of the overall score. Eq. (17) ensures all probabilities sum to one, allowing fair operator selection in the next iteration through roulette wheel selection (Eqs. (12) and (13)).

$$\Delta f_{i,op}^g = \max\left(0, \frac{f(x_{i,op}^g) - f(u_{i,op}^g)}{|f(x_{i,op}^g)| + \epsilon}\right) \tag{14}$$

$$S_{op}^g = \begin{cases} \frac{1}{NP_{op}^g} \sum_{i=1}^{NP_{op}^g} \Delta f_{i,op}^g, & NP_{op}^g > 0, \\ 0, & NP_{op}^g = 0, \end{cases} \quad \forall op \in \{1, \dots, N_{op}\} \tag{15}$$

$$ST_{op}^g = \alpha_{EMA} \cdot S_{op}^g + (1 - \alpha_{EMA}) \cdot ST_{op}^{g-1}, \quad ST_{op}^0 = 0, \quad \forall op \in \{1, \dots, N_{op}\} \tag{16}$$

$$P_{op}^{g+1} = \frac{\exp(c \cdot ST_{op}^g)}{\sum_{k=1}^{N_{op}} \exp(c \cdot ST_k^g)}, \quad \forall op \in \{1, \dots, N_{op}\} \tag{17}$$

The PASES method is progressive because the operator's overall performance is accumulated throughout the generations, highlighting the consistent best-performing operator over the iterations. It is smooth because the softmax function ensures smooth operator selection by

**Table 1**
Summary of DE method categories, algorithm examples, and their pros and limitations.

| Category | Method concept | Example algorithms | Advantages | Limitations |
|---|---|---|---|---|
| Mutation Operators | Single mutation rule | WDE, EODE, BSD, BeSD, meanDE, QRDE, JADE, JADEGMO | Simple to implement, low overhead | Limited adaptability, not effective across diverse problems |
| | Multiple mutation rules (random selection) | MDE, BDE, mDEW | Enhances exploration, easy hybridization | Lacks guidance, no operator performance feedback |
| | Multiple rules with scheduled switching | dFDBLSHADE | Structured phase-wise operator use | Acts as single-operator at each stage, lacks per-individual adaptation |
| | Adaptive operator selection based on performance | MadDE, ALSHADE, MTDE, IMODE, APGSKIMODE | Individual-level adaptation, performance-aware selection | Short-term feedback only, risk of premature operator rejection |
| Crossover Mechanism | Binomial crossover | dFDBLSHADE, WDE, JADEGMO, mDEW, JADE, MTDE, QEDE, ALSHADE, EODE, MDE, BSD, BDE, BeSD, meanDE | Simple, efficient, widely supported | Ignores variable correlations, may underperform in structured problems |
| | Random selection between binomial and exponential | IMODE, MadDE, APGSKIMODE | Gains from both crossover types | Random switching is unguided and not problem-specific |
| Control Parameters | Fixed CR/F | EODE, QRDE, meanDE (CR), mDEW (CR) | Stable, low computation | May lead to imbalance, poor generalization |
| | Random CR/F in [0,1] | MDE, BSD, BDE, BeSD, WDE, meanDE (F), mDEW (F) | Increases diversity, fast implementation | Uncontrolled behavior, risk of inappropriate search pressure |
| | Historical memory-based adaptive CR/F | JADE, MadDE, IMODE, APGSKIMODE, ALSHADE, MTDE, JADEGMO, dFDBLSHADE | Success-driven, problem-aware adaptation | Becomes static during stagnation, may reuse ineffective parameters |
| Archive Usage | No archive (mutation from population only) | EODE, MDE, BSD, meanDE, QRDE, WDE, mDEW | Simple, low memory requirement | Poor diversity in late stages, risk of premature convergence |
| | Archive with random update | IMODE, APGSKIMODE, MadDE, BDE, BeSD, JADE, JADEGMO, dFDBLSHADE | Enhances diversity using historical solutions | Random update may lose informative individuals |
| | Archive with elitist update (replace worst) | ALSHADE, MTDE | Promotes high-quality solutions in archive | Reduces diversity, mirrors population, archive becomes redundant |

converting scores into probabilities proportional to their exponential values. This method is adaptive because the selection probability is updated dynamically based on the progressive performance metric of each operator. Furthermore, this makes the proposed algorithm problem independent, focusing on the best operators, regardless of the type of the optimization problem.

### 3.2. Adaptive mutation and crossover selection

As discussed in Section 2.2.1, mutation is the primary operator in Differential Evolution (DE) responsible for introducing diversity and exploring new regions of the search space. Traditional DE algorithms typically rely on a single mutation rule, which may constrain performance when applied across diverse problem landscapes [56].

To overcome this limitation, DA2MODE adopts a multi-operator mutation strategy by integrating three distinct mutation rules from different DE categories: DE/current-to-$\phi$best/1 (Eq. (4)), DE/current-to-$\phi$best/1/archive (Eq. (5)), and DE/weighted-rand-to-$\phi$best/1 (Eq. (6)). The PASES method introduced in Section 3.1 is applied to dynamically select the most suitable mutation strategy during each iteration. This method enables adaptive mutation selection based on both short-term improvements and long-term historical performance.

Similarly, as discussed in Section 2.2.3, DE's crossover operator is crucial in generating offspring by combining information from the mutant and its corresponding parent. While binomial crossover remains dominant in most DE variants due to its simplicity and element-wise recombination, exponential crossover has demonstrated superior performance in problems with positional dependency among variables [22].

Unlike existing methods that alternate between crossover types randomly, DA2MODE integrates both binomial and exponential crossover mechanisms and deploys the PASES method to select the most effective crossover strategy adaptively. This dual adaptation allows DA2MODE to exploit the complementary advantages of both crossover types while maintaining robustness across a wide range of problem structures.

### 3.3. Adaptive Non-Elite Archive Update (ANEAU)

As discussed in Section 2.2.5, archive mechanisms play a critical role in maintaining diversity in DE algorithms. However, existing approaches either update the archive randomly or populate it with elite individuals. While the latter accelerates convergence, it often leads to population mirroring and premature convergence. To overcome this limitation, the proposed Adaptive Non-Elite Archive Update (ANEAU) method selectively stores a fraction of non-elite solutions to promote diversity without compromising convergence.

In ANEAU, a dynamic fraction $p_A$ of the worst-performing individuals is added to the archive at each iteration. The value of $p_A$ is gradually reduced over time using a linear decay schedule, as defined in Eq. (18). Here, $p_{A,\text{init}}$ and $p_{A,\min}$ represent the initial and minimum archive ratios, respectively; $NI$ is the current iteration; and $maxIter$ is the total number of iterations.

$$p_A = \left(\frac{p_{A,\min} - p_{A,\text{init}}}{\text{maxIter}}\right) \cdot NI + p_{A,\text{init}} \tag{18}$$

After generating new solutions, individuals are sorted in descending order of fitness (i.e., worse solutions first), and the worst $n_{\text{sel}}$ individuals are selected using Eq. (19), where $NP$ is the current population size.

$$n_{\text{sel}} = \text{round}(p_A \cdot NP) \tag{19}$$

These non-elite solutions are appended to the archive. If the archive exceeds its maximum allowed size, a random subset of entries is removed to maintain the limit. This randomized removal helps preserve diversity better than deterministic pruning strategies.

By focusing on non-elite individuals and adapting $p_A$ over time, ANEAU encourages broader exploration during the early stages and more exploitation later in the search. This mechanism prevents premature convergence and enables more robust performance across diverse problem landscapes.

### 3.4. Adaptive control parameters

The control parameters in DA2MODE are adapted based on the core ideas of the SHADE algorithm's memory-based approach (reviewed in Section 2.2.4), but with additional modifications to ensure continued diversity whenever no improvements occur. Specifically, we maintain two sets of historical memory arrays, $M_{CR}$ and $M_F$, that record representative crossover probability values ($CR_i$) and mutation factors ($F_i$), respectively.

Let $S_{CR}$ be the set of successful crossover probabilities at generation $g$. Each $CR_i$ in $S_{CR}$ is associated with an improvement metric $\Delta f_k = |f(u_{k,g}) - f(x_{k,g})|$, measuring the absolute fitness difference between the parent $x_{k,g}$ and its child $u_{k,g}$. The weight $w_k^{Cr}$ in Eq. (20) reflects each improvement's relative contribution. We then compute a weighted arithmetic mean $\text{mean}_{WA}(S_{CR})$ (Eq. (21)). If $S_{CR}$ is non-empty, $M_{CR,k}^{g+1}$ is assigned $\text{mean}_{WA}(S_{CR})$ (Eq. (22)); otherwise, it is drawn randomly from a normal distribution $\mathcal{N}(0.5, 0.15)$, thereby preserving diversity whenever no successful updates were made.

$$w_k^{Cr} = \frac{\Delta f_k}{\sum_{k=1}^{|S_{CR}|} \Delta f_k} \tag{20}$$

$$\text{mean}_{WA}(S_{CR}) = \frac{\sum_{k=1}^{|S_{CR}|} w_k^{Cr} \cdot CR_k}{\sum_{k=1}^{|S_{CR}|} w_k^{Cr}} \tag{21}$$

$$M_{CR,k}^{g+1} = \begin{cases} \text{mean}_{WA}(S_{CR}) & \text{if } S_{CR} \neq \emptyset \\ \text{randn}(0.5, 0.15) & \text{otherwise} \end{cases} \tag{22}$$

Analogously, $S_F$ is the set of successful mutation factors $F_i$ at generation $g$, each weighted by $w_k^f$ from Eq. (23). Unlike $CR_i$, whose mean is a simple weighted arithmetic average, the mutation factor uses a weighted Lehmer mean $\text{mean}_{WL}(S_F)$ (Eq. (24)) to emphasize larger $F_i$ values if they yield higher improvements. As before, $M_{F,k}^{g+1}$ is replaced by $\text{mean}_{WL}(S_F)$ whenever $S_F \neq \emptyset$, or sampled from $\mathcal{N}(0.5, 0.15)$ otherwise (Eq. (25)).

$$w_k^f = \frac{\Delta f_k}{\sum_{k=1}^{|S_F|} \Delta f_k} \tag{23}$$

$$\text{mean}_{WL}(S_F) = \frac{\sum_{k=1}^{|S_F|} w_k^f \cdot F_k^2}{\sum_{k=1}^{|S_F|} w_k^f \cdot F_k} \tag{24}$$

$$M_{F,k}^{g+1} = \begin{cases} \text{mean}_{WL}(S_F) & \text{if } S_F \neq \emptyset \\ \text{randn}(0.5, 0.15) & \text{otherwise} \end{cases} \tag{25}$$

At the start of each iteration, the $i$th individual's crossover probability $CR_i$ and mutation factor $F_i$ are sampled from the updated memory arrays $M_{CR,r_i}$ and $M_{F,r_i}$, where $r_i$ is an index randomly selected from $[1, H]$ and $H$ is the memory size. $CR_i$ is generated based on a normal distribution of standard deviation of 0.1 and a mean of $M_{CR,r_i}$, as in Eq. (26). Whereas, $F_i$ is generated based on a Cauchy distribution with a scale parameter 0.1 and a location parameter of $M_F$, as in Eq. (27).

$$CR_i = \text{randn}(M_{CR,r_i}, 0.1) \tag{26}$$

$$F_i = \text{randc}(M_{F,r_i}, 0.1) \tag{27}$$

### 3.5. The complete DA2MODE algorithm

This section outlines the overall structure of the DA2MODE algorithm, which integrates the proposed mechanisms into a cohesive optimization framework. The main steps of the algorithm are illustrated in Fig. 1 and detailed in Algorithm 1.

The algorithm begins by initializing the population, operator selection probabilities, parameter memories, and archive structures. Each generation involves dynamically resizing the population via LPSR, followed by mutation and crossover operations. Mutation and crossover operators are selected adaptively using the PASES strategy based on current and cumulative performance. Offspring are generated and evaluated, and selection is applied to retain the best solutions.

Subsequently, the archive is updated using the ANEAU method to maintain diversity. The operator selection probabilities and memory arrays ($M_F$ and $M_{CR}$) are also updated to guide future generations. The process iterates until a convergence criterion is met, with the global best solution returned as the final output.

### 3.6. Computational complexity analysis

The computational complexity of the proposed DA2MODE algorithm is analyzed in terms of the decision space dimension $D$, the population size $\text{NP}_t$ at generation $t$, and the total number of generations $G$. The initialization phase, which includes generating $\text{NP}_0$ candidate solutions and evaluating their fitness, requires $\mathcal{O}(\text{NP}_0\, D)$ operations. In each generation, the algorithm performs mutation, crossover, boundary control, and fitness evaluations for the current population, leading to a dominant cost of $\mathcal{O}(\text{NP}_t\, D)$, since fitness evaluations generally scale linearly with $D$ for standard benchmark functions.

Additional internal mechanisms such as adaptive parameter control, archive management, the PASES reward update, and the archive update method (ANEAU) contribute only linear or sub-linear overheads (i.e., $\mathcal{O}(\text{NP}_t)$ or less), and do not alter the leading order of the algorithm's complexity. Therefore, the overall complexity across $G$ generations is $\mathcal{O}(G\, \overline{\text{NP}}\, D)$, where $\overline{\text{NP}}$ denotes the average population size over time under the population size reduction strategy.

Notably, this matches the asymptotic complexity of other state-of-the-art DE variants such as ALSHADE, IMODE, and APGSK, all of which involve one mutation, crossover, and fitness evaluation per individual per generation. As $G$ is typically fixed for all algorithms under fair comparisons (i.e., bounded by maximum function evaluations), this factor becomes a constant multiplier. Hence, DA2MODE maintains the same order of computational cost as comparable methods while offering improved exploration and adaptive capabilities.

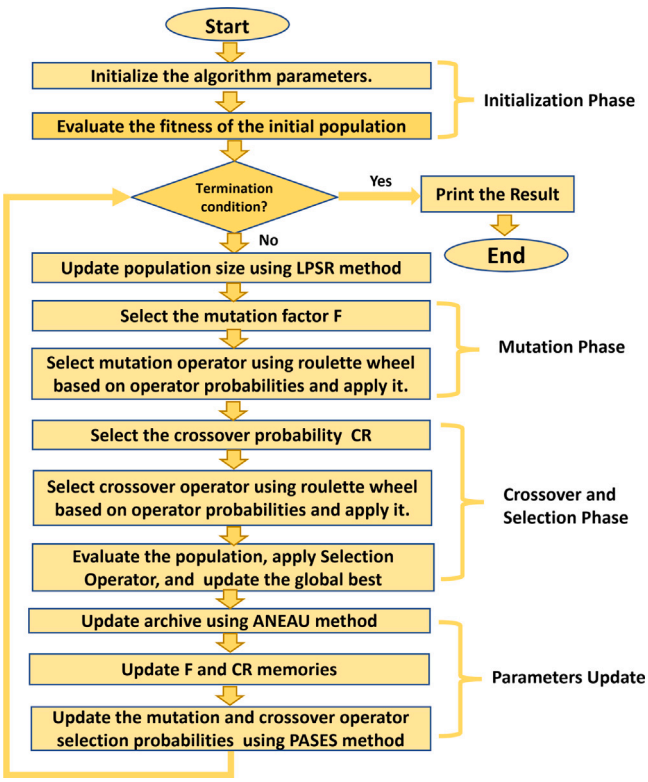



**Fig. 1.** The proposed DA2MODE algorithm flowchart.

**Algorithm 1** The proposed DA2MODE algorithm

Initialize the parameters of the DA2MODE. ▷ **Initialization**
Initialize the memories $M_{CR}$, $M_F$ and the archive A.
Initialize $P_{op}^{Mut}$ and $P_{op}^{Cr}$ as equal operator selection probabilities.
Initialize $ST_{op}^{Mut}$ and $ST_{op}^{Cr}$ as cumulative scores for the operators.
Initialize the population.
Evaluate the fitness and sort the population based on it.
**while** Termination Condition **do** ▷ **Algorithm loop**
  Update the population size $NP^t$ using LPSR method (Eq. (10)).
  **for** each individual $i = 1$ to $NP^t$ **do** ▷ **Mutation Phase**
    Select mutation factor $F_i$ from the memory $M_F$ using Eq. (27).
    Select mutation rule using $P_{op}^{Mut}$ and roulette wheel Eq. (12), (13).
    Apply the selected mutation rule; one of equations: (4), (5), (6).
    Apply the boundary handling in Eq. (11).
  **end for**
  **for** each individual $i = 1$ to $NP^t$ **do** ▷ **Crossover Phase**
    Select a crossover probability $CR_i$ from memory $M_{Cr}$ (Eq. (26)).
    Select crossover rule using $P_{op}^{Cr}$ and roulette wheel Eqs. (12), (13).
    Apply selected crossover; Bin. (Eq. (7)) or Expo. (Eq. (8)).
    Evaluate the cost of the new individuals.
  **end for**
  Perform selection operator, as in Eq. (9).
  Sort the new population and update the global best.
  Update the archive A using ANEAU Eqs. (18) and (19).
  Update mutation probability $P_{op}^{Mut}$ using PASES Eqs. (14) to (17).
  Update crossover probability $P_{op}^{Cr}$ using PASES Eqs. (14) to (17).
  Update the CR and F memory $M_{CR}$, $M_F$ using Eqs. (20) to (25).
**end while**
Return the global best solution.

## 4. Experiment setup

This section outlines the experimental framework used to evaluate the performance of the DA2MODE algorithm, including benchmark definitions, parameter sensitivity tests, and comparison with 33 state-of-the-art algorithms. CEC2020-2022, CEC2017/2018, and CEC2013 LSGO are used to assess performance across different problem scales and complexities under consistent conditions.

### *4.1. CEC benchmark functions*

The performance of the proposed DA2MODE algorithm is comprehensively assessed using four established IEEE CEC benchmark suites: CEC2020/2021, CEC2022, CEC2017/2018, and CEC2013 Large-Scale Global Optimization (LSGO). These suites present a broad range of optimization problems involving variations in modality, separability, dimensionality, and landscape complexity.

CEC benchmark problems are commonly grouped by modality. Unimodal functions contain a single global optimum, whereas multimodal functions include multiple local optima in the search space. More complex categories include hybrid functions, which combine multiple basic functions in distinct regions. Additionally, composition functions blend several components with shifts, rotations, and biases to create challenging global structures [57]. In terms of variable dependency, benchmark functions differ structurally. Separable functions consist of independent variables, while partially separable functions include multiple variable groups, either with or without a separable subcomponent. Overlapping functions share variables across subcomponents, increasing interdependence. Fully non-separable functions treat all variables as interdependent [58].

The CEC2020-2021 suite consists of 10 functions evaluated at 10D and 20D, including one unimodal (F1), three basic multimodal (F2–F4), three hybrid (F5–F7), and three composition functions (F8–F10). CEC2022 expands this with 12 functions, structured as one unimodal (F11), four basic multimodal (F12–F15), three hybrid (F16–F18), and four composition functions (F19–F22), also tested at 10D and 20D. Complete definitions and structure of these suites are detailed in Appendix A (Tables A.1–A.2) and official sources [18,37].

CEC2017/2018 targets high-dimensional optimization, comprising 29 functions evaluated at 30D, 50D, and 100D. The set includes one unimodal (F1), seven multimodal (F2–F8), ten hybrid (F9–F19), and ten composition functions (F20–F29), many of which involve rotation, bias, or full non-separability. More information is provided in Appendix A (Table A.3) and the official documentation [57].

The CEC2013 LSGO suite includes 15 large-scale functions evaluated at 1000D, designed to test scalability. These are divided into five structural categories: separable (F1–F3), partially separable Group I with a separable component (F4–F7), partially separable Group II without separable components (F8–F11), overlapping functions (F12–F14), and fully non-separable (F15). Each category increases the degree of variable interaction and optimization complexity. Full details are provided in the original CEC2013 technical report [58] and summarized in Appendix A (Table A.4).

The overall benchmarking procedure is conducted in three stages: (1) low-dimensional tests (10D and 20D) using CEC2020-2022, (2) high-dimensional tests (30D–100D) using CEC2017/2018, and (3) large-scale tests (1000D) using CEC2013 LSGO for top performers. All benchmark functions are defined as minimization tasks, where the global optimum is denoted by $F_i(X^*) = F_i^*$. The optimization error is calculated as $E_i(X) = F_i(X) - F_i^*$.

Termination criteria include either reaching a maximum number of function evaluations (MaxFEs) or achieving an error below $1.0 \times 10^{-8}$.

**Table 2**
Parameter Settings for CEC2020-2022, CEC2017–2018, and CEC2013 LSGO Benchmark Functions.

| CEC | Parameter | Value |
|---|---|---|
| CEC2020-2022 | Dimensions Size ($D$) | 10 and 20 |
| | Maximum Function Evaluations (MaxFEs) | 200,000 for $D = 10$, 500,000 for $D = 20$ |
| | Fitness Function | $E_i(x) = F_i(X) - F_i(X^*)$ |
| | Tolerance of error | $1.0E-08$ |
| | Number of runs | 30 |
| | Dimensions search Space | $[-100, 100]^{nd}$ |
| | No. of Functions | 22 (F1 to F22) |
| CEC2017–2018 | Dimensions Size ($D$) | 30, 50, and 100 |
| | MaxFEs | $10000 * D$ |
| | Fitness Function | $E_i(x) = F_i(X) - F_i(X^*)$ |
| | Tolerance of error | $1.0E-08$ |
| | Number of runs | 51 |
| | Dimensions search Space | $[-100, 100]^{nd}$ |
| | No. of Functions | 29 (F1 to F29) |
| CEC2013 LSGO | Dimensions Size ($D$) | 1000 for most, 905 for F13–F14 |
| | MaxFEs | 500,0000 |
| | Fitness Function | $E_i(x) = F_i(X) - F_i(X^*)$ |
| | Tolerance of error | $1.0E-08$ |
| | Number of runs | 25 |
| | Dimension Search Space | Fun. Specific (See Table A.4) |
| | No. of Functions | 15 (F1 to F15) |

The search space is fixed at $[-100, 100]^D$ across all suites, except for CEC2013, which uses function-specific bounds as defined in Appendix A. Benchmark-specific parameters are detailed in Table 2.

### 4.2. Sensitivity analysis of DA2MODE parameters

DA2MODE algorithm has two key parameters: the minimum fraction of non-elite solutions stored in the archive, $p_{A,\min}$, and the exponential smoothing factor, $\alpha_{\text{EMA}}$. The parameter $p_{A,\min}$ (see Section 3.3) defines the minimum portion of non-elite solutions added to the archive, which directly affects population diversity, especially in later stages. The smoothing factor $\alpha_{\text{EMA}}$ (see Section 3.1) controls how much weight is given to recent versus past operator performance. A small $\alpha_{\text{EMA}}$ gives more influence to historical data, slowing down adaptation. In contrast, a large value reacts more quickly but may introduce instability. Selecting suitable values for these two parameters is essential to balance exploration and exploitation.

To determine the best settings, we ran experiments on the 29 CEC2017 benchmark functions [59] at dimensions 10, 30, 50, and 100. For each dimension, we tested all combinations of $p_{A,\min} \in 0.1, 0.2, \ldots, 0.8$ and $\alpha_{\text{EMA}} \in 0.1, 0.2, \ldots, 0.8$ using eight independent runs per configuration. The stopping criterion was set to $1000 \times D$ function evaluations, where $D$ is the dimensionality. For each setting, the average error is recorded, and the Friedman test is used to compare the rankings. The results are visualized in heatmaps and bar charts in Fig. 2, where each heatmap cell shows the average rank for a specific parameter combination.

The results show that the algorithm maintains better performance across all dimensions when $p_{A,\min}$ is 0.5 or higher. Lower values reduce diversity in later generations, leading to higher average errors and an increased risk of premature convergence. Higher values like 0.7 or 0.8 did not significantly improve performance and led to slightly higher computational cost. Thus, $p_{A,\min} = 0.5$ provides a reliable and balanced setting.

For $\alpha_{\text{EMA}}$, values around 0.5 to 0.6 gave the most stable and effective results. Lower values ($\leq 0.4$) caused slow adaptation due to overreliance on past performance, while higher values ($\geq 0.7$) made the operator selection too reactive with rapid fluctuation. Therefore, setting $\alpha_{\text{EMA}} = 0.6$ ensures a smooth and adaptive balance. In summary, the sensitivity analysis confirms that $p_{A,\min} = 0.5$ and $\alpha_{\text{EMA}} = 0.6$ are the most effective settings for DA2MODE. These parameters preserve adequate non-elite diversity in the archive and smoothly adapt operator selection.

### 4.3. Parameter settings of all the algorithms

To evaluate the performance of the DA2MODE algorithm, a comprehensive set of 33 comparison algorithms is selected from classical metaheuristics, CEC competition winners, and recent DE variants. The first group comprises classical metaheuristic algorithms, including GA [60], DE [61], PSO [36], SA [62], TLBO [34], ABC [60], BAS [63], FA [60], CMAES [64], GWO [32], WOA [65], MFO [35], and HHO [36]. In addition, recent CEC competition winners are included: HSES [25] (CEC2018 winner), IMODE [20] and AGSK [38] (first and second in CEC2020), MadDE [24] and APGSKIMODE [23] (top performers in CEC2021), EA4eig [26] (CEC2022 winner), and the recent ALSHADE algorithm [21].

The second group focuses on more recent and advanced DE variants, including JADE [29], JADEGMO [31], meanDE [27], MDE [41], WDE [39], BSD [43], BDE [44], QRDE [46], MTDE [42], mDEW [27], EODE [40], BeSD [45], and dFDBLSHADE [28]. All algorithms are executed under identical experimental conditions. Parameter settings adhere to the recommendations in the respective original publications or official competition documentation. Each algorithm is independently run 30 times per function for the CEC2020, CEC2021, and CEC2022 suites, 51 times for the CEC2017 suite, and 25 times for the large-scale CEC2013 suite (for top-performing algorithms). Detailed parameter configurations are summarized in Table 3.

## 5. Results and statistical analysis: CEC2020-2022 part 1

The DA2MODE algorithm is benchmarked on the 10D and 20D functions of the CEC2020/2021 and CEC2022 benchmark suites. It is evaluated against a diverse set of 20 algorithms, covering both baseline metaheuristic methods and recent CEC competition winners. The baseline

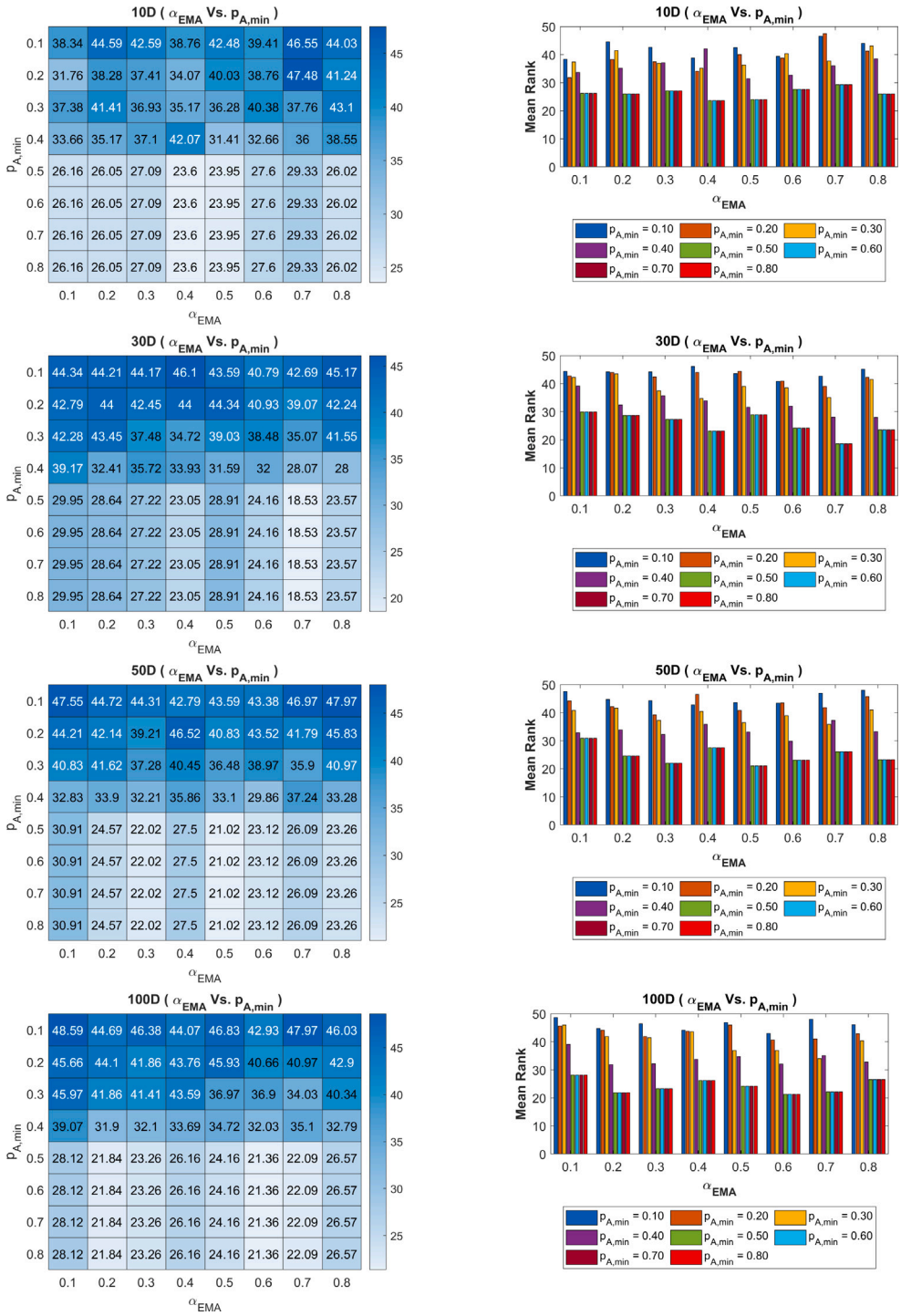



**Fig. 2.** The heatmap and the bar chart for the mean sensitivity analysis.

algorithms include GA [60], DE [61], PSO [36], SA [62], TLBO [34], ABC [60], BAS [63], FA [60], HHO [36], GWO [32], MFO [35], WOA [65], and CMAES [64]. The CEC-winning algorithms includes AGSK [38], HSES [25], MadDE [24], IMODE [20], ALSHADE [21], EA4eig [26], and APGSKIMODE [23]. Each algorithm is tested on 30 independent runs per function. The best, worst, median, mean, and standard deviation (SD) of the results are reported in Appendix B (Tables B.5 and B.6).

Representative violin plots for functions F3, F8, F14, and F19 are shown in Fig. 3, illustrating the distribution of final errors across all algorithms. BAS and CMAES are excluded from the visual plots due to their high error magnitudes. The complete violin plots are available in Appendix C (Figs. C.1a–C.1d and Figs. C.2a–C.2d). From these plots, DA2MODE generally displays the tightest (most compact) cost distributions and low final error. In contrast, competing algorithms often exhibit either higher median values, wider spreads, or both.

### 5.1. Statistical analysis: FEs-based group comparison

Following the ranking strategy in [37], each algorithm is evaluated per function based on whether it reaches a target error of $1.0 \times 10^{-8}$. If the target error is achieved, the algorithm is ranked by the

**Table 3**
Parameter settings for all the evolutionary and meta-heuristic optimization algorithms.

| Algorithm | Parameters |
|---|---|
| ABC [60] | $NP = 30$, abandon limit = 0.6 * D * NP,<br>No. of onlooker bees = NP, $a = 1$ |
| GA [60] | $NP = 30$, $P_c = 0.8$, tournament size = 3<br>$P_m$ =0.3, $\mu = 0.02$ |
| PSO [36,61] | $NP = 30$, $c_1 = 1$, $c_2 = 1$, $w = 0.3$ |
| DE [61] | $NP = 30$, $F = 0.5$, $CR = 0.5$ |
| SA [33,62] | max No. of sub-iteration = 20, No. of neighbors per individual = 5 ,<br>$NP = 30$, $\alpha = 0.99$, $T_0 = 0.1$, mutation rate $\mu = 0.5$ |
| TLBO [34] | $NP = 30$, teacher factor $TF = 1$ or 2 (randomly chosen) |
| BAS [63] | $NP = 30$, $d^1 = 2$, $\eta_d = 0.95$, $d_0 = 0.01$<br>$\delta^1 = 0.5$, $\eta_\delta = 0.95$, $\delta_0 = 0.00$ |
| FA [60] | $m = 2$, mutation range = 0.05 * ( ub - lb), $\gamma = 1$,<br>$NP = 30$, $\beta_0 = 2$, $\alpha = 0.2$, damping ratio = 0.98 |
| HHO [36] | $NP = 30$, escaping energy: randomly varies between [−2,2] |
| GWO [32] | $NP = 30$, $a$: linearly decreases from 2 to 0 |
| MFO [35] | $NP = 30$, $a$: linearly decreases from −2 to −1 , $b = 1$ |
| WOA [65] | $NP = 30$, $a$: linearly decreases from 2 to 0 , $b = 1$ |
| CMAES [64] | $C_c = \frac{4}{D+4}$, $c_{cov} = \frac{2}{(D+\sqrt{2})^2}$<br>$NP = 30$, $\mu = NP/2$, $d_\sigma = c_\sigma^{-1} + 1$ |
| AGSK [38] | $NP_{init} = 20 \cdot D$, $NP_{min} = 12$, $c = 0.05$<br>$p = 0.05$, $Kw_P = [0.85, 0.05, 0.05, 0.05]$<br>$Kf = [0.1, 1.0, 0.5, 1.0]$, $Kr = [0.2, 0.1, 0.9, 0.9]$ |
| HSES [25] | $\lambda = round(3 \cdot ln(D) + 80)$,<br>Phase 1: $N = 100$, $M = 200$, $I = 20$, $cc = 0.96$<br>Phase 4: $(M = 200, N = 160)$ for $D \leq 30$,<br>$(M = 450, N = 360)$ for $D = 50$, $(M = 600, N = 480)$ for $D > 50$ |
| MadDE [24] | $NP_{init} = 2 \cdot D^2$, $NP_{min} = 4$, $p_{qBX} = 0.01$, $p = 0.18$<br>$\lvert A \rvert = 2.3 \cdot NP$, H = $10 \cdot D$, $CR_{init} = 0.2$, $F_{init} = 0.2$ |
| IMODE [20] | $NP_{init} = 6 * D^2$, $NP_{min} = 4$<br>$\lvert A \rvert = 2.6 \cdot NP$, H = $20 \cdot D$, $P_{ls} = 0.1$, $FE_{ls} = 0.85 \cdot MaxFEs$ |
| ALSHADE [21] | $NP_{init} = 18 \cdot D^2$, $NP_{min} = 4$<br>$\lvert A \rvert = 2.6 \cdot NP$, H = $6 \cdot D$, $p = 0.11$, $e = 0.5$ |
| EA4eig [26] | $NP_{init} = 100$, $NP_{min} = 10$<br>$\lvert A \rvert = 2.6 \cdot NP$, H = $5 \cdot D$, $k = 1$, $p^{max} = 0.25$ |
| APGSKIMODE [23] | $PS_2 = (30 \cdot D)/4$, $PS_2^{min} = 12$, $PS_1 = 30 \cdot D - PS_2$, $NP_1^{min} = 4$<br>$p = 0.05$, $Kw_P = [0.85, 0.05, 0.05, 0.05]$, $c = 0.05$<br>$A_{rate} = 1.4$ , H = $15 \cdot D$, $e = 0.5$<br>$p^{init} = 0.3$, $p^{min} = 0.15$, $CS = 50$ |
| MDE [41] | $NP = 30$, $t = 3$ |
| WDE [39] | $NP = 30$, $K = 2$ |
| EODE [40] | $NP = 30$, $V = 1$, $a_1 = 2$, $a_2$ =1<br>$CR = 0.9$, $FD = 0.5$, $GP = 0.5$ |
| MTDE [42] | $NP = 30$, $H_{sb} = 5$, $\mu f = 0.5$, $Mu = log(D)$, $\sigma = 0.2$<br>$initial = 0.0001$, $WinIter = 20$, $final = 2$ |
| mDEW [27] | $NP = 50$, $F1 = 0.25$, $F_2 = 0.5 * (1 - 2 * rand)$, $CR = 0.75$, |
| BSD [43] | $NP = 30$ |
| QRDE [46] | $NP = 30$, $\alpha_0 = 1$, $CR = 0.2$, $F = 0.8$ |
| BDE [44] | $NP = 30$ |
| dFDBLSHADE [28] | $A$ =1.4, $H = 5$, $MCR_{init} = 0.5$, $MF_{init} = 0.5$,<br>$NP_{min} = 4$, $NP_{init} = 18 \cdot D$, $p_{best} = 0.11$ |
| BeSD [45] | $NP = 30$, $K = 5$ |
| JADEGMO [31] | $NP = 30$, $c = 0.1$, $top = 1$, $F_{init} = 0.5$, $CR_{init}$ =0.5 |
| JADE [29] | $NP = 30$, $A = 1$, $p = 0.05$, $c = 0.1$, $F_{init} = 0.5$, $CR_{init}$ =0.5 |
| meanDE [27] | $NP = 30$, $F_1 = 0.25$, $F_2 = 0.5 * (1 - 2 * rand)$, $CR = 0.9$ |
| DA2MODE | $NP_{init} = 60 \cdot D^{2/3}$, $NP_{min} = 4$<br>$\lvert A \rvert = 1.3 \cdot NP$, $H = 6 \cdot D$, $CR_{init} = 0.8$, $F_{init} = 0.3$<br>$p_{A,init} = 1$, $p_{A,min} = 0.5$, $\alpha_{EMA} = 0.6$ |

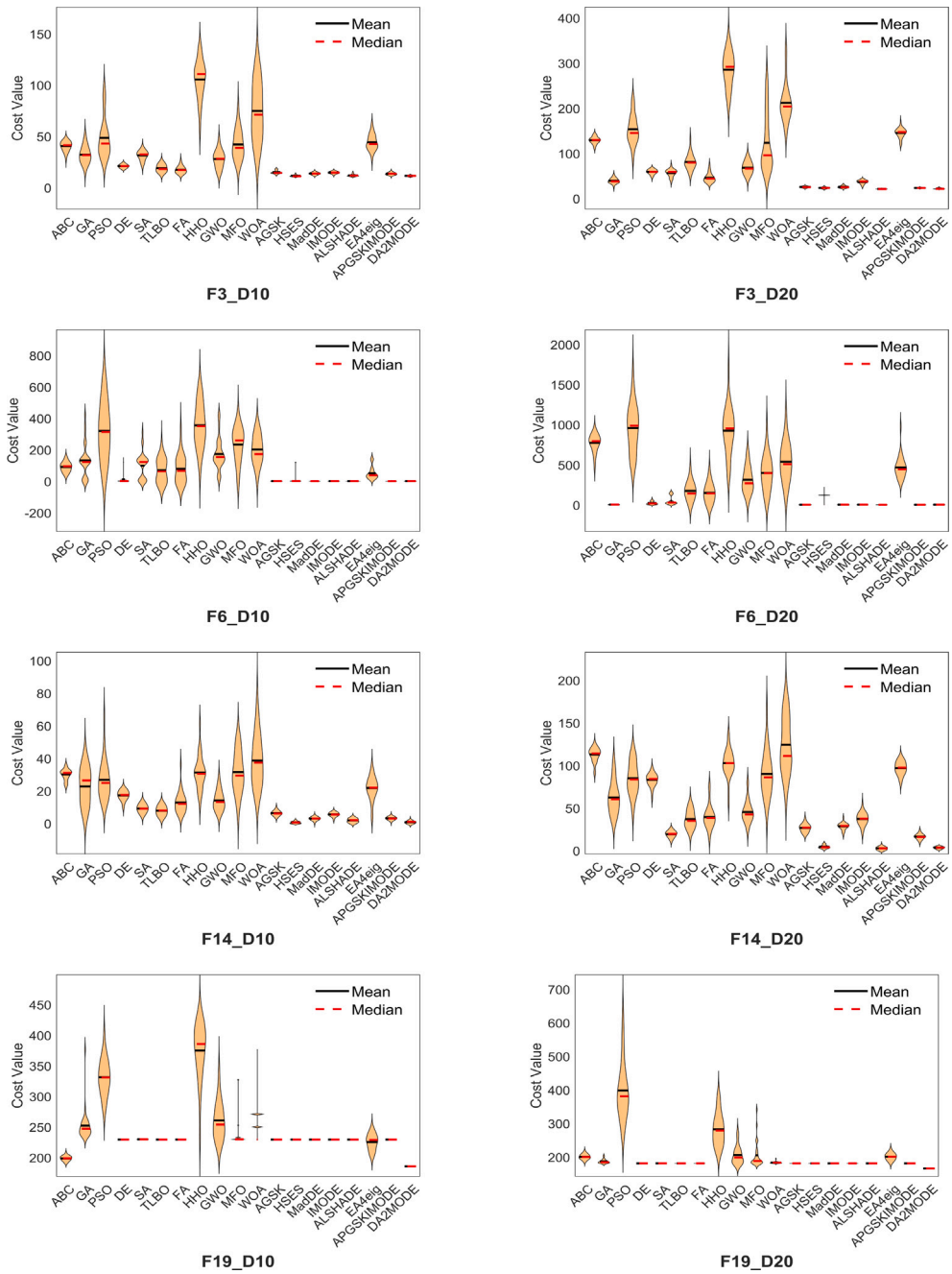



**Fig. 3.** Violin plots for all the algorithms for selective 10D and 20D CEC2020-2022 benchmark functions.

number of function evaluations (FEs) performed at the termination. Otherwise, the ranking is based on the final error at MaxFEs. Fig. 4 illustrates this method for representative functions. For F12–20D, only DA2MODE reaches the target tolerance and thus ranks highest. In contrast, for F19–20D and F22–10D, where no algorithm meets the target, DA2MODE achieves the lowest final error and is ranked highest accordingly.

To aggregate these per-function rankings, we adopt a weighted sum of ranks [37], as given in Eq. (28). In this formulation, $rank_{i,m}^{D}$ denotes the rank of algorithm $m$ on function $i$ at dimension $D$. A higher weight is assigned to the 20D results to reflect their greater complexity.

$$SR_m = 0.4 \sum_{i=1}^{22} rank_{i,m}^{10D} + 0.6 \sum_{i=1}^{22} rank_{i,m}^{20D} \tag{28}$$

Table 4 presents the final ranking scores based on the FE-based evaluation strategy for both best and median error metrics across 10D and 20D. DA2MODE achieves the top position in both cases, with total scores of 400.1 and 420.5, confirming its consistent superiority in convergence speed and final solution quality. ALSHADE, APGSKIMODE, and MadDE follow, but with noticeably lower ranks, while baseline methods like PSO, BAS, and HHO appear at the bottom due to poor convergence or higher final errors.

### 5.2. Statistical analysis: Friedman and Wilcoxon tests

A statistical analysis is performed on all algorithms using 10D and 20D benchmark functions, employing Friedman and Wilcoxon signed-rank tests. The Friedman test is used to establish overall rankings, while the Wilcoxon test is conducted to compare DA2MODE against

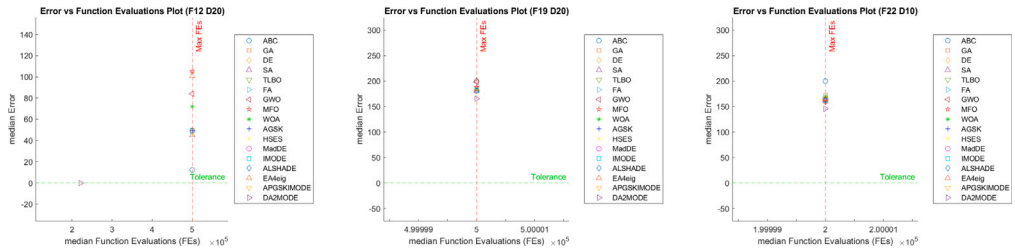



**Fig. 4.** The relationship between the best function evaluations and the best error for all the algorithms on some 10D and 20D CEC2020-2022 functions.

**Table 4**
The ranking table for the best and median metrics considering both error and the function evaluations. Top-ranked results are shown in bold.

| Algorithm | Best error metric ranks | | | | Median error metric ranks | | | |
|---|---|---|---|---|---|---|---|---|
| | SR 10D | SR 20D | SR | Place | SR 10D | SR 20D | SR | Place |
| ABC | 132 | 142 | 138 | 18 | 179 | 178 | 178.4 | 14 |
| GA | 167 | 256 | 220.4 | 11 | 167 | 222 | 200 | 12 |
| PSO | 116 | 95 | 103.4 | 19 | 92 | 95 | 93.8 | 19 |
| DE | 322 | 313.5 | 316.9 | 7 | 336 | 313.5 | 322.5 | 7 |
| SA | 187 | 239 | 218.2 | 12 | 214 | 258 | 240.4 | 11 |
| TLBO | 312.5 | 277 | 291.2 | 9 | 285 | 257 | 268.2 | 10 |
| BAS | 28 | 22 | 24.4 | 21 | 22 | 22 | 22 | 21 |
| FA | 276 | 299 | 289.8 | 10 | 257 | 288 | 275.6 | 9 |
| HHO | 89 | 102 | 96.8 | 20 | 78 | 93 | 87 | 20 |
| GWO | 198 | 196 | 196.8 | 14 | 192 | 193 | 192.6 | 13 |
| MFO | 225.5 | 195 | 207.2 | 13 | 168.5 | 148 | 156.2 | 16 |
| WOA | 158 | 172 | 166.4 | 16 | 137 | 139 | 138.2 | 17 |
| CMAES | 144 | 145.5 | 144.9 | 17 | 136.5 | 96 | 112.2 | 18 |
| AGSK | 334.5 | 331.5 | 332.7 | 5 | 358 | 348.5 | 352.3 | 5 |
| HSES | 322 | 339 | 332.2 | 6 | 341 | 358 | 351.2 | 6 |
| MadDE | 379.5 | 353 | 363.6 | 4 | 393.5 | 372 | 380.6 | 4 |
| IMODE | 333.5 | 267 | 293.6 | 8 | 346 | 290 | 312.4 | 8 |
| ALSHADE | 378.5 | 395.5 | 388.7 | 2 | 390 | 423 | 409.8 | 2 |
| EA4eig | 208 | 152 | 174.4 | 15 | 190 | 153 | 167.8 | 15 |
| APGSKIMODE | 383.5 | 381.5 | 382.3 | 3 | 391 | 406.5 | 400.3 | 3 |
| DA2MODE | 387.5 | 408.5 | **400.1** | **1** | 408.5 | 428.5 | **420.5** | **1** |

each competing algorithm individually. The Friedman test results in Table 5 confirm the statistical superiority of DA2MODE across both 10D and 20D CEC2020-2022 benchmarks. In 10D, DA2MODE achieves the third-best mean rank (3.80), closely following APGSKIMODE (3.39) and MadDE (3.45). In 20D, DA2MODE ranks first with the best mean rank (3.07), ahead of ALSHADE (3.20) and APGSKIMODE (3.48), with a significant $p$-value of $3.93 \times 10^{-62}$.

The Wilcoxon test results in Table 6 highlight DA2MODE's consistent dominance across 44 comparisons per algorithm. As illustrated in Fig. 5, DA2MODE achieves perfect wins (44/44) against EA4eig, WOA, MFO, GWO, HHO, BAS, and PSO. It maintains strong superiority with 40+ wins against ABC, GA, and SA. Compared to the most competitive methods, DA2MODE still outperforms APGSKIMODE (19 wins vs. 14 losses) and MadDE (20 wins vs. 15 losses). Only ALSHADE shows a slight advantage, winning 18 comparisons compared to DA2MODE's 17.

A dimension-wise breakdown (Fig. 6) shows ALSHADE outperforming DA2MODE in 20D (12 vs. 6), while DA2MODE leads in 10D (11 vs. 6). Against MadDE, DA2MODE loses in 10D (6 vs. 10) but recovers in 20D with a solid margin (14 wins vs. 5 losses).

In category-wise analysis (Fig. 7), DA2MODE records perfect scores on unimodal functions and only three total losses on multimodal benchmarks, all to ALSHADE. In hybrid functions, MadDE, ALSHADE, and APGSKIMODE each gain an advantage with 9 wins out of 12, suggesting their strength in structured hybrids. However, DA2MODE regains superiority in composition functions, surpassing ALSHADE (7 vs. 6) and MadDE (8 vs. 5), underscoring its robustness in tackling complex landscapes.

### 5.3. Convergence analysis

Fig. 8 displays the median convergence curves for some representative functions from different categories (F2, F7, F12, and F19), showing that DA2MODE generally achieves faster cost reductions early on and maintains or improves its lead throughout the run for both 10D and 20D. The complete set of convergence plots can be found in Appendix D (Figs. D.5a–D.5d and Figs. D.6a–D.6d).

These trends align with Page's test results in Fig. 9, where each algorithm's performance was compared at 19 cut-points across 22 benchmark functions (i.e., $N = 19$, $k = 22$). Page's test is a non-parametric procedure that statistically evaluates whether one algorithm converges faster over progressive stages of the run [66].

The Page test results confirm that DA2MODE converges faster than AGSK, APGSKIMODE, IMODE, MadDE, and ALSHADE. Specifically, the differences (AGSK−DA2MODE), (APGSKIMODE−DA2MODE), (IMODE−DA2MODE), (MadDE − DA2MODE), and (ALSHADE − DA2MODE) all show significantly increasing trends in both 10D and 20D ($p - val \leq 0.05$), indicating that DA2MODE converges more quickly. The only exception is HSES: neither (DA2MODE − HSES) nor (HSES − DA2MODE) shows a significant trend, suggesting similar convergence behavior. Although ALSHADE shows slightly faster early-stage descent in some 10D functions, DA2MODE overtakes it later, achieving better final accuracy and overall convergence speed.

## 6. Results and statistical analysis: CEC2020-2022 part 2

This section provides a detailed evaluation of the proposed DA2MODE algorithm on the CEC2020-2022 benchmark suite, using a diverse set of

**Table 5**
Statistical Analysis for the mean error of all algorithms, for all the 10D and 20D CEC2020-2022 benchmark functions. The DA2MODE is set as the reference of all comparisons. In the Sign Test: '+' means the proposed DA2MODE is better, and '=' means draw. In the Wilcoxon Test: R+ > R- means the proposed DA2MODE is better. In the Friedman test, the best algorithm is the one with the minimum mean rank. The level of significance $\alpha$ is between 0.05 and 0.1. If the $p$-value $\alpha$, the results are significant. Best or top-ranked results are shown in bold.

| Dim | Algorithm | Wilcoxon signed-rank test | | | | | Friedman test | | |
|---|---|---|---|---|---|---|---|---|---|
| | | +/=/- | R+ | R- | $p$-value | H | SumRanks | MeanRanks | Rank |
| 10 | ABC | +22/=0/-0 | 253 | 0 | 0.00004010 | TRUE | 290 | 13.181818 | 13 |
| | GA | +22/=0/-0 | 253 | 0 | 0.00004010 | TRUE | 327 | 14.863636 | 15 |
| | PSO | +22/=0/-0 | 253 | 0 | 0.00004010 | TRUE | 391 | 17.772727 | 19 |
| | DE | +17/=4/-1 | 170 | 1 | 0.00023323 | TRUE | 181.5 | 8.250000 | 8 |
| | SA | +21/=0/-1 | 249 | 4 | 0.00006978 | TRUE | 245 | 11.136364 | 11 |
| | TLBO | +20/=1/-1 | 230 | 1 | 0.00006899 | TRUE | 212 | 9.636364 | 10 |
| | BAS | +22/=0/-0 | 253 | 0 | 0.00004010 | TRUE | 462 | 21.000000 | 21 |
| | FA | +21/=0/-1 | 246 | 7 | 0.00010461 | TRUE | 211 | 9.590909 | 9 |
| | HHO | +22/=0/-0 | 253 | 0 | 0.00004010 | TRUE | 409 | 18.590909 | 20 |
| | GWO | +22/=0/-0 | 253 | 0 | 0.00004010 | TRUE | 305 | 13.863636 | 14 |
| | MFO | +22/=0/-0 | 253 | 0 | 0.00004010 | TRUE | 337 | 15.318182 | 16 |
| | WOA | +22/=0/-0 | 253 | 0 | 0.00004010 | TRUE | 342 | 15.545455 | 17 |
| | CMAES | +21/=1/-0 | 231 | 0 | 0.00005957 | TRUE | 383.5 | 17.431818 | 18 |
| | AGSK | +12/=4/-6 | 109 | 62 | 0.30610299 | FALSE | 105.5 | 4.795455 | 6 |
| | HSES | +17/=4/-1 | 167 | 4 | 0.00038618 | TRUE | 173.5 | 7.886364 | 7 |
| | MadDE | +6/=6/-10 | 62 | 74 | 0.75636886 | FALSE | 76 | 3.454545 | 2 |
| | IMODE | +9/=6/-7 | 80 | 56 | 0.53492521 | FALSE | 99 | 4.500000 | 5 |
| | ALSHADE | +11/=5/-6 | 113 | 40 | 0.08401675 | FALSE | 96 | 4.363636 | 4 |
| | EA4eig | +22/=0/-0 | 253 | 0 | 0.00004010 | TRUE | 278 | 12.636364 | 12 |
| | APGSKIMODE | +7/=6/-9 | 61 | 75 | 0.71738089 | FALSE | 74.5 | **3.386364** | **1** |
| | DA2MODE | NA | NA | NA | NA | NA | 83.5 | 3.795455 | 3 |
| | NA | | | | | | Friedman $p$-value = $8.416611E-65$ | | |
| 20 | ABC | +21/=0/-1 | 246 | 7 | 0.00010461 | TRUE | 293 | 13.318182 | 13 |
| | GA | +21/=0/-1 | 245 | 8 | 0.00011949 | TRUE | 268 | 12.181818 | 12 |
| | PSO | +22/=0/-0 | 253 | 0 | 0.00004010 | TRUE | 395 | 17.954545 | 19 |
| | DE | +17/=4/-1 | 164 | 7 | 0.00062920 | TRUE | 173.5 | 7.886364 | 7 |
| | SA | +22/=0/-0 | 253 | 0 | 0.00004010 | TRUE | 216 | 9.818182 | 10 |
| | TLBO | +20/=1/-1 | 230 | 1 | 0.00006899 | TRUE | 221.5 | 10.068182 | 11 |
| | BAS | +22/=0/-0 | 253 | 0 | 0.00004010 | TRUE | 462 | 21.000000 | 21 |
| | FA | +20/=2/-0 | 210 | 0 | 0.00008857 | TRUE | 206 | 9.363636 | 9 |
| | HHO | +22/=0/-0 | 253 | 0 | 0.00004010 | TRUE | 386 | 17.545455 | 18 |
| | GWO | +22/=0/-0 | 253 | 0 | 0.00004010 | TRUE | 302 | 13.727273 | 14 |
| | MFO | +22/=0/-0 | 253 | 0 | 0.00004010 | TRUE | 353 | 16.045455 | 17 |
| | WOA | +22/=0/-0 | 253 | 0 | 0.00004010 | TRUE | 341 | 15.500000 | 16 |
| | CMAES | +21/=1/-0 | 231 | 0 | 0.00005957 | TRUE | 396 | 18.000000 | 20 |
| | AGSK | +18/=2/-2 | 185 | 25 | 0.00282086 | TRUE | 129.5 | 5.886364 | 5 |
| | HSES | +16/=4/-2 | 154 | 17 | 0.00285252 | TRUE | 138 | 6.272727 | 6 |
| | MadDE | +14/=3/-5 | 125 | 65 | 0.08538900 | TRUE | 97.5 | 4.431818 | 4 |
| | IMODE | +19/=1/-2 | 203 | 28 | 0.00235563 | TRUE | 174.5 | 7.931818 | 8 |
| | ALSHADE | +6/=4/-12 | 85 | 86 | 0.68740887 | FALSE | 70.5 | 3.204545 | 2 |
| | EA4eig | +22/=0/-0 | 253 | 0 | 0.00004010 | TRUE | 315 | 14.318182 | 15 |
| | APGSKIMODE | +12/=5/-5 | 102 | 51 | 0.22738527 | FALSE | 76.5 | 3.477273 | 3 |
| | DA2MODE | NA | NA | NA | NA | NA | 67.5 | **3.068182** | **1** |
| | NA | | | | | | Friedman $p$-value = $3.933677E-62$ | | |

recently developed and advanced DE variants for comparison. The evaluated algorithms comprise JADE [29], JADEGMO [31], meanDE [27], MDE [41], WDE [39], BSD [43], BDE [44], QRDE [46], MTDE [42], mDEW [27], EODE [40], BeSD [45], and dFDBLSHADE [28]. Each method is assessed over 30 independent runs for all benchmark functions at 10D and 20D dimensions.

Detailed performance results for each function are available in Appendix B.2 (Tables B.7 and B.8). A visual summary is provided in Fig. 10, which displays violin plots for selected functions from each category: Multimodal (F2 and F14), Hybrid (F6), and Composition (F22). These plots demonstrate the compact and stable performance of DA2MODE compared to its peers. The complete collection of violin and box plots for all functions and dimensions can be found in Appendix C.2 (Figs. C.3a–C.3d and Figs. C.4a–C.4d).

### 6.1. Statistical analysis: Group comparison

Table 7 presents a comprehensive comparison of 14 DE variants based on the median FE-based rankings and the Friedman test for 10D and 20D. DA2MODE achieves the best overall performance, ranking first in all three metrics. In the FE-based ranking, DA2MODE achieves the highest total score (SR) of 268.7, indicating the best overall performance. In the Friedman test, it also ranks first among all algorithms, with the lowest average rank of 3.70 at 10D and 2.89 at 20D. These rankings are statistically significant, supported by extremely low $p$-values: $2.9472 \times 10^{-14}$ for 10D and $8.4895 \times 10^{-20}$ for 20D.

### 6.2. Statistical analysis: Paired comparison

Table 8 shows the detailed pairwise sign test results between DA2MODE and each of the 13 competing DE variants. As seen in the overall performance in Fig. 11, DA2MODE secures at least 30 wins against the majority of algorithms, including MDE, WDE, EODE, MTDE, BSD, QRDE, dFDBLSHADE, and meanDE. It achieves perfect dominance over JADE and JADEGMO with scores of $+42/=1/-1$ and $+42/=2/-0$, respectively. The most competitive comparison occurs against mDEW, where DA2MODE wins in 24 cases versus 12 losses. Against BeSD, it achieves 27 wins, while BeSD only wins in 7 functions.

As illustrated in Fig. 12, DA2MODE consistently outperforms all competitors across both 10D and 20D settings. At 10D, it maintains a

**Table 6**
Detailed sign test results between the DA2MODE and every other algorithm for the 10D and 20D CEC2020-2022 benchmark functions. Best results are shown in bold, highlighting cases where DA2MODE outperforms the competing algorithms.

| Alg. | Category | 10D | 20D | Total |
|---|---|---|---|---|
| ABC | Unimodal | +2/=0/-0 | +2/=0/-0 | +4/=0/-0 |
| | Multimodal | +7/=0/-0 | +7/=0/-0 | +14/=0/-0 |
| | Hybrid | +6/=0/-0 | +6/=0/-0 | +12/=0/-0 |
| | Composition | +7/=0/-0 | +6/=0/-1 | +13/=0/-1 |
| | Total | +22/=0/-0 | +21/=0/-1 | **+43/=0/-1** |
| GA | Unimodal | +2/=0/-0 | +2/=0/-0 | +4/=0/-0 |
| | Multimodal | +7/=0/-0 | +7/=0/-0 | +14/=0/-0 |
| | Hybrid | +6/=0/-0 | +6/=0/-0 | +12/=0/-0 |
| | Composition | +7/=0/-0 | +6/=0/-1 | +13/=0/-1 |
| | Total | +22/=0/-0 | +21/=0/-1 | **+43/=0/-1** |
| PSO | Unimodal | +2/=0/-0 | +2/=0/-0 | +4/=0/-0 |
| | Multimodal | +7/=0/-0 | +7/=0/-0 | +14/=0/-0 |
| | Hybrid | +6/=0/-0 | +6/=0/-0 | +12/=0/-0 |
| | Composition | +7/=0/-0 | +7/=0/-0 | +14/=0/-0 |
| | Total | +22/=0/-0 | +22/=0/-0 | **+44/=0/-0** |
| DE | Unimodal | +0/=2/-0 | +0/=2/-0 | +0/=4/-0 |
| | Multimodal | +5/=2/-0 | +5/=2/-0 | +10/=4/-0 |
| | Hybrid | +5/=0/-1 | +6/=0/-0 | +11/=0/-1 |
| | Composition | +7/=0/-0 | +6/=0/-1 | +13/=0/-1 |
| | Total | +17/=4/-1 | +17/=4/-1 | **+34/=8/-2** |
| SA | Unimodal | +2/=0/-0 | +2/=0/-0 | +4/=0/-0 |
| | Multimodal | +7/=0/-0 | +7/=0/-0 | +14/=0/-0 |
| | Hybrid | +6/=0/-0 | +6/=0/-0 | +12/=0/-0 |
| | Composition | +6/=0/-1 | +7/=0/-0 | +13/=0/-1 |
| | Total | +21/=0/-1 | +22/=0/-0 | **+43/=0/-1** |
| TLBO | Unimodal | +1/=1/-0 | +1/=1/-0 | +2/=2/-0 |
| | Multimodal | +7/=0/-0 | +7/=0/-0 | +14/=0/-0 |
| | Hybrid | +6/=0/-0 | +6/=0/-0 | +12/=0/-0 |
| | Composition | +6/=0/-1 | +6/=0/-1 | +12/=0/-2 |
| | Total | +20/=1/-1 | +20/=1/-1 | **+40/=2/-2** |
| BAS | Unimodal | +2/=0/-0 | +2/=0/-0 | +4/=0/-0 |
| | Multimodal | +7/=0/-0 | +7/=0/-0 | +14/=0/-0 |
| | Hybrid | +6/=0/-0 | +6/=0/-0 | +12/=0/-0 |
| | Composition | +7/=0/-0 | +7/=0/-0 | +14/=0/-0 |
| | Total | +22/=0/-0 | +22/=0/-0 | **+44/=0/-0** |
| FA | Unimodal | +2/=0/-0 | +1/=1/-0 | +3/=1/-0 |
| | Multimodal | +7/=0/-0 | +6/=1/-0 | +13/=1/-0 |
| | Hybrid | +6/=0/-0 | +6/=0/-0 | +12/=0/-0 |
| | Composition | +6/=0/-1 | +7/=0/-0 | +13/=0/-1 |
| | Total | +21/=0/-1 | +20/=2/-0 | **+41/=2/-1** |
| HHO | Unimodal | +2/=0/-0 | +2/=0/-0 | +4/=0/-0 |
| | Multimodal | +7/=0/-0 | +7/=0/-0 | +14/=0/-0 |
| | Hybrid | +6/=0/-0 | +6/=0/-0 | +12/=0/-0 |
| | Composition | +7/=0/-0 | +7/=0/-0 | +14/=0/-0 |
| | Total | +22/=0/-0 | +22/=0/-0 | **+44/=0/-0** |
| GWO | Unimodal | +2/=0/-0 | +2/=0/-0 | +4/=0/-0 |
| | Multimodal | +7/=0/-0 | +7/=0/-0 | +14/=0/-0 |
| | Hybrid | +6/=0/-0 | +6/=0/-0 | +12/=0/-0 |
| | Composition | +7/=0/-0 | +7/=0/-0 | +14/=0/-0 |
| | Total | +22/=0/-0 | +22/=0/-0 | **+44/=0/-0** |
| MFO | Unimodal | +2/=0/-0 | +2/=0/-0 | +4/=0/-0 |
| | Multimodal | +7/=0/-0 | +7/=0/-0 | +14/=0/-0 |
| | Hybrid | +6/=0/-0 | +6/=0/-0 | +12/=0/-0 |
| | Composition | +7/=0/-0 | +7/=0/-0 | +14/=0/-0 |
| | Total | +22/=0/-0 | +22/=0/-0 | **+44/=0/-0** |
| WOA | Unimodal | +2/=0/-0 | +2/=0/-0 | +4/=0/-0 |
| | Multimodal | +7/=0/-0 | +7/=0/-0 | +14/=0/-0 |
| | Hybrid | +6/=0/-0 | +6/=0/-0 | +12/=0/-0 |
| | Composition | +7/=0/-0 | +7/=0/-0 | +14/=0/-0 |
| | Total | +22/=0/-0 | +22/=0/-0 | **+44/=0/-0** |
| CMAES | Unimodal | +2/=0/-0 | +2/=0/-0 | +4/=0/-0 |
| | Multimodal | +6/=1/-0 | +6/=1/-0 | +12/=2/-0 |
| | Hybrid | +6/=0/-0 | +6/=0/-0 | +12/=0/-0 |
| | Composition | +7/=0/-0 | +7/=0/-0 | +14/=0/-0 |
| | Total | +21/=1/-0 | +21/=1/-0 | **+42/=2/-0** |
| AGSK | Unimodal | +0/=2/-0 | +0/=2/-0 | +0/=4/-0 |
| | Multimodal | +6/=1/-0 | +7/=0/-0 | +13/=1/-0 |
| | Hybrid | +3/=0/-3 | +5/=0/-1 | +8/=0/-4 |
| | Composition | +3/=1/-3 | +6/=0/-1 | +9/=1/-4 |
| | Total | +12/=4/-6 | +18/=2/-2 | **+30/=6/-8** |
| HSES | Unimodal | +0/=2/-0 | +0/=2/-0 | +0/=4/-0 |
| | Multimodal | +4/=2/-1 | +5/=2/-0 | +9/=4/-1 |
| | Hybrid | +6/=0/-0 | +6/=0/-0 | +12/=0/-0 |
| | Composition | +7/=0/-0 | +5/=0/-2 | +12/=0/-2 |
| | Total | +17/=4/-1 | +16/=4/-2 | **+33/=8/-3** |
| MadDE | Unimodal | +0/=2/-0 | +0/=2/-0 | +0/=4/-0 |
| | Multimodal | +3/=3/-1 | +6/=1/-0 | +9/=4/-1 |
| | Hybrid | +0/=0/-6 | +3/=0/-3 | +3/=0/-9 |
| | Composition | +3/=1/-3 | +5/=0/-2 | +8/=1/-5 |
| | Total | +6/=6/-10 | +14/=3/-5 | **+20/=9/-15** |
| IMODE | Unimodal | +0/=2/-0 | +1/=1/-0 | +1/=3/-0 |
| | Multimodal | +3/=3/-1 | +7/=0/-0 | +10/=3/-1 |
| | Hybrid | +3/=0/-3 | +6/=0/-0 | +9/=0/-3 |
| | Composition | +3/=1/-3 | +5/=0/-2 | +8/=1/-5 |
| | Total | +9/=6/-7 | +19/=1/-2 | **+28/=7/-9** |
| ALSHADE | Unimodal | +0/=2/-0 | +0/=2/-0 | +0/=4/-0 |
| | Multimodal | +5/=2/-0 | +2/=2/-3 | +7/=4/-3 |
| | Hybrid | +2/=0/-4 | +1/=0/-5 | +3/=0/-9 |
| | Composition | +4/=1/-2 | +3/=0/-4 | +7/=1/-6 |
| | Total | +11/=5/-6 | +6/=4/-12 | +17/=9/-18 |
| EA4eig | Unimodal | +2/=0/-0 | +2/=0/-0 | +4/=0/-0 |
| | Multimodal | +7/=0/-0 | +7/=0/-0 | +14/=0/-0 |
| | Hybrid | +6/=0/-0 | +6/=0/-0 | +12/=0/-0 |
| | Composition | +7/=0/-0 | +7/=0/-0 | +14/=0/-0 |
| | Total | +22/=0/-0 | +22/=0/-0 | **+44/=0/-0** |
| APGSK_ IMODE | Unimodal | +0/=2/-0 | +0/=2/-0 | +0/=4/-0 |
| | Multimodal | +4/=3/-0 | +5/=2/-0 | +9/=5/-0 |
| | Hybrid | +0/=0/-6 | +3/=0/-3 | +3/=0/-9 |
| | Composition | +3/=1/-3 | +4/=1/-2 | +7/=2/-5 |
| | Total | +7/=6/-9 | +12/=5/-5 | **+19/=11/-14** |

strong win-to-loss ratio against most algorithms, with its weakest performance being against mDEW (10 wins vs. 7 losses) and dFDBLSHADE (13 wins vs. 7 losses). In the 20D setting, the advantage is even more apparent. For instance, against mDEW, it secures 14 wins versus only 6 losses, and against dFDBLSHADE, it dominates with 19 wins compared to 3 losses. These results confirm that DA2MODE scales effectively and maintains superior performance as dimensionality increases.

From the function category perspective, as shown in Fig. 13, DA2MODE shows perfect or nearly perfect scores in the Unimodal and Multimodal categories. It wins or ties in all Unimodal cases without a single loss. In Multimodal functions (14 comparisons per algorithm), DA2MODE has no losses except three against dFDBLSHADE and one against BeSD. In Hybrid functions (12 per algorithm), it achieves at least 8 wins against each competitor. In the Composition category, DA2MODE shows strong performance, although WDE, mDEW, and BSD record slight advantages in specific cases.

### 6.3. Convergence analysis and page test

Fig. 14 displays representative convergence trends on selected CEC2020-2022 functions: F2 and F12 (Multimodal), F7 (Hybrid), and F22 (Composition). The complete set of convergence curves is available in Appendix D.2 (Figs. D.7a–D.7d and Figs. D.8a–D.8d). To statistically verify convergence behavior, the Page test is conducted in A–B

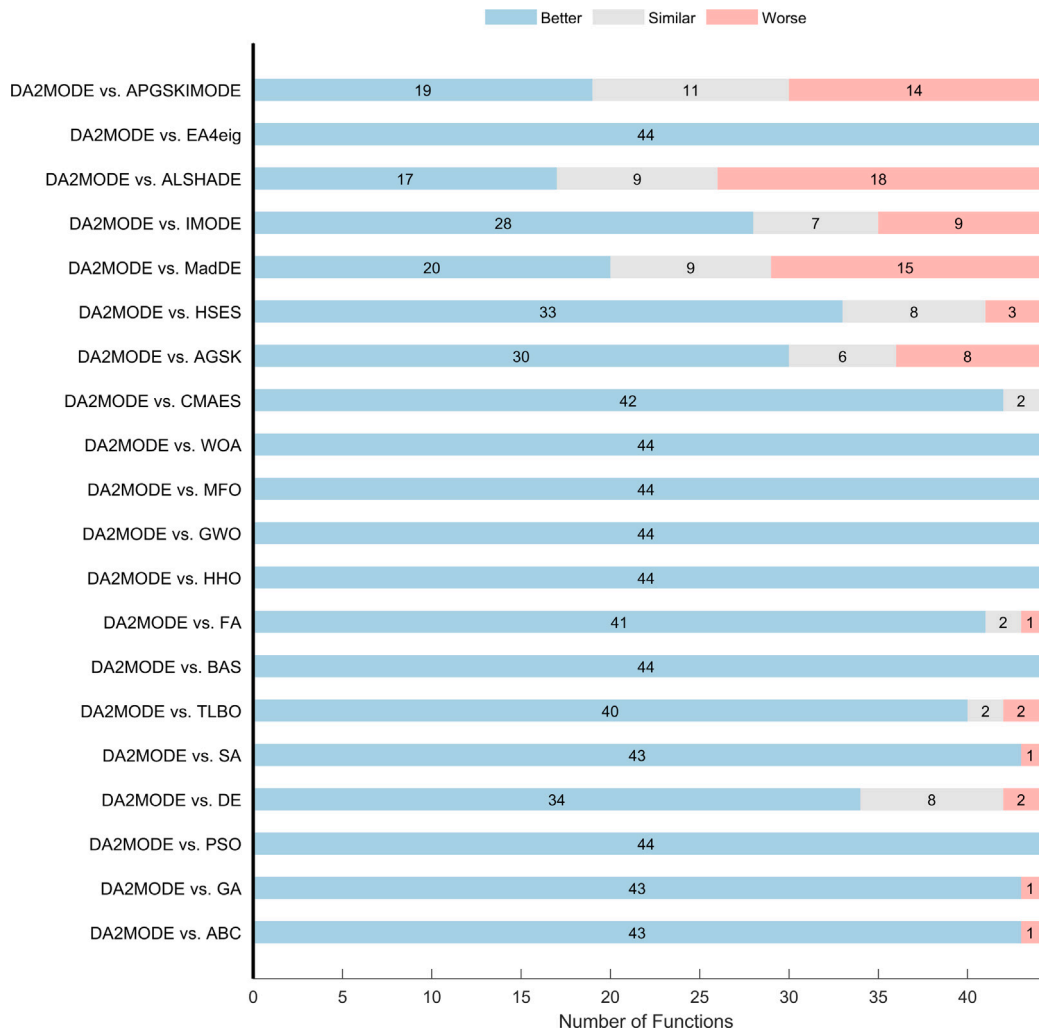



**Fig. 5.** Detailed Wilcoxon Signed-rank test results distributions for all the 22 function of CEC2020-2022 benchmark functions, where the DA2MODE is the reference. (Algorithm perspective).

**Table 7**
Detailed ranking of the 14 DE variants based on Friedman test (10D and 20D) and FE-based score (CEC2020-2022). Best or top-ranked results are shown in bold.

| Algorithm | Median FE-based ranking | | | | Friedman test (10D) | | | Friedman test (20D) | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | SR 10D | SR 20D | SR | Place | SumRanks | MeanRanks | Rank | SumRanks | MeanRanks | Rank |
| MDE | 126 | 148 | 139.2 | 11 | 211 | 9.5909 | 12 | 169.5 | 7.7045 | 9 |
| WDE | 153 | 176 | 166.8 | 7 | 163 | 7.4091 | 7 | 135 | 6.1364 | 5 |
| EODE | 155 | 152 | 153.2 | 9 | 200 | 9.0909 | 10 | 186 | 8.4545 | 11 |
| MTDE | 190 | 189 | 189.4 | 4 | 127.5 | 5.7955 | 3 | 151 | 6.8636 | 7 |
| mDEW | 211 | 225 | 219.4 | 2 | 93 | 4.2273 | 2 | 88.5 | 4.0227 | 2 |
| BSD | 123.5 | 150 | 139.4 | 10 | 180 | 8.1818 | 9 | 170.5 | 7.7500 | 10 |
| QRDE | 101 | 116 | 110 | 13 | 238 | 10.8182 | 13 | 215.5 | 9.7955 | 12 |
| BDE | 190.5 | 201.5 | 197.1 | 3 | 131 | 5.9545 | 5 | 133.5 | 6.0682 | 4 |
| dFDBLSHADE | 192 | 178.5 | 183.9 | 5 | 139.5 | 6.3409 | 6 | 150 | 6.8182 | 6 |
| BeSD | 166 | 178 | 173.2 | 6 | 129.5 | 5.8864 | 4 | 133 | 6.0455 | 3 |
| JADEGMO | 101 | 67 | 80.6 | 14 | 238.5 | 10.8409 | 14 | 263 | 11.9545 | 13 |
| JADE | 168.5 | 107.5 | 131.9 | 12 | 205 | 9.3182 | 11 | 282 | 12.8182 | 14 |
| meanDE | 174 | 146 | 157.2 | 8 | 172.5 | 7.8409 | 8 | 169 | 7.6818 | 8 |
| DA2MODE | 258.5 | 275.5 | **268.7** | **1** | 81.5 | **3.7045** | **1** | 63.5 | **2.8864** | **1** |
| | | | | | Friedman *p*-value = **2.9472E−14** | | | Friedman *p*-value = **8.4895E−20** | | |

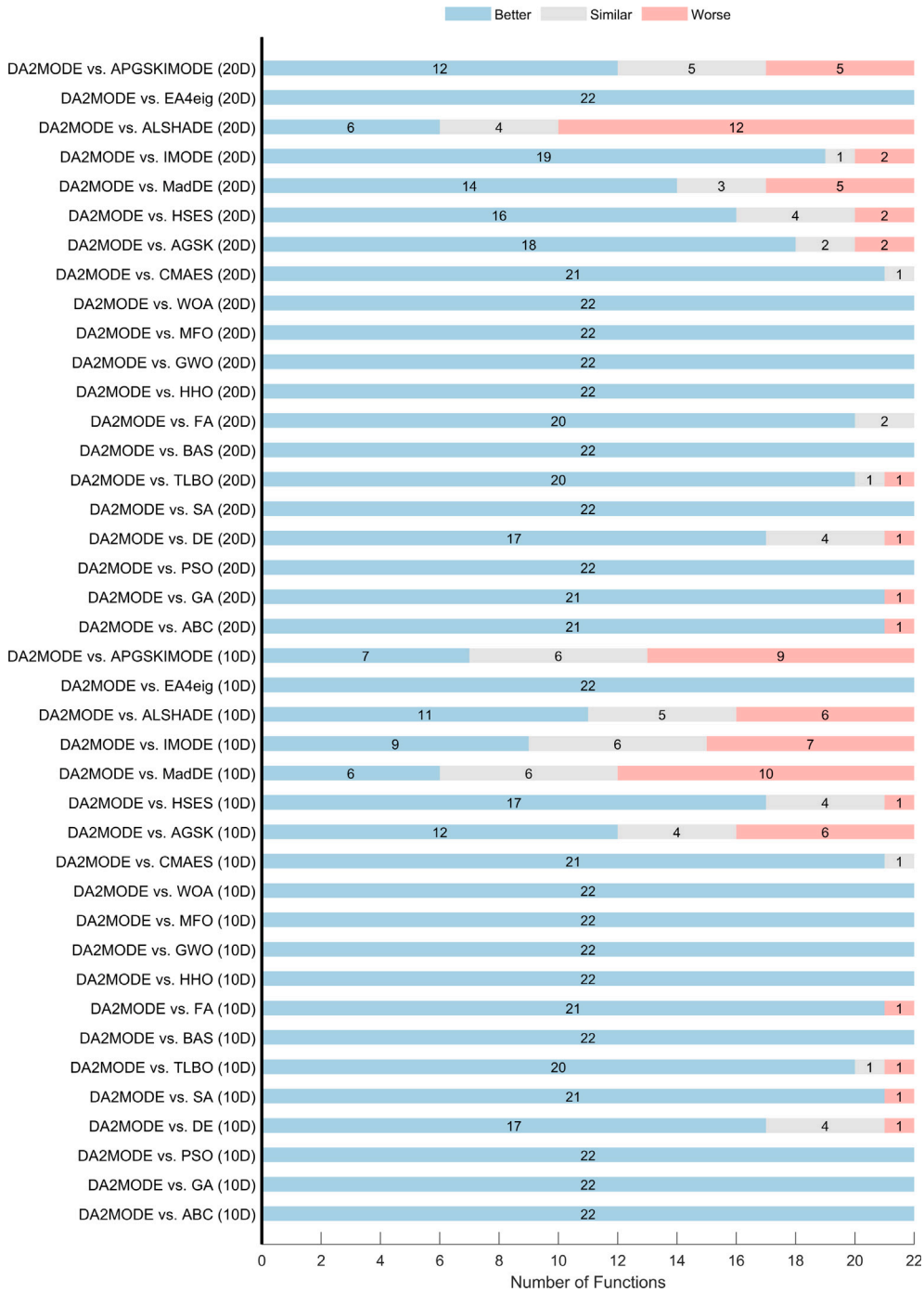



**Fig. 6.** Detailed Wilcoxon Signed-rank test results distributions for all the 22 function (10D and 20D) of CEC2020-2022 benchmark functions, where the DA2MODE is the reference. (Dimensions perspective).

format, where DA2MODE was consistently placed second to test if it significantly converges faster than mDEW, BeSD, and BDE. The resulting trends in Fig. 15 reveal statistically significant increasing trends in all three cases (mDEW–DA2MODE, BeSD–DA2MODE, and BDE–DA2MODE), confirming DA2MODE's superior convergence speed relative to these top-performing alternatives.

## 7. Results and statistical analysis: CEC2017–2018 part 1

The DA2MODE algorithm is also evaluated using the CEC2017–2018 benchmark suite at 30D, 50D, and 100D dimensions. It is compared against 20 algorithms, including classical meta-heuristics such as GA, DE, PSO, SA, TLBO, ABC, BAS, FA, CMAES, GWO, WOA, MFO, and HHO, as well as CEC-winning algorithms such as HSES, IMODE, AGSK, MadDE, APGSKIMODE, EA4eig, and ALSHADE. The statistical metrics (best, worst, median, mean, and SD) are summarized in Appendix E (Tables E.9–E.11).

Representative violin plots for functions F2, F8, F15, F22, and F28 across all three dimensions are shown in Fig. 16. DA2MODE consistently demonstrates lower error values and more compact solution distributions. BAS and CMAES are excluded from the visualizations due to their relatively large error scales that obscure comparisons. The full visual distribution analysis is provided in Appendix F (Figs. F.9a–F.9e, Figs. F.10a–F.10e and Figs. F.11a–F.11e).

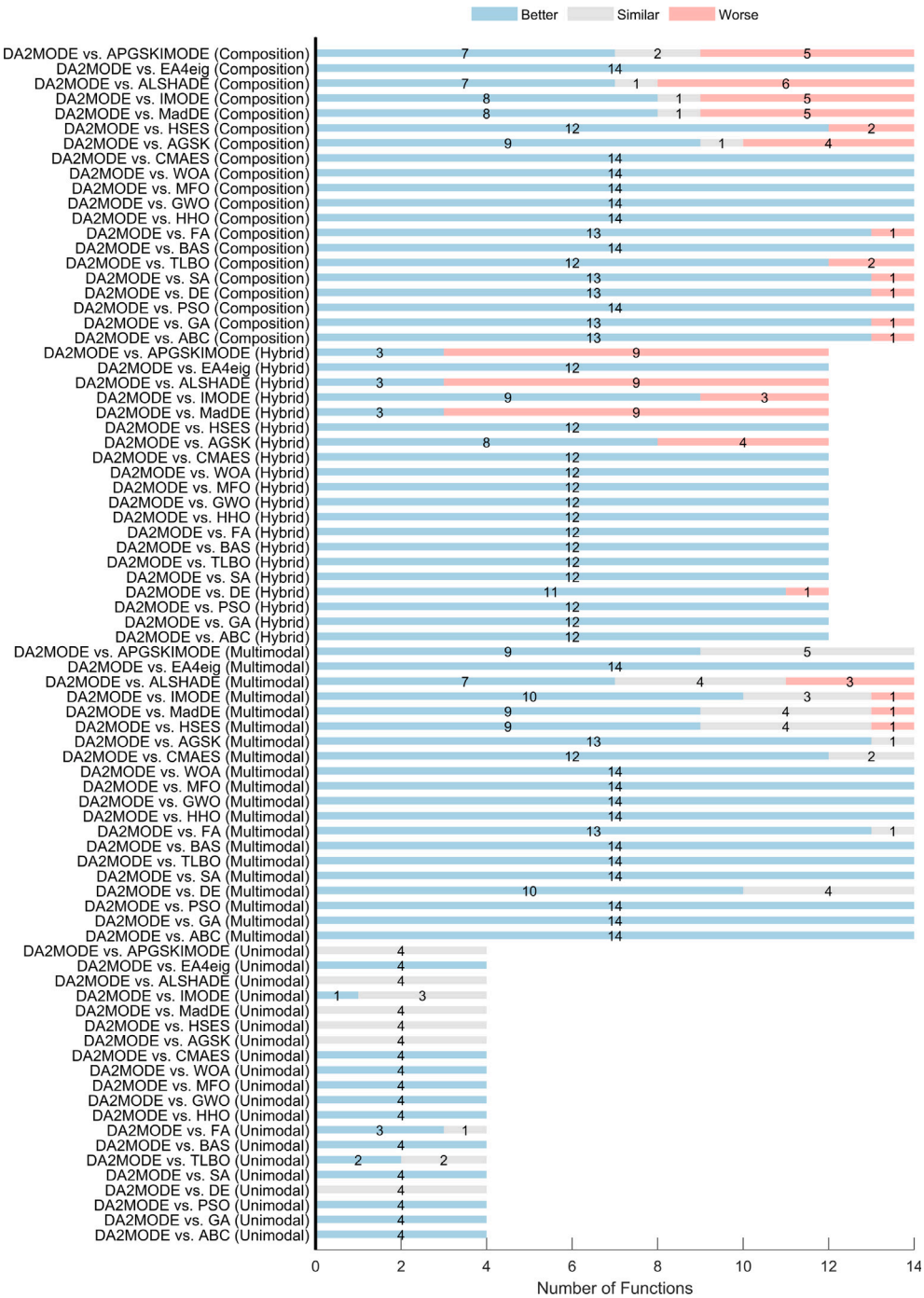



**Fig. 7.** Detailed Wilcoxon Signed-rank test results distributions for all the 22 function of CEC2020-2022 benchmark functions, where the DA2MODE is the reference. (Categories perspective).

### *7.1. Statistical analysis: Group comparison*

Following the same FEs-based ranking approach in [37], Fig. 17 shows the relationship between FEs and the best errors achieved on selected functions and dimensions. Weights of 20%, 30%, and 50% are assigned to 30D, 50D, and 100D, respectively (Eq. (29)), emphasizing performance in more demanding higher dimensions. Table 9 summarizes each algorithm's weighted sum rank ($SR_m$) for the best and median error metrics, alongside their respective ranks among all the algorithms.

$$SR_m = 0.2\sum_{i=1}^{29} rank_{i,m}^{30D} + 0.3\sum_{i=1}^{29} rank_{i,m}^{50D} + 0.5\sum_{i=1}^{29} rank_{i,m}^{100D} \tag{29}$$

In the best-error category, DA2MODE attains first place with the highest sum rank (563.9), indicating that it either achieves $1.0E-08$ quickly or maintains the lowest error at MaxFEs more consistently than its competitors. HSES and ALSHADE follow in second and third places, respectively, while PSO and BAS show lower ranks. A similar pattern occurs for the median-error metric, where DA2MODE again holds first place (570), with ALSHADE, HSES, and AGSK ranking behind. The consistency of DA2MODE's top position in both best and median metrics underscores its robustness across multiple trials, dimensions, and function categories.

Another ranking approach is also used, following the method in [18], where algorithms are evaluated based on normalized best errors and

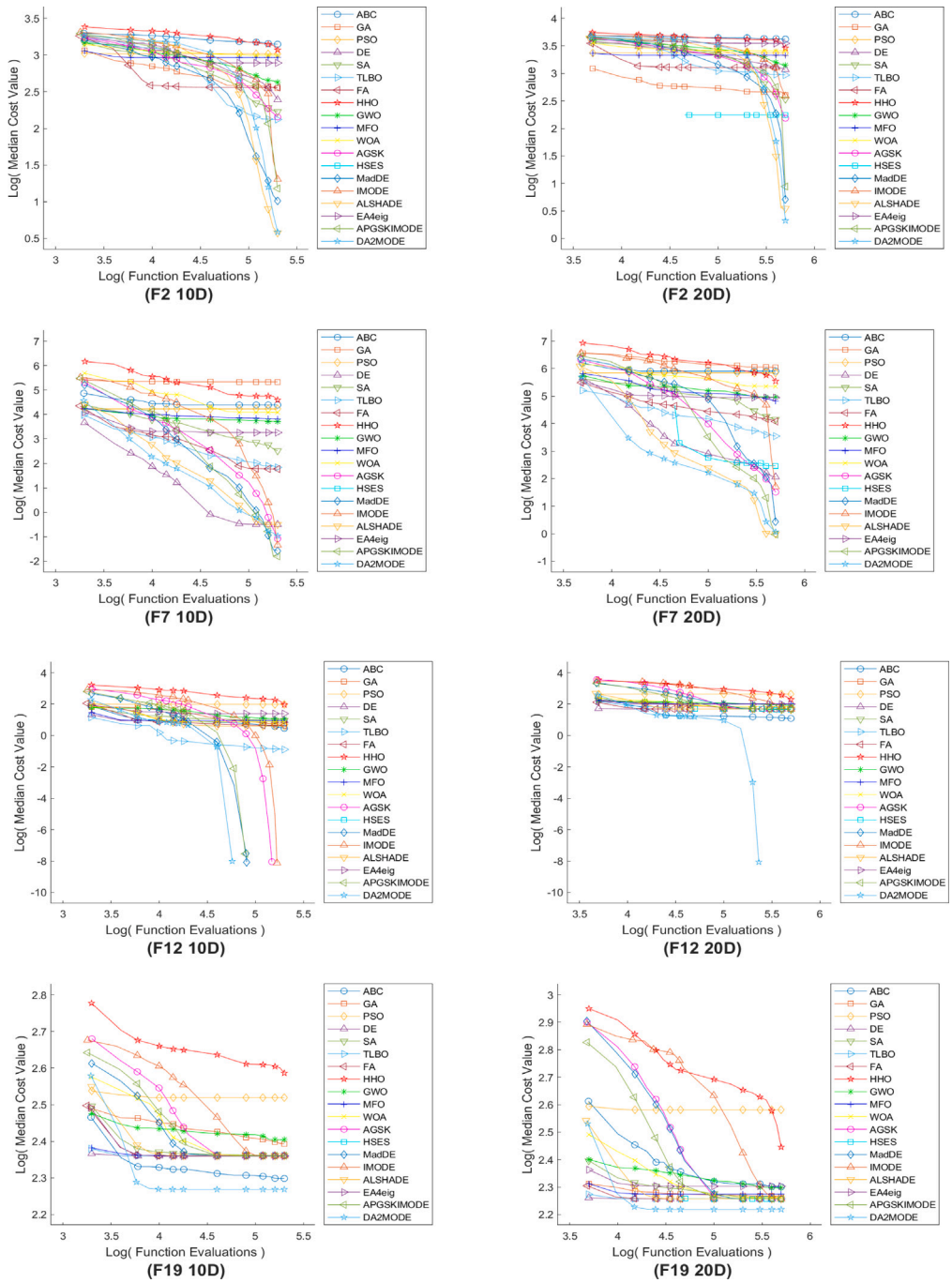



**Fig. 8.** Median convergence plots for all the algorithms for selective 10D and 20D CEC2020-2022 benchmark functions.

their ranks in mean error. A total score between 0 and 100 is then calculated for each algorithm using Eqs. (30)–(32). Table 10 shows the final scores, where $SNE_m$ is the weighted sum of normalized best errors, and $SR_m$ is the weighted sum of mean error ranks across all functions and dimensions.

A total score of 100 indicates the best overall performance, while lower scores reflect weaker results. DA2MODE achieves the highest total SNE-SR score of 93.94, clearly outperforming all other algorithms. HSES and ALSHADE follow with scores of 87.22 and 82.81, while the remaining algorithms score below 50, showing a noticeable performance gap.

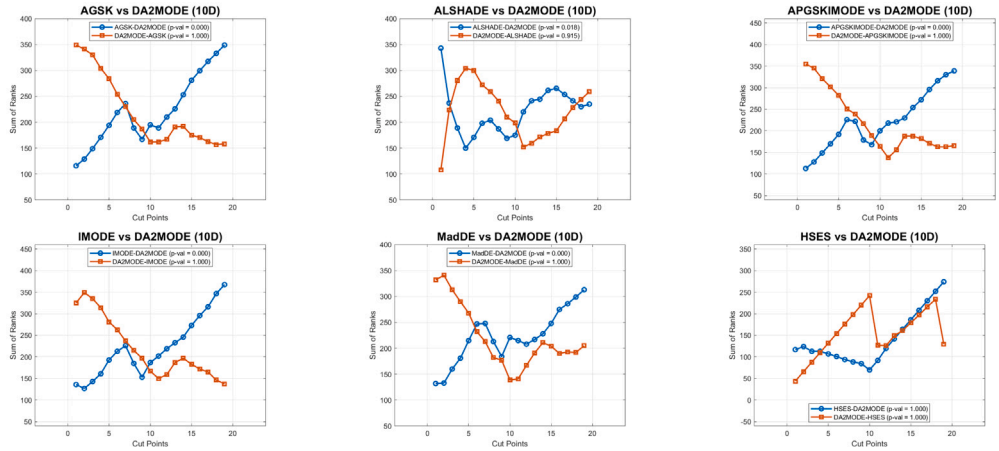
$$Score_m = Score1_m + Score2_m \tag{30}$$

$$Score1_m = \left(1 - \frac{SNE_m - SNE_{min}}{SNE_m}\right) \times 50 \tag{31}$$

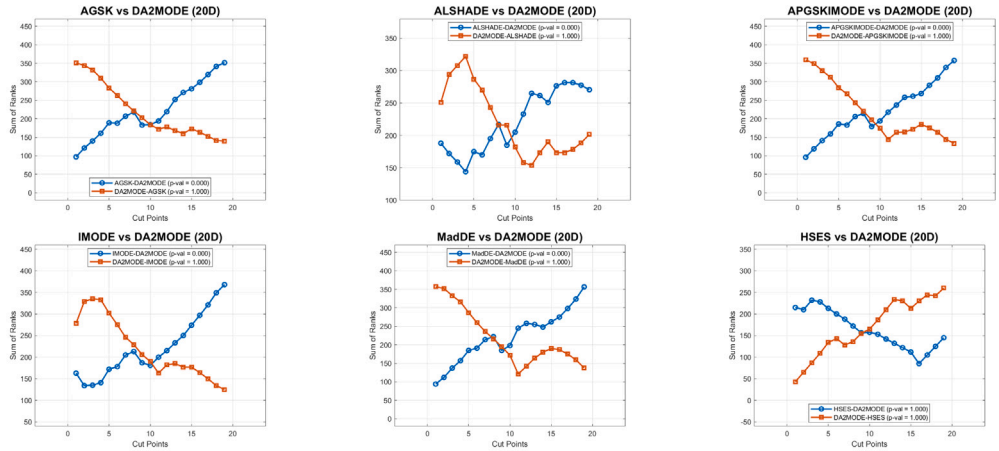
$$Score2_m = \left(1 - \frac{SR_m - SR_{min}}{SR_m}\right) \times 50 \tag{32}$$

### 7.2. Statistical analysis: Friedman and Wilcoxon tests

Table 11 shows that DA2MODE consistently achieves the lowest mean ranks across all dimensions. At 30D, it records a mean rank of 2.21 with a very small $p$-value of $2.80 \times 10^{-90}$. At 50D, the performance improves further, with a mean rank of 1.93 and $p = 1.46 \times 10^{-82}$. At 100D, DA2MODE remains in first place with a mean rank of 2.62 and $p = 1.54 \times 10^{-79}$. These consistently low $p$-values confirm that DA2MODE




(a) 10 Dim.




(b) 20 Dim.

**Fig. 9.** Page Test Convergence trend graph between the DA2MODE and top state-of- the-art algorithms for CEC2020-2022 benchmark functions.

is statistically superior to all other algorithms across low, medium, and high dimensions.

As reported in Table 11, the Wilcoxon signed-rank test results confirm DA2MODE's strong statistical dominance across various benchmark dimensions and function types. The overall algorithm-wise performance in Fig. 18 shows that DA2MODE achieves a perfect score (87/87 wins) against a wide range of classical and modern algorithms, including EA4eig, WOA, MFO, GWO, HHO, FA, BAS, TLBO, PSO, GA, and ABC. Compared to the more competitive ALSHADE and HSES, it records close results: $+42/=5/-40$ with ALSHADE and a clear advantage of $+51/=3/-33$ with HSES.

Dimension-wise comparisons are shown in Fig. 19. At 30D, DA2MODE is slightly behind ALSHADE (12 wins vs. 14 losses). However, as dimensionality increases, DA2MODE gains the upper hand. It achieves more wins than ALSHADE at 50D (15 wins vs. 12 losses) and 100D (15 wins vs. 13 losses). Furthermore, DA2MODE consistently outperforms HSES in all three dimensions.

Function category-wise analysis in Fig. 20 further highlights DA2MODE's adaptability. In unimodal functions, it matches ALSHADE and HSES. In the more challenging multimodal category (21 functions per algorithm), HSES leads with 17 wins, while DA2MODE manages only 3; similarly, ALSHADE achieves 14 wins compared to DA2MODE's 6. However, DA2MODE recovers strongly in hybrid functions (30 per algorithm), outperforming HSES in 21 cases and maintaining near parity with ALSHADE (16 wins vs. 14 losses). Its dominance becomes most apparent in the composition category (the most complex group), where DA2MODE defeats HSES in 25 out of 30 functions and ALSHADE in 19. These trends underscore DA2MODE's strength in handling complex, high-dimensional, and composition-heavy landscapes. (See Table 12.)

### 7.3. Convergence analysis

Fig. 21 shows the median convergence plots for four representative functions (F2, F13, F17, F26, and F29) at 30D, 50D, and 100D. The complete set of convergence plots is provided in Appendix G (Figs. G.15a–G.15e, Figs. G.16a–G.16e and Figs. G.17a–G.17e). DA2MODE typically achieves faster drops in cost value in the early stages of the search, maintaining or further improving its lead as the iteration count grows. DA2MODE's convergence curves not only reach lower final cost values but also do so more rapidly regardless of the dimension of the function category, emphasizing its superiority.

## 8. Results and statistical analysis: CEC2017-2018 part 2

This section evaluates the performance of DA2MODE on the CEC2017–2018 benchmark suite using a second group of advanced and recent DE variants. The compared algorithms include JADE [29], JADEGMO [31], meanDE [27], MDE [41], WDE [39], BSD [43], BDE [44], QRDE [46], MTDE [42], mDEW [27], EODE [40], BeSD [45], and dFDBLSHADE [28]. Each algorithm is tested over 51 independent runs on the full set of benchmark functions at dimensions 30D, 50D, and 100D.

Summary statistics and performance tables are reported in Appendix E.2 (Tables E.12–E.14). Representative violin plots for selected

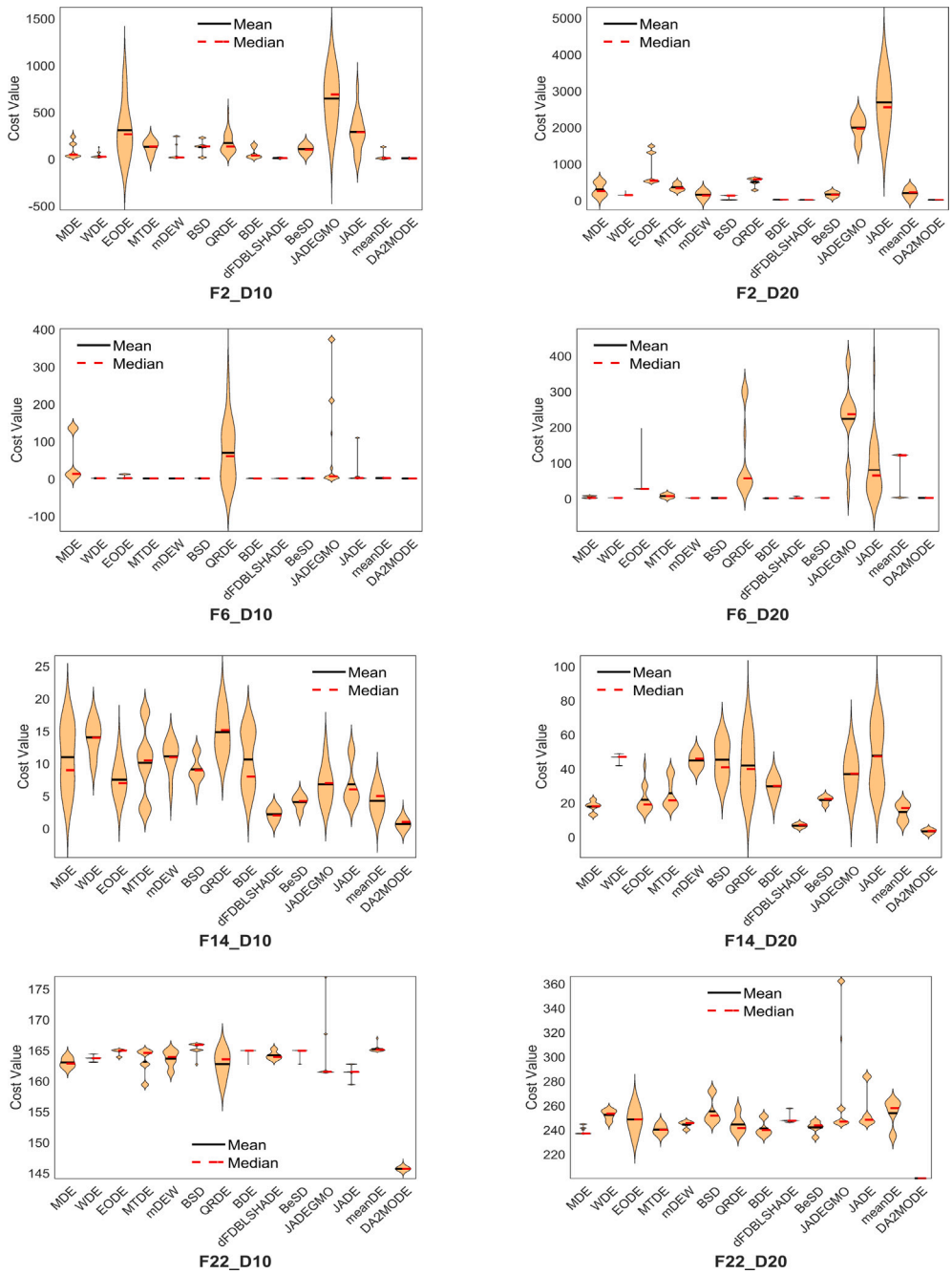



**Fig. 10.** Violin plots for all DE variants for selective 10D and 20D CEC2020-2022 benchmark functions.

functions are presented in Fig. 22, including F2 (Unimodal), F6 (Multimodal), F15 (Hybrid), and F22 and F28 (Composition). The complete plots for all functions across all dimensions are available in Appendix F.2 (Figs. F.12a–F.12e, Figs. F.13a–F.13e and Figs. F.14a–F.14e).

### 8.1. Statistical analysis: Group comparison

Table 13 presents the comparative performance of the 14 DE variants using two ranking strategies: the SNE-SR-based metric (Eqs. (30)–(32) [37]), and the Median FE-based score (Eq. (29) [18]). DA2MODE clearly outperforms all competitors, achieving the highest possible total SNE-SR score (100.0000) and ranking first in both metrics. It also records the highest average sum rank in the FE-based metric (SR = 398.7), reflecting its superior efficiency across all problem dimensions.

The second-best algorithm in the SNE-SR metric is BDE, with a total SNE-SR score of 41.4870. It also ranks second in the median FE-based ranking, with an average SR of 274.9. These results highlight a substantial performance margin, as DA2MODE achieves more than twice the SNE-SR score of the next-best competitor and a significantly higher FE-based score, reinforcing its leading position across both accuracy and convergence measures.

Table 14 shows the Friedman test results based on mean error for 30D, 50D, and 100D. DA2MODE achieves the best mean ranks in all three cases: 1.2414 (30D), 1.1207 (50D), and 1.2414 (100D). The corresponding p-values are exceptionally low: $3.19 \times 10^{-34}$ for 30D, $9.75 \times 10^{-33}$ for 50D, and again $3.19 \times 10^{-34}$ for 100D, confirming the statistical significance of these results. BDE follows as the second-best performer, with mean ranks of 4.6897, 5.8793, and 4.6897

**Table 8**
Detailed sign test results between the DA2MODE and every other DE variant for the 10D and 20D CEC2020-2022 benchmark functions. Best results are shown in bold, highlighting cases where DA2MODE outperforms the competing algorithms.

| Alg. | Category | 10D | 20D | Total |
|---|---|---|---|---|
| MDE | Unimodal | +0/=2/-0 | +0/=2/-0 | +0/=4/-0 |
| | Multimodal | +5/=2/-0 | +6/=1/-0 | +11/=3/-0 |
| | Hybrid | +6/=0/-0 | +6/=0/-0 | +12/=0/-0 |
| | Composition | +7/=0/-0 | +5/=0/-2 | +12/=0/-2 |
| | Total | +18/=4/-0 | +17/=3/-2 | **+35/=7/-2** |
| WDE | Unimodal | +2/=0/-0 | +2/=0/-0 | +4/=0/-0 |
| | Multimodal | +7/=0/-0 | +7/=0/-0 | +14/=0/-0 |
| | Hybrid | +6/=0/-0 | +5/=0/-1 | +11/=0/-1 |
| | Composition | +3/=0/-4 | +1/=0/-6 | +4/=0/-10 |
| | Total | +18/=0/-4 | +15/=0/-7 | **+33/=0/-11** |
| EODE | Unimodal | +0/=2/-0 | +0/=2/-0 | +0/=4/-0 |
| | Multimodal | +5/=2/-0 | +6/=1/-0 | +11/=3/-0 |
| | Hybrid | +6/=0/-0 | +6/=0/-0 | +12/=0/-0 |
| | Composition | +6/=1/-0 | +6/=0/-1 | +12/=1/-1 |
| | Total | +17/=5/-0 | +18/=3/-1 | **+35/=8/-1** |
| MTDE | Unimodal | +0/=2/-0 | +0/=2/-0 | +0/=4/-0 |
| | Multimodal | +6/=1/-0 | +7/=0/-0 | +13/=1/-0 |
| | Hybrid | +5/=0/-1 | +6/=0/-0 | +11/=0/-1 |
| | Composition | +3/=1/-3 | +7/=0/-0 | +10/=1/-3 |
| | Total | +14/=4/-4 | +20/=2/-0 | **+34/=6/-4** |
| mDEW | Unimodal | +0/=2/-0 | +0/=2/-0 | +0/=4/-0 |
| | Multimodal | +5/=2/-0 | +6/=1/-0 | +11/=3/-0 |
| | Hybrid | +3/=0/-3 | +5/=0/-1 | +8/=0/-4 |
| | Composition | +2/=1/-4 | +3/=0/-4 | +5/=1/-8 |
| | Total | +10/=5/-7 | +14/=3/-5 | **+24/=8/-12** |
| BSD | Unimodal | +1/=1/-0 | +2/=0/-0 | +3/=1/-0 |
| | Multimodal | +5/=2/-0 | +6/=1/-0 | +11/=3/-0 |
| | Hybrid | +5/=0/-1 | +5/=0/-1 | +10/=0/-2 |
| | Composition | +3/=1/-3 | +3/=0/-4 | +6/=1/-7 |
| | Total | +14/=4/-4 | +16/=1/-5 | **+30/=5/-9** |
| QRDE | Unimodal | +1/=1/-0 | +1/=1/-0 | +2/=2/-0 |
| | Multimodal | +5/=2/-0 | +5/=2/-0 | +10/=4/-0 |
| | Hybrid | +6/=0/-0 | +6/=0/-0 | +12/=0/-0 |
| | Composition | +7/=0/-0 | +6/=0/-1 | +13/=0/-1 |
| | Total | +19/=3/-0 | +18/=3/-1 | **+37/=6/-1** |

| Alg. | Category | 10D | 20D | Total |
|---|---|---|---|---|
| BDE | Unimodal | +0/=2/-0 | +0/=2/-0 | +0/=4/-0 |
| | Multimodal | +5/=2/-0 | +6/=1/-0 | +11/=3/-0 |
| | Hybrid | +4/=0/-2 | +4/=0/-2 | +8/=0/-4 |
| | Composition | +3/=1/-3 | +7/=0/-0 | +10/=1/-3 |
| | Total | +12/=5/-5 | +17/=3/-2 | **+29/=8/-7** |
| dFDBLSHADE | Unimodal | +1/=1/-0 | +2/=0/-0 | +3/=1/-0 |
| | Multimodal | +5/=0/-2 | +6/=0/-1 | +11/=0/-3 |
| | Hybrid | +5/=0/-1 | +5/=0/-1 | +10/=0/-2 |
| | Composition | +2/=1/-4 | +6/=0/-1 | +8/=1/-5 |
| | Total | +13/=2/-7 | +19/=0/-3 | **+32/=2/-10** |
| BeSD | Unimodal | +0/=2/-0 | +0/=2/-0 | +0/=4/-0 |
| | Multimodal | +3/=3/-1 | +5/=2/-0 | +8/=5/-1 |
| | Hybrid | +5/=0/-1 | +5/=0/-1 | +10/=0/-2 |
| | Composition | +3/=1/-3 | +6/=0/-1 | +9/=1/-4 |
| | Total | +11/=6/-5 | +16/=4/-2 | **+27/=10/-7** |
| JADEGMO | Unimodal | +1/=1/-0 | +2/=0/-0 | +3/=1/-0 |
| | Multimodal | +6/=1/-0 | +7/=0/-0 | +13/=1/-0 |
| | Hybrid | +6/=0/-0 | +6/=0/-0 | +12/=0/-0 |
| | Composition | +7/=0/-0 | +7/=0/-0 | +14/=0/-0 |
| | Total | +20/=2/-0 | +22/=0/-0 | **+42/=2/-0** |
| JADE | Unimodal | +1/=1/-0 | +2/=0/-0 | +3/=1/-0 |
| | Multimodal | +7/=0/-0 | +7/=0/-0 | +14/=0/-0 |
| | Hybrid | +6/=0/-0 | +6/=0/-0 | +12/=0/-0 |
| | Composition | +6/=0/-1 | +7/=0/-0 | +13/=0/-1 |
| | Total | +20/=1/-1 | +22/=0/-0 | **+42/=1/-1** |
| meanDE | Unimodal | +0/=2/-0 | +1/=1/-0 | +1/=3/-0 |
| | Multimodal | +6/=1/-0 | +7/=0/-0 | +13/=1/-0 |
| | Hybrid | +6/=0/-0 | +5/=0/-1 | +11/=0/-1 |
| | Composition | +6/=1/-0 | +6/=0/-1 | +12/=1/-1 |
| | Total | +18/=4/-0 | +19/=1/-2 | **+37/=5/-2** |

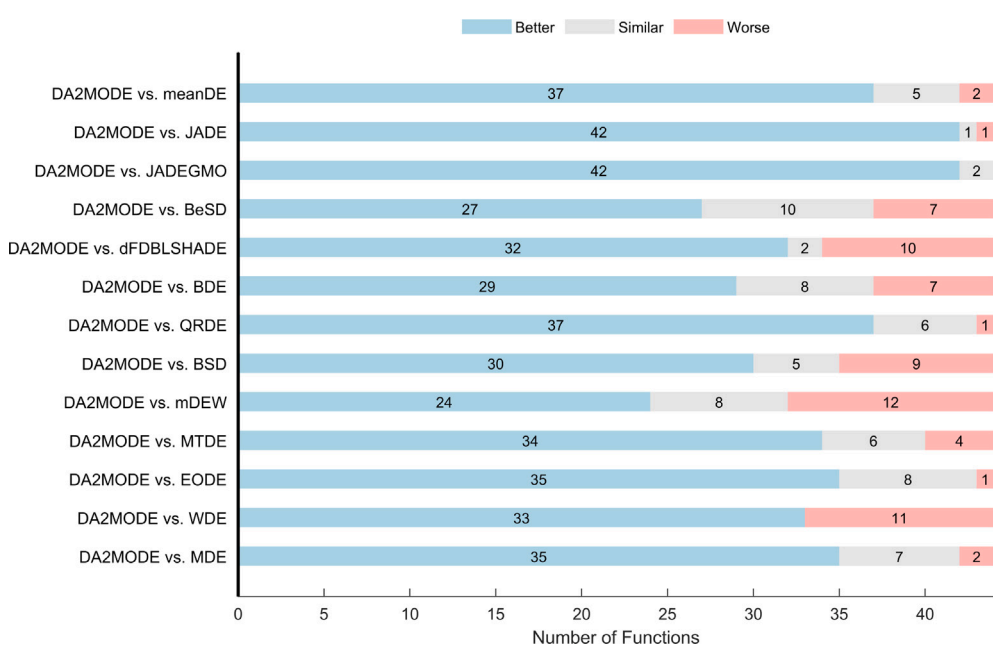



**Fig. 11.** Detailed Wilcoxon Signed-rank test results distributions for all the 22 function of CEC2020-2022 benchmark functions, where the DA2MODE is the reference among 14 DE variants. (Algorithm perspective).

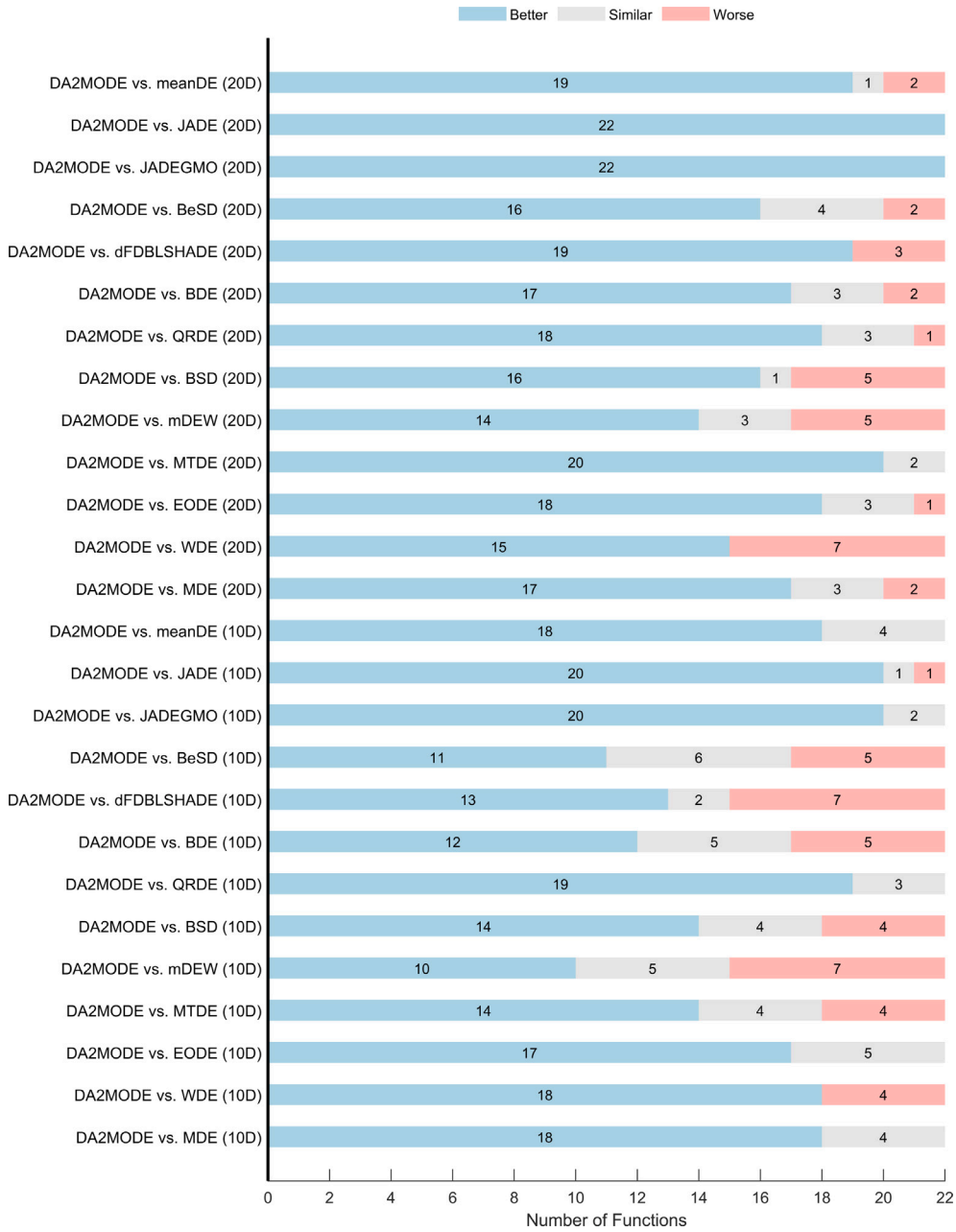



**Fig. 12.** Detailed Wilcoxon Signed-rank test results distributions for all the 22 function (10D and 20D) of CEC2020-2022 benchmark functions, where the DA2MODE is the reference among 14 DE variants. (Dimensions perspective).

for the respective dimensions, reflecting consistent yet clearly lower performance compared to DA2MODE.

### 8.2. Statistical analysis: Paired comparison

Table 15 presents the detailed Wilcoxon signed-rank test outcomes. DA2MODE consistently secures dominant win–loss records across nearly all pairwise comparisons, demonstrating statistically significant superiority across diverse function types and dimensionalities.

For instance, it achieves perfect or near-perfect outcomes (e.g., + 87/ = 0/ − 0) against algorithms such as meanDE, JADE, JADEGMO, MTDE, and MDE. Even in more competitive variants, including BDE, dFDBLSHADE, and mDEW, DA2MODE maintains a decisive advantage, with win–loss records of + 82/ = 0/ − 5, + 84/ = 0/ − 3, and + 84/ = 0/ − 3, respectively, as shown in Fig. 23.

The dimension-wise analysis further confirms the method's consistency, as illustrated in Fig. 24. Each dimension includes 29 benchmark functions, and DA2MODE wins in no fewer than 26 functions at 30D, no fewer than 28 functions at 50D, and at least 27 functions at 100D in all pairwise comparisons.

Category-wise results, visualized in Fig. 25, confirm the algorithm's adaptability to varied landscape complexities. DA2MODE exhibits perfect dominance in all unimodal functions, winning every comparison (+ 6/ = 0/ − 0 per algorithm). In the multimodal category (21 functions per algorithm), it wins at least 19 out of 21 functions, even against the strongest competitors. In the hybrid function group (30 functions per algorithm), DA2MODE consistently achieves either full wins or only one or two losses, winning 30 or at least 28 cases in every comparison. Similarly, in the composition functions (also 30 per algorithm), it records 30 or at least 29 wins, further underscoring its strong adaptability to complex, composite landscapes.

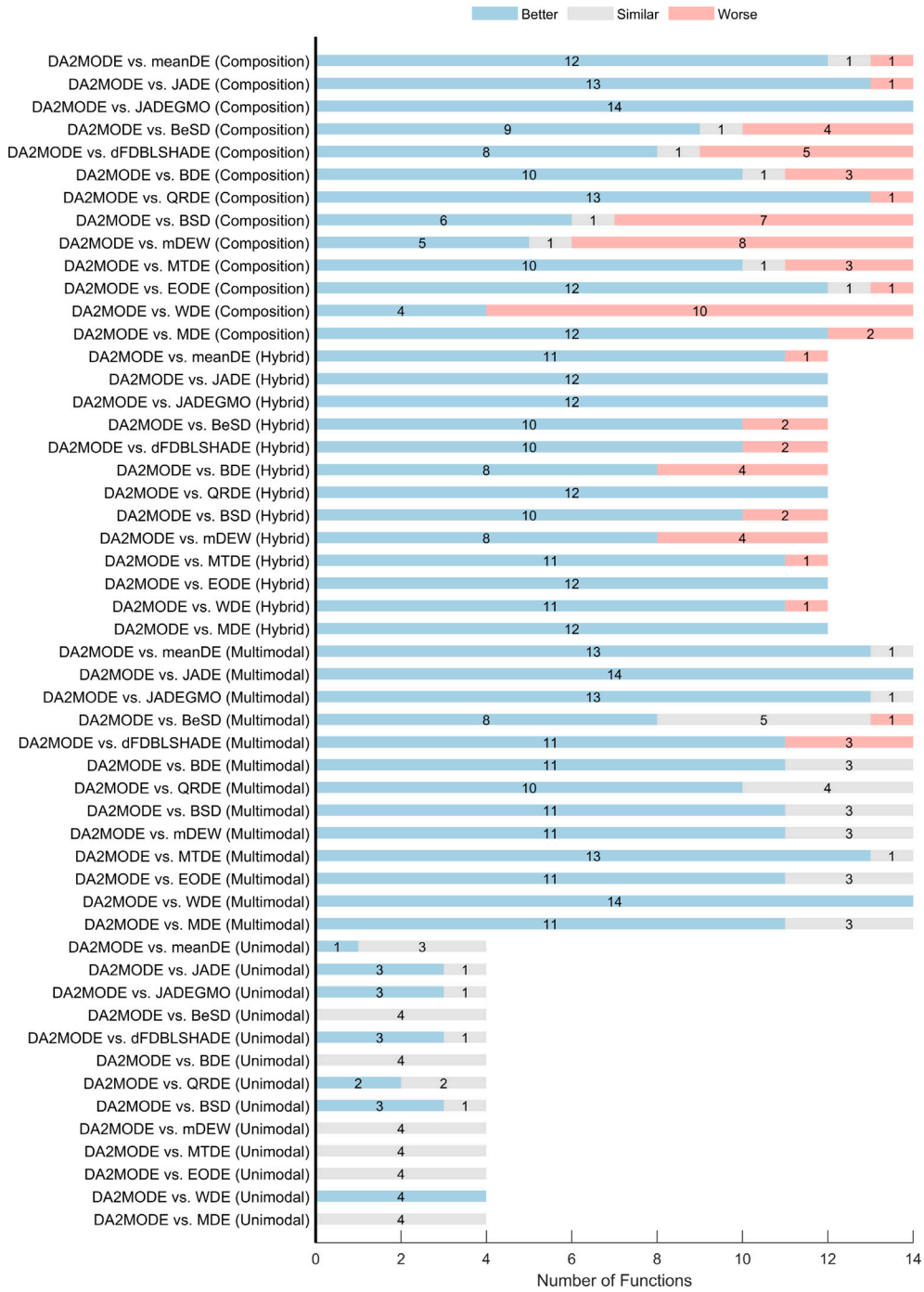



**Fig. 13.** Detailed Wilcoxon Signed-rank test results distributions for all the 22 function of CEC2020-2022 benchmark functions, where the DA2MODE is the reference among 14 DE variants. (Categories perspective).

### *8.3. Convergence analysis*

Fig. 26 illustrates representative convergence plots for selected benchmark functions from the CEC2017–2018 suite across 30D, 50D, and 100D dimensions. The selected functions are F2 (Unimodal), F13 (Multimodal), F17 (Hybrid), and F26 and F29 (Composition). The plots show the median function error over function evaluations for all 14 DE variants. Across all dimensions and problem types, DA2MODE consistently demonstrates faster convergence, starting from higher initial to lower final errors than the other algorithms. The complete set of convergence plots is available in Appendix G.2 (Figs. G.18a–G.18e, Figs. G.19a–G.19e and Figs. G.20a–G.20e).

## 9. Results and statistical analysis: CEC2013-LSGO

This section presents the performance evaluation of the DA2MODE algorithm on the CEC2013-LSGO benchmark suite, which comprises 15 large-scale optimization problems with 1000 decision variables. DA2MODE is compared against a diverse set of 12 top-performing algorithms, including recent DE variants such as EODE, BeSD, BSD, MDE, dFDBLSHADE, meanDE, and BDE, as well as leading baseline and CEC-winning methods from Group 1, including APGSKIMODE, AGSK, SA, and ALSHADE. Although the HSES algorithm has demonstrated competitive performance in CEC2020-2022 and CEC2017–2018 competitions, it was excluded from this evaluation due to excessive

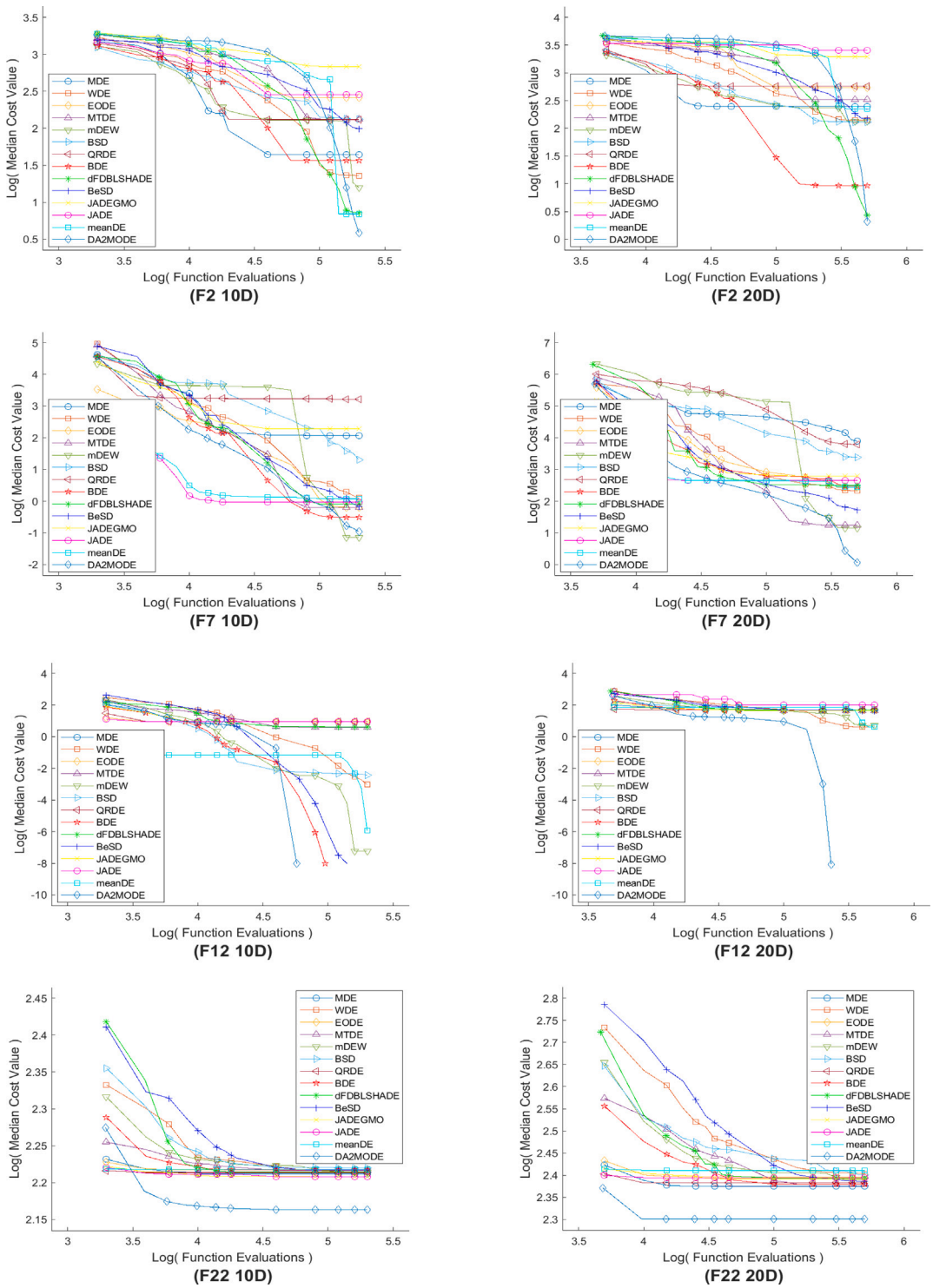


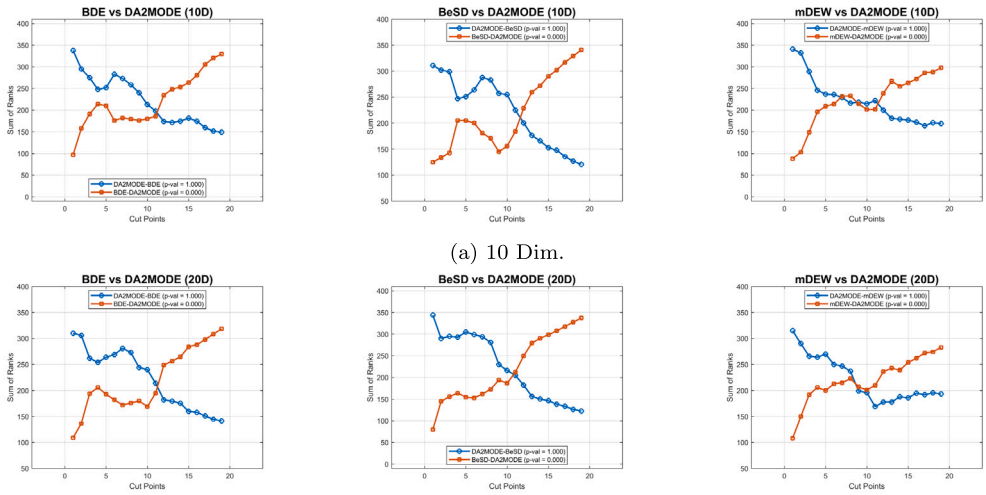

**Fig. 14.** Median convergence plots for all DE variants for selective 10D and 20D CEC2020-2022 benchmark functions.

runtime and memory usage when applied to the 1000D CEC2013-LSGO problems under the 500,000 MaxFEs constraint.

Each algorithm was executed for 25 independent runs [58]. The full result tables are provided in Appendix H (Table H.15). Representative distributions of the best error across 25 runs are visualized using violin plots in Fig. 27, showcasing results for functions F1 (separable), F6 (partially separable I), F8 (partially separable II), F12 (overlapping), and F15 (non-separable). DA2MODE demonstrates consistently compact and tight distributions across most functions. Complete plots for all functions are available in Appendix I (Figs. I.21a–I.21c).

### 9.1. Statistical analysis: Group comparison

Table 16 presents a comprehensive comparison of algorithm performance across the 1000D CEC2013-LSGO functions using three statistical perspectives: the Friedman test, the SNE-SR-based ranking (as defined in Eqs. (30) and (32)), and the Median FE-based evaluation. DA2MODE consistently outperforms all other algorithms, achieving the top rank across all criteria. It secures the lowest mean rank of 2.73 in the Friedman test, the highest SNE-SR combined score of 87.33, and




(a) 10 Dim.

(b) 20 Dim.

**Fig. 15.** Page Test Convergence trend graph between the DA2MODE and top DE variants for CEC2020-2022 benchmark functions.

**Table 9**
The ranking table for the best and median metrics considering both error and the function evaluations for the 30D, 50D, and 100D CEC2017–2018. Best or top-ranked results are shown in bold.

| Algorithm | Best FE-based ranking | | | | | Median FE-based ranking | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | SR 30D | SR 50D | SR 100D | SR | Place | SR 30D | SR 50D | SR 100D | SR | Place |
| ABC | 218 | 212 | 186 | 200.2 | 17 | 260 | 258 | 212 | 235.4 | 14 |
| GA | 307 | 321 | 367 | 341.2 | 11 | 282 | 318 | 365 | 334.3 | 11 |
| PSO | 127 | 116 | 96 | 108.2 | 20 | 121 | 101 | 96 | 102.5 | 20 |
| DE | 357 | 333 | 344 | 343.3 | 10 | 376 | 352 | 348 | 354.8 | 9 |
| SA | 293 | 391 | 439 | 395.4 | 8 | 335 | 416 | 450 | 416.8 | 6 |
| TLBO | 375 | 379 | 354 | 365.7 | 9 | 349 | 335 | 342 | 341.3 | 10 |
| BAS | 29 | 29 | 32 | 30.5 | 21 | 29 | 29 | 29 | 29 | 21 |
| FA | 430 | 425 | 437 | 432 | 5 | 400 | 411 | 423 | 414.8 | 7 |
| HHO | 102 | 105 | 130 | 116.9 | 19 | 98 | 114 | 143 | 125.3 | 19 |
| GWO | 279 | 293 | 300 | 293.7 | 13 | 288 | 295 | 296 | 294.1 | 13 |
| MFO | 222 | 230 | 217 | 221.9 | 14 | 186 | 176 | 172 | 176 | 18 |
| WOA | 186 | 201 | 222 | 208.5 | 16 | 164 | 189 | 219 | 199 | 15 |
| CMAES | 184 | 212 | 233 | 216.9 | 15 | 126 | 207 | 194 | 184.3 | 17 |
| AGSK | 458 | 435 | 417 | 430.6 | 6 | 479 | 449 | 444 | 452.5 | 4 |
| HSES | 528 | 549 | 566 | 553.3 | 2 | 542 | 538 | 559 | 549.3 | 3 |
| MadDE | 429 | 321 | 252 | 308.1 | 12 | 452 | 354 | 274 | 333.6 | 12 |
| IMODE | 380 | 393 | 406 | 396.9 | 7 | 389 | 378 | 403 | 392.7 | 8 |
| ALSHADE | 553 | 565 | 544 | 552.1 | 3 | 572.5 | 566 | 560 | 564.3 | 2 |
| EA4eig | 193 | 176 | 186 | 184.4 | 18 | 192 | 187 | 200 | 194.5 | 16 |
| APGSKIMODE | 485 | 441 | 412 | 435.3 | 4 | 483 | 443 | 410 | 434.5 | 5 |
| DA2MODE | 564 | 572 | 559 | **563.9** | **1** | 575.5 | 583 | 560 | **570** | **1** |

the best position in the Median FE-based evaluation with the highest sum rank (SR) of 153.

BDE demonstrates consistent second-place performance in all three metrics, with a Friedman mean rank of 4.00, a combined SNE-SR score of 84.17, and an FE-based sum rank of 137. While DA2MODE and BDE consistently hold the top two positions, the ranks of the remaining algorithms differ across the three evaluation methods because each method focuses on different aspects, such as accuracy of results, consistency across runs, or speed of finding solutions. The statistical significance of the differences among the algorithms is confirmed by a Friedman test $p$-value of $1.6469\times10^{-17}$, indicating robust performance variation across the group and validating DA2MODE's superiority.

### 9.2. Statistical analysis: Paired comparison

The paired comparison results in Table 17 demonstrate the consistent superiority of DA2MODE over all other algorithms across the five CEC2013-LSGO function categories. For most comparisons, DA2MODE achieves a strong positive win-loss count (e.g., + 15/ = 0/ − 0 against APGSKIMODE, dFDBLSHADE, and meanDE), with only minimal losses recorded in a few cases, such as BDE (+ 9/ = 0/ − 6) and MDE (+ 10/ = 0/ − 5).

In partially separable and overlapping functions, DA2MODE records strong wins across all algorithms, often with perfect scores (e.g., + 4/ = 0/ − 0). For fully non-separable functions, it maintains superiority with consistent + 1 outcomes in every case. In the fully separable category, DA2MODE outperforms nearly all competitors except BDE and BSD, which show better advantages.

These outcomes highlight DA2MODE's robust performance in high-dimensional settings. Figs. 28 and 29 further illustrate the distribution of wins and losses, with the former providing an algorithm-level overview and the latter grouping results by function category.

## 10. DA2MODE application to constrained engineering optimization problems

To further assess the practical effectiveness of the proposed DA2MODE algorithm, it is applied to four well-known constrained engineering optimization problems [67]. The same set of top-performing algorithms used in the CEC2013 LSGO benchmarking is employed for

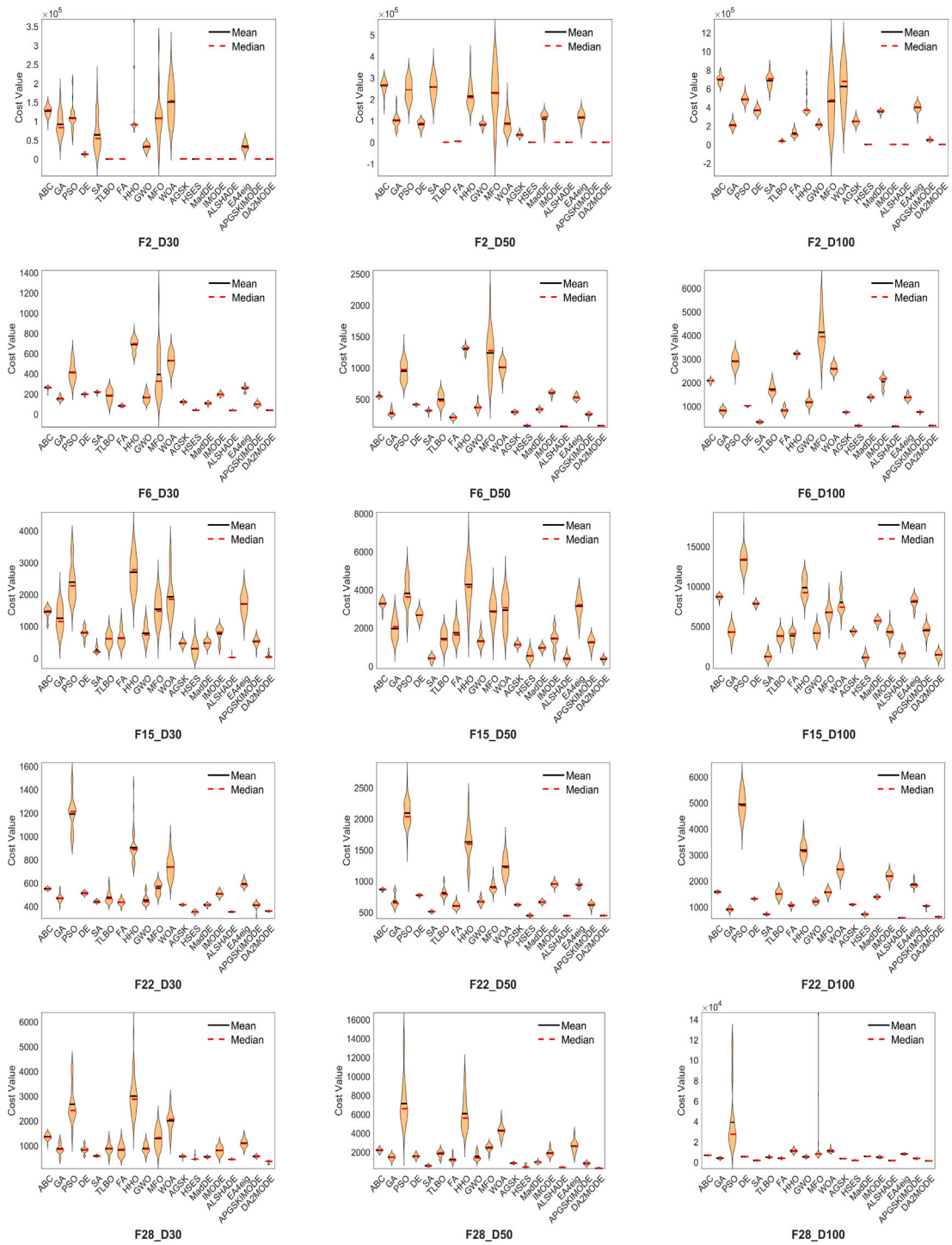



**Fig. 16.** Violin plots for all the algorithms for selective 30D, 50D, and 100D CEC2017–2018 benchmark functions.

comparison. Each algorithm is independently executed over 24 runs, with the maximum number of function evaluations uniformly limited to 12,000 for all problems, as recommended in [68]. This setup ensures a fair and consistent evaluation framework across all tested methods.

### *10.1. Design of tension/compression spring*

The tension/compression spring problem design aims to minimize the weight of a spring subject to four non-linear constraints related to shear stress, deflection, surge frequency, and geometric limitations. The spring schematic is illustrated in Fig. 30. The objective function and constraints are defined as in Appendix J.1, with the decision variables being the mean coil diameter $x_1$ ($D$), wire diameter $x_2$ ($d$), and the number of active coils $x_3$ ($N$).

Table 18 shows that DA2MODE achieves the best median cost (0.0126652328), the highest success rate (75%), and fewer function evaluations (7848) compared to all other algorithms, which exhausted the full limit of 12,000 function evaluations. In contrast, although ALSHADE and APGSKIMODE attained competitive median costs, their success rates were much lower (37.5%), indicating less consistency.

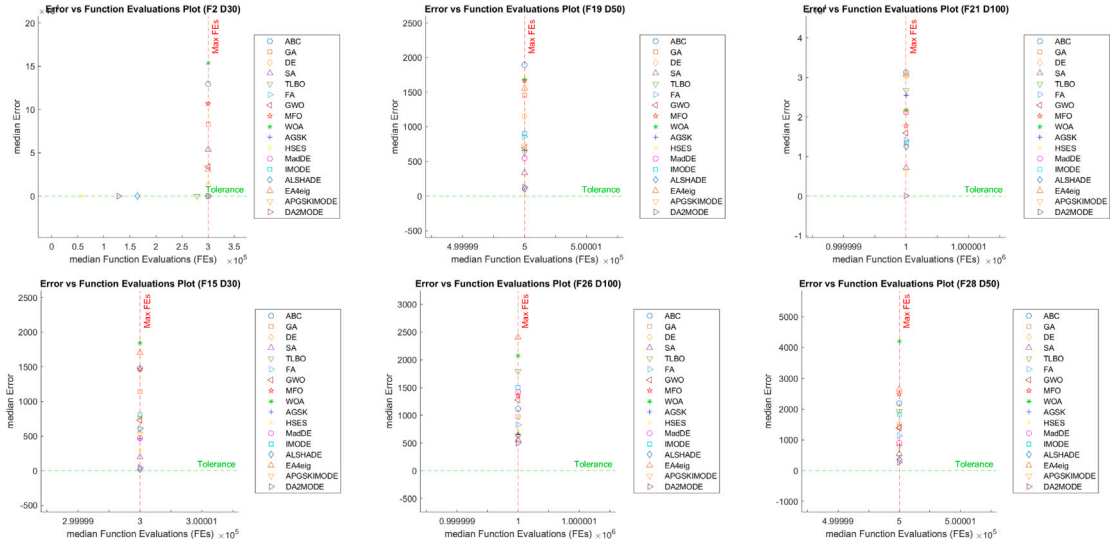



**Fig. 17.** The relationship between the best function evaluations and the best error for all the algorithms on some 30D, 50D, and 100D CEC2017-2018 functions.

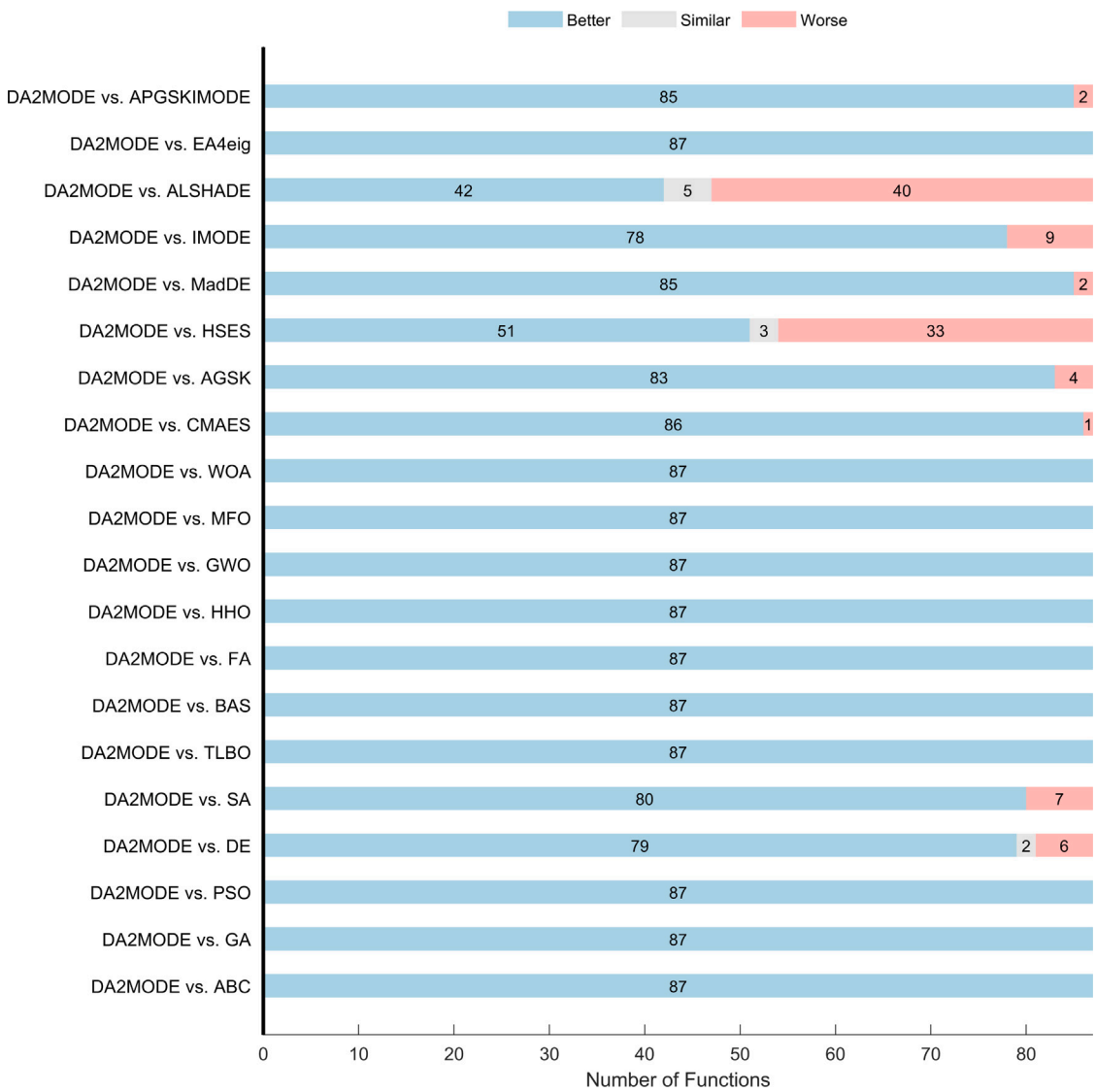



**Fig. 18.** Detailed Wilcoxon Signed-rank test results distributions for all the function of CEC2017-2018 benchmark functions, where the DA2MODE is the reference. (Algorithm perspective).

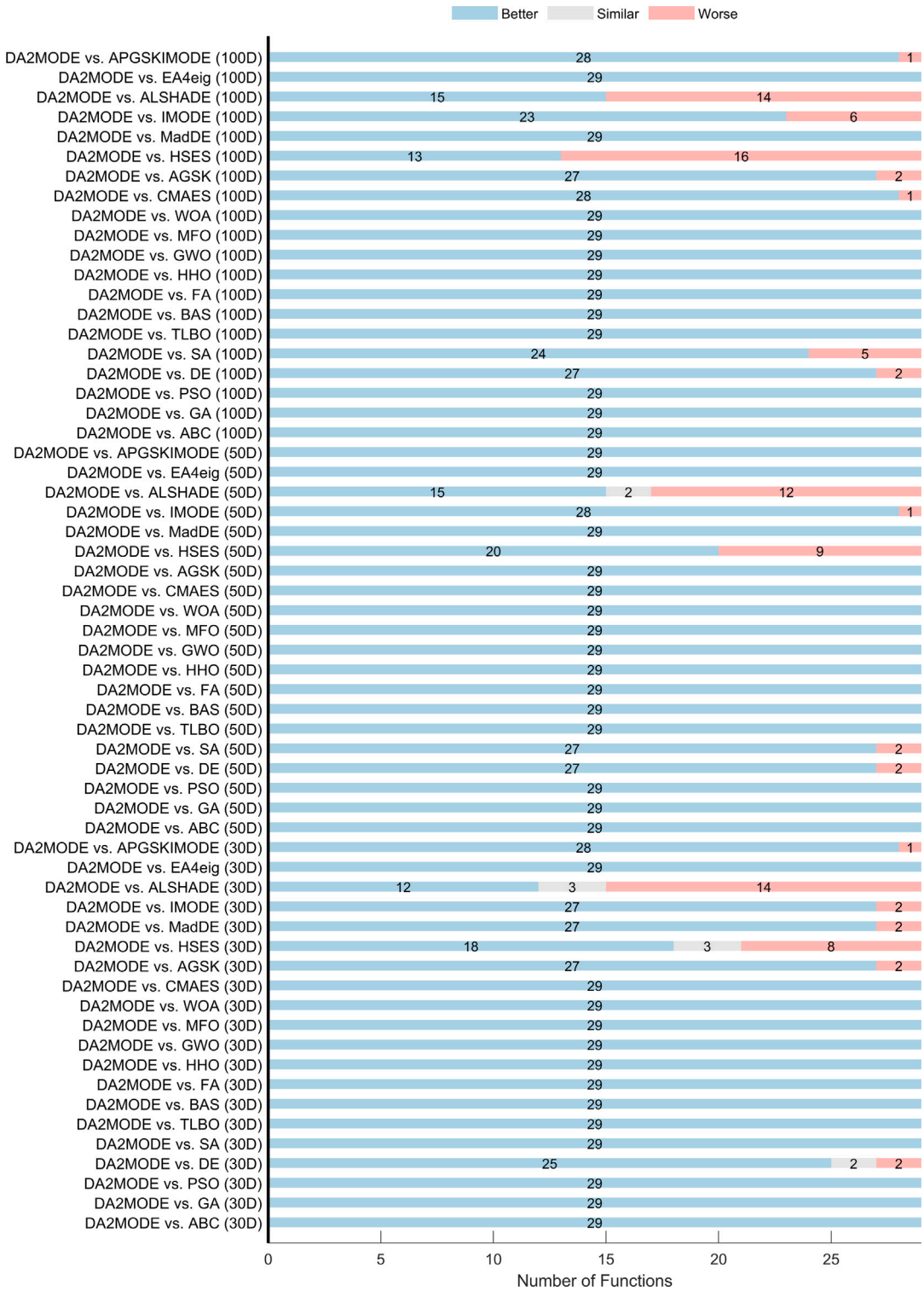



**Fig. 19.** Detailed Wilcoxon Signed-rank test results distributions for all the 30D, 50D, and 100D function of CEC2017-2018 benchmark functions, where the DA2MODE is the reference. (Dimensions perspective).

### *10.2. Cantilever beam problem*

The cantilever beam design problem aims to minimize the weight of a beam by optimizing the cross-sectional dimensions $x_1$ through $x_5$, as shown in Fig. 31. The objective is linear in the design variables, while the constraint ensures structural strength by limiting the combined deflection, as illustrated in Appendix J.2. Each variable $x_i$ (for $i = 1, \ldots, 5$) represents the thickness of one beam segment, with bounds between 0.01 and 100.

Table 19 presents the median outcomes for the cantilever beam problem, highlighting the strong performance of both ALSHADE and DA2MODE, which achieved the best-known cost value of 1.3399576000 with a 100% success rate. However, DA2MODE exhibited a significant computational advantage by requiring only 6523 function evaluations, less than ALSHADE's that terminated at 8532 FEs.

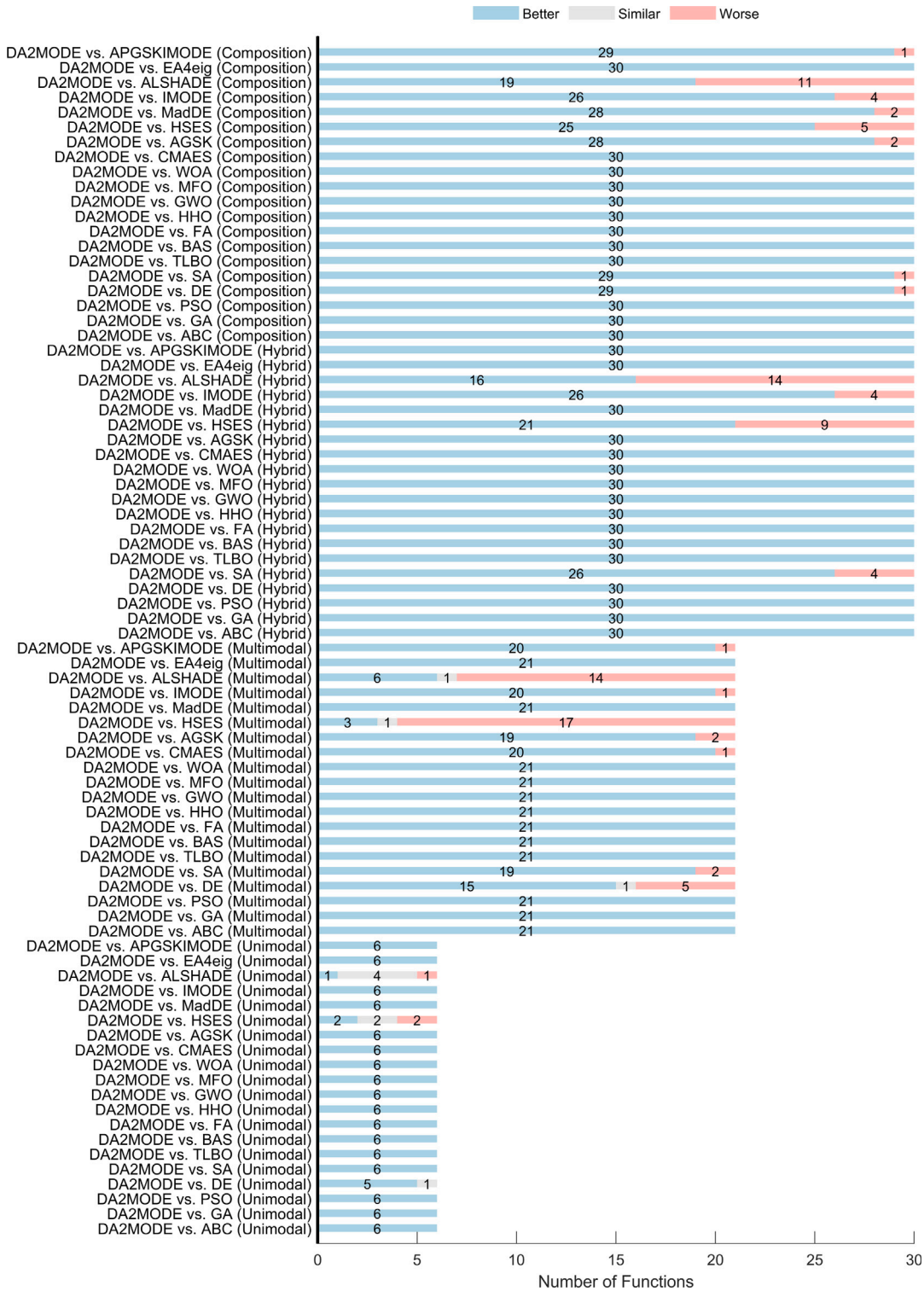



**Fig. 20.** Detailed Wilcoxon Signed-rank test results distributions for all the 30D, 50D, and 100D of CEC2017-2018 benchmark functions, where the DA2MODE is the reference. (Categories perspective).

### *10.3. Optimal design of I-shaped beam*

The I-shaped beam optimization problem focuses on minimizing the cost function associated with structural performance, subject to geometric and stress-related constraints, as described in Appendix J.3. The design variables include the flange width $x_1$, section height $x_2$, web thickness $x_3$, and flange thickness $x_4$, each bounded within specified ranges. The objective involves maximizing the beam's moment of inertia while satisfying structural load conditions. Fig. 32 visually represents the beam configuration.

As presented in Table 20, all algorithms successfully generated feasible solutions for the I-shaped beam design problem, with most achieving nearly identical cost values around 0.013074119. However, DA2MODE slightly outperformed others by attaining the lowest median cost of 0.0130741000 while demonstrating a 100% success rate.

**Table 10**
Score and the ranking of the algorithms based on the weighted sum of the normalized best error (SNE) and the sum rank of the mean error (SR) for CEC2017–2018. Best or top-ranked results are shown in bold.

| Algorithm | SNE | Score1 | SR | Score2 | Total score | Place |
|---|---|---|---|---|---|---|
| ABC | 6.035723 | 7.326306 | 397.000000 | 8.513854 | 15.84015997 | 17 |
| GA | 2.382791 | 18.557881 | 301.600000 | 11.206897 | 29.764778 | 8 |
| PSO | 8.390414 | 5.270247 | 535.100000 | 6.316576 | 11.58682328 | 20 |
| DE | 4.357882 | 10.147028 | 283.650000 | 11.916094 | 22.06312199 | 13 |
| SA | 1.927946 | 22.936097 | 214.100000 | 15.787015 | 38.72311224 | 5 |
| TLBO | 2.592993 | 17.053479 | 300.000000 | 11.266667 | 28.32014529 | 10 |
| BAS | 28.831506 | 1.533723 | 609.000000 | 5.550082 | 7.083805421 | 21 |
| FA | 1.985594 | 22.270183 | 223.700000 | 15.109522 | 37.3797045 | 6 |
| HHO | 7.206777 | 6.135829 | 512.000000 | 6.601563 | 12.73739196 | 19 |
| GWO | 2.760991 | 16.015828 | 349.600000 | 9.668192 | 25.68401981 | 11 |
| MFO | 4.360598 | 10.140709 | 472.400000 | 7.154953 | 17.29566261 | 14 |
| WOA | 4.992435 | 8.857312 | 438.800000 | 7.702826 | 16.56013743 | 16 |
| CMAES | 6.449792 | 6.855965 | 475.900000 | 7.102332 | 13.95829758 | 18 |
| AGSK | 2.836980 | 15.586842 | 179.900000 | 18.788216 | 34.37505761 | 7 |
| HSES | 0.884391 | 50.000000 | 90.800000 | 37.224670 | 87.2246696 | 2 |
| MadDE | 3.204246 | 13.800300 | 299.600000 | 11.281709 | 25.08200881 | 12 |
| IMODE | 2.888144 | 15.310716 | 244.300000 | 13.835448 | 29.14616411 | 9 |
| ALSHADE | 1.203935 | 36.729171 | 73.350000 | 46.080436 | 82.80960749 | 3 |
| EA4eig | 4.780978 | 9.249061 | 435.200000 | 7.766544 | 17.01560482 | 15 |
| APGSKIMODE | 1.998955 | 22.121339 | 195.400000 | 17.297851 | 39.41918907 | 4 |
| DA2MODE | 1.006339 | 43.941009 | 67.600000 | 50.000000 | **93.94100899** | **1** |

**Table 11**
Statistical Analysis for the mean error of all algorithms, for all the 30D, 50D, and 100D CEC2017–2018 benchmark functions. The DA2MODE is set as the reference of all comparisons. Best or top-ranked results are shown in bold.

| Dim | Algorithm | Wilcoxon signed-rank test | | | | | Friedman test | | |
|---|---|---|---|---|---|---|---|---|---|
| | | +/=/- | R+ | R- | *p*-value | H | SumRanks | MeanRanks | Rank |
| 30 | ABC | **+29/ = 0/ − 0** | 435 | 0 | 2.56308E−06 | TRUE | 369 | 12.724138 | 14 |
| | GA | **+29/ = 0/ − 0** | 435 | 0 | 2.56308E−06 | TRUE | 352 | 12.137931 | 12 |
| | PSO | **+29/ = 0/ − 0** | 435 | 0 | 2.56308E−06 | TRUE | 519 | 17.896552 | 18 |
| | DE | **+25/ = 2/ − 2** | 373 | 5 | 9.84273E−06 | TRUE | 264.5 | 9.120690 | 9 |
| | SA | **+29/ = 0/ − 0** | 435 | 0 | 2.56308E−06 | TRUE | 297 | 10.241379 | 11 |
| | TLBO | **+29/ = 0/ − 0** | 435 | 0 | 2.56308E−06 | TRUE | 294 | 10.137931 | 10 |
| | BAS | **+29/ = 0/ − 0** | 435 | 0 | 2.56308E−06 | TRUE | 609 | 21.000000 | 21 |
| | FA | **+29/ = 0/ − 0** | 435 | 0 | 2.56308E−06 | TRUE | 248 | 8.551724 | 8 |
| | HHO | **+29/ = 0/ − 0** | 435 | 0 | 2.56308E−06 | TRUE | 541 | 18.655172 | 20 |
| | GWO | **+29/ = 0/ − 0** | 435 | 0 | 2.56308E−06 | TRUE | 364 | 12.551724 | 13 |
| | MFO | **+29/ = 0/ − 0** | 435 | 0 | 2.56308E−06 | TRUE | 463 | 15.965517 | 16 |
| | WOA | **+29/ = 0/ − 0** | 435 | 0 | 2.56308E−06 | TRUE | 471 | 16.241379 | 17 |
| | CMAES | **+29/ = 0/ − 0** | 435 | 0 | 2.56308E−06 | TRUE | 520 | 17.931034 | 19 |
| | AGSK | **+27/ = 0/ − 2** | 419 | 16 | 1.31812E−05 | TRUE | 161 | 5.551724 | 5 |
| | HSES | **+18/ = 3/ − 8** | 269 | 82 | 0.017562701 | TRUE | 104 | 3.586207 | 3 |
| | MadDE | **+27/ = 0/ − 2** | 407 | 28 | 4.17462E−05 | TRUE | 176 | 6.068966 | 6 |
| | IMODE | **+27/ = 0/ − 2** | 409 | 26 | 3.46032E−05 | TRUE | 241 | 8.310345 | 7 |
| | ALSHADE | **+12/ = 3/ − 14** | 202 | 149 | 0.500917774 | FALSE | 66.5 | 2.293103 | 2 |
| | EA4eig | **+29/ = 0/ − 0** | 435 | 0 | 2.56308E−06 | TRUE | 431 | 14.862069 | 15 |
| | APGSKIMODE | **+28/ = 0/ − 1** | 420 | 15 | 1.1939E−05 | TRUE | 144 | 4.965517 | 4 |
| | DA2MODE | NA | NA | NA | NA | NA | 64 | **2.206897** | **1** |
| | | | NA | | | | Friedman *p*-value = $2.79663E-90$ | | |
| 50 | ABC | **+29/ = 0/ − 0** | 435 | 0 | 2.56308E−06 | TRUE | 374 | 12.896552 | 14 |
| | GA | **+29/ = 0/ − 0** | 435 | 0 | 2.56308E−06 | TRUE | 319 | 11.000000 | 12 |
| | PSO | **+29/ = 0/ − 0** | 435 | 0 | 2.56308E−06 | TRUE | 536 | 18.482759 | 20 |
| | DE | **+27/ = 0/ − 2** | 432 | 3 | 3.51496E−06 | TRUE | 282.5 | 9.741379 | 10 |
| | SA | **+27/ = 0/ − 2** | 412 | 23 | 2.60261E−05 | TRUE | 214 | 7.379310 | 6 |
| | TLBO | **+29/ = 0/ − 0** | 435 | 0 | 2.56308E−06 | TRUE | 304 | 10.482759 | 11 |
| | BAS | **+29/ = 0/ − 0** | 435 | 0 | 2.56308E−06 | TRUE | 609 | 21.000000 | 21 |
| | FA | **+29/ = 0/ − 0** | 435 | 0 | 2.56308E−06 | TRUE | 227 | 7.827586 | 7 |
| | HHO | **+29/ = 0/ − 0** | 435 | 0 | 2.56308E−06 | TRUE | 521 | 17.965517 | 19 |
| | GWO | **+29/ = 0/ − 0** | 435 | 0 | 2.56308E−06 | TRUE | 346 | 11.931034 | 13 |
| | MFO | **+29/ = 0/ − 0** | 435 | 0 | 2.56308E−06 | TRUE | 481 | 16.586207 | 18 |
| | WOA | **+29/ = 0/ − 0** | 435 | 0 | 2.56308E−06 | TRUE | 447 | 15.413793 | 16 |
| | CMAES | **+29/ = 0/ − 0** | 435 | 0 | 2.56308E−06 | TRUE | 473 | 16.310345 | 17 |
| | AGSK | **+29/ = 0/ − 0** | 435 | 0 | 2.56308E−06 | TRUE | 174 | 6.000000 | 4 |
| | HSES | **+20/ = 0/ − 9** | 337 | 98 | 0.009766957 | TRUE | 100 | 3.448276 | 3 |
| | MadDE | **+29/ = 0/ − 0** | 435 | 0 | 2.56308E−06 | TRUE | 278 | 9.586207 | 9 |
| | IMODE | **+28/ = 0/ − 1** | 432 | 3 | 3.51496E−06 | TRUE | 262 | 9.034483 | 8 |
| | ALSHADE | **+15/ = 2/ − 12** | 266 | 112 | 0.064324371 | TRUE | 68.5 | 2.362069 | 2 |
| | EA4eig | **+29/ = 0/ − 0** | 435 | 0 | 2.56308E−06 | TRUE | 440 | 15.172414 | 15 |
| | APGSKIMODE | **+29/ = 0/ − 0** | 435 | 0 | 2.56308E−06 | TRUE | 187 | 6.448276 | 5 |
| | DA2MODE | NA | NA | NA | NA | NA | 56 | **1.931034** | **1** |
| | | | NA | | | | Friedman *p*-value = $1.45907E-82$ | | |
| 100 | ABC | **+29/ = 0/ − 0** | 435 | 0 | 2.56308E−06 | TRUE | 422 | 14.551724 | 15 |
| | GA | **+29/ = 0/ − 0** | 435 | 0 | 2.56308E−06 | TRUE | 271 | 9.344828 | 9 |
| | PSO | **+29/ = 0/ − 0** | 435 | 0 | 2.56308E−06 | TRUE | 541 | 18.655172 | 20 |
| | DE | **+27/ = 0/ − 2** | 432 | 3 | 3.51496E−06 | TRUE | 292 | 10.068966 | 10 |
| | SA | **+24/ = 0/ − 5** | 369 | 66 | 0.001053203 | TRUE | 181 | 6.241379 | 4 |
| | TLBO | **+29/ = 0/ − 0** | 435 | 0 | 2.56308E−06 | TRUE | 300 | 10.344828 | 11 |
| | BAS | **+29/ = 0/ − 0** | 435 | 0 | 2.56308E−06 | TRUE | 609 | 21.000000 | 21 |
| | FA | **+29/ = 0/ − 0** | 435 | 0 | 2.56308E−06 | TRUE | 212 | 7.310345 | 6 |
| | HHO | **+29/ = 0/ − 0** | 435 | 0 | 2.56308E−06 | TRUE | 495 | 17.068966 | 19 |
| | GWO | **+29/ = 0/ − 0** | 435 | 0 | 2.56308E−06 | TRUE | 346 | 11.931034 | 12 |
| | MFO | **+29/ = 0/ − 0** | 435 | 0 | 2.56308E−06 | TRUE | 471 | 16.241379 | 18 |
| | WOA | **+29/ = 0/ − 0** | 435 | 0 | 2.56308E−06 | TRUE | 421 | 14.517241 | 14 |
| | CMAES | **+28/ = 0/ − 1** | 434 | 1 | 2.8489E−06 | TRUE | 460 | 15.862069 | 17 |

(*continued on next page*)

**Table 11** (*continued*).

| Dim | Algorithm | Wilcoxon signed-rank test | | | | | Friedman test | | |
|---|---|---|---|---|---|---|---|---|---|
| | | +/=/- | R+ | R- | *p*-value | H | SumRanks | MeanRanks | Rank |
| | AGSK | **+27/ = 0/ − 2** | 432 | 3 | 3.51496E−06 | TRUE | 191 | 6.586207 | 5 |
| | HSES | +13/=0/-16 | 232 | 203 | 0.753873158 | FALSE | 80 | 2.758621 | 3 |
| | MadDE | **+29/ = 0/ − 0** | 435 | 0 | 2.56308E−06 | TRUE | 362 | 12.482759 | 13 |
| | IMODE | **+23/ = 0/ − 6** | 380 | 55 | 0.000441795 | TRUE | 235 | 8.103448 | 8 |
| | ALSHADE | **+15/ = 0/ − 14** | 289 | 146 | 0.122090348 | FALSE | 79 | 2.724138 | 2 |
| | EA4eig | **+29/ = 0/ − 0** | 435 | 0 | 2.56308E−06 | TRUE | 434 | 14.965517 | 16 |
| | APGSKIMODE | **+28/ = 0/ − 1** | 434 | 1 | 2.8489E−06 | TRUE | 221 | 7.620690 | 7 |
| | DA2MODE | NA | NA | NA | NA | NA | 76 | **2.620690** | **1** |
| | | | NA | | | | Friedman *p*-value = $1.54402E-79$ | | |

**Table 12**
Detailed sign test results between the DA2MODE and every other algorithm for the 30D, 50D, and 100D CEC2017–2018 benchmark functions. Best results are shown in bold, highlighting cases where DA2MODE outperforms the competing algorithms.

| Alg. | Category | 30D | 50D | 100D | Total |
|---|---|---|---|---|---|
| ABC | Unimodal | +2/=0/-0 | +2/=0/-0 | +2/=0/-0 | +6/=0/-0 |
| | Multimodal | +7/=0/-0 | +7/=0/-0 | +7/=0/-0 | +21/=0/-0 |
| | Hybrid | +10/=0/-0 | +10/=0/-0 | +10/=0/-0 | +30/=0/-0 |
| | Composition | +10/=0/-0 | +10/=0/-0 | +10/=0/-0 | +30/=0/-0 |
| | Total | +29/=0/-0 | +29/=0/-0 | +29/=0/-0 | **+87/=0/-0** |
| GA | Unimodal | +2/=0/-0 | +2/=0/-0 | +2/=0/-0 | +6/=0/-0 |
| | Multimodal | +7/=0/-0 | +7/=0/-0 | +7/=0/-0 | +21/=0/-0 |
| | Hybrid | +10/=0/-0 | +10/=0/-0 | +10/=0/-0 | +30/=0/-0 |
| | Composition | +10/=0/-0 | +10/=0/-0 | +10/=0/-0 | +30/=0/-0 |
| | Total | +29/=0/-0 | +29/=0/-0 | +29/=0/-0 | **+87/=0/-0** |
| PSO | Unimodal | +2/=0/-0 | +2/=0/-0 | +2/=0/-0 | +6/=0/-0 |
| | Multimodal | +7/=0/-0 | +7/=0/-0 | +7/=0/-0 | +21/=0/-0 |
| | Hybrid | +10/=0/-0 | +10/=0/-0 | +10/=0/-0 | +30/=0/-0 |
| | Composition | +10/=0/-0 | +10/=0/-0 | +10/=0/-0 | +30/=0/-0 |
| | Total | +29/=0/-0 | +29/=0/-0 | +29/=0/-0 | **+87/=0/-0** |
| DE | Unimodal | +1/=1/-0 | +2/=0/-0 | +2/=0/-0 | +5/=1/-0 |
| | Multimodal | +5/=1/-1 | +5/=0/-2 | +5/=0/-2 | +15/=1/-5 |
| | Hybrid | +10/=0/-0 | +10/=0/-0 | +10/=0/-0 | +30/=0/-0 |
| | Composition | +9/=0/-1 | +10/=0/-0 | +10/=0/-0 | +29/=0/-1 |
| | Total | +25/=2/-2 | +27/=0/-2 | +27/=0/-2 | **+79/=2/-6** |
| SA | Unimodal | +2/=0/-0 | +2/=0/-0 | +2/=0/-0 | +6/=0/-0 |
| | Multimodal | +7/=0/-0 | +6/=0/-1 | +6/=0/-1 | +19/=0/-2 |
| | Hybrid | +10/=0/-0 | +9/=0/-1 | +7/=0/-3 | +26/=0/-4 |
| | Composition | +10/=0/-0 | +10/=0/-0 | +9/=0/-1 | +29/=0/-1 |
| | Total | +29/=0/-0 | +27/=0/-2 | +24/=0/-5 | **+80/=0/-7** |
| TLBO | Unimodal | +2/=0/-0 | +2/=0/-0 | +2/=0/-0 | +6/=0/-0 |
| | Multimodal | +7/=0/-0 | +7/=0/-0 | +7/=0/-0 | +21/=0/-0 |
| | Hybrid | +10/=0/-0 | +10/=0/-0 | +10/=0/-0 | +30/=0/-0 |
| | Composition | +10/=0/-0 | +10/=0/-0 | +10/=0/-0 | +30/=0/-0 |
| | Total | +29/=0/-0 | +29/=0/-0 | +29/=0/-0 | **+87/=0/-0** |
| BAS | Unimodal | +2/=0/-0 | +2/=0/-0 | +2/=0/-0 | +6/=0/-0 |
| | Multimodal | +7/=0/-0 | +7/=0/-0 | +7/=0/-0 | +21/=0/-0 |
| | Hybrid | +10/=0/-0 | +10/=0/-0 | +10/=0/-0 | +30/=0/-0 |
| | Composition | +10/=0/-0 | +10/=0/-0 | +10/=0/-0 | +30/=0/-0 |
| | Total | +29/=0/-0 | +29/=0/-0 | +29/=0/-0 | **+87/=0/-0** |
| FA | Unimodal | +2/=0/-0 | +2/=0/-0 | +2/=0/-0 | +6/=0/-0 |
| | Multimodal | +7/=0/-0 | +7/=0/-0 | +7/=0/-0 | +21/=0/-0 |
| | Hybrid | +10/=0/-0 | +10/=0/-0 | +10/=0/-0 | +30/=0/-0 |
| | Composition | +10/=0/-0 | +10/=0/-0 | +10/=0/-0 | +30/=0/-0 |
| | Total | +29/=0/-0 | +29/=0/-0 | +29/=0/-0 | **+87/=0/-0** |
| HHO | Unimodal | +2/=0/-0 | +2/=0/-0 | +2/=0/-0 | +6/=0/-0 |
| | Multimodal | +7/=0/-0 | +7/=0/-0 | +7/=0/-0 | +21/=0/-0 |
| | Hybrid | +10/=0/-0 | +10/=0/-0 | +10/=0/-0 | +30/=0/-0 |
| | Composition | +10/=0/-0 | +10/=0/-0 | +10/=0/-0 | +30/=0/-0 |
| | Total | +29/=0/-0 | +29/=0/-0 | +29/=0/-0 | **+87/=0/-0** |
| GWO | Unimodal | +2/=0/-0 | +2/=0/-0 | +2/=0/-0 | +6/=0/-0 |
| | Multimodal | +7/=0/-0 | +7/=0/-0 | +7/=0/-0 | +21/=0/-0 |
| | Hybrid | +10/=0/-0 | +10/=0/-0 | +10/=0/-0 | +30/=0/-0 |
| | Composition | +10/=0/-0 | +10/=0/-0 | +10/=0/-0 | +30/=0/-0 |
| | Total | +29/=0/-0 | +29/=0/-0 | +29/=0/-0 | **+87/=0/-0** |
| MFO | Unimodal | +2/=0/-0 | +2/=0/-0 | +2/=0/-0 | +6/=0/-0 |
| | Multimodal | +7/=0/-0 | +7/=0/-0 | +7/=0/-0 | +21/=0/-0 |
| | Hybrid | +10/=0/-0 | +10/=0/-0 | +10/=0/-0 | +30/=0/-0 |
| | Composition | +10/=0/-0 | +10/=0/-0 | +10/=0/-0 | +30/=0/-0 |
| | Total | +29/=0/-0 | +29/=0/-0 | +29/=0/-0 | **+87/=0/-0** |
| WOA | Unimodal | +2/=0/-0 | +2/=0/-0 | +2/=0/-0 | +6/=0/-0 |
| | Multimodal | +7/=0/-0 | +7/=0/-0 | +7/=0/-0 | +21/=0/-0 |
| | Hybrid | +10/=0/-0 | +10/=0/-0 | +10/=0/-0 | +30/=0/-0 |
| | Composition | +10/=0/-0 | +10/=0/-0 | +10/=0/-0 | +30/=0/-0 |
| | Total | +29/=0/-0 | +29/=0/-0 | +29/=0/-0 | **+87/=0/-0** |
| CMAES | Unimodal | +2/=0/-0 | +2/=0/-0 | +2/=0/-0 | +6/=0/-0 |
| | Multimodal | +7/=0/-0 | +7/=0/-0 | +6/=0/-1 | +20/=0/-1 |
| | Hybrid | +10/=0/-0 | +10/=0/-0 | +10/=0/-0 | +30/=0/-0 |
| | Composition | +10/=0/-0 | +10/=0/-0 | +10/=0/-0 | +30/=0/-0 |
| | Total | +29/=0/-0 | +29/=0/-0 | +28/=0/-1 | **+86/=0/-1** |
| AGSK | Unimodal | +2/=0/-0 | +2/=0/-0 | +2/=0/-0 | +6/=0/-0 |
| | Multimodal | +7/=0/-0 | +7/=0/-0 | +5/=0/-2 | +19/=0/-2 |
| | Hybrid | +10/=0/-0 | +10/=0/-0 | +10/=0/-0 | +30/=0/-0 |
| | Composition | +8/=0/-2 | +10/=0/-0 | +10/=0/-0 | +28/=0/-2 |
| | Total | +27/=0/-2 | +29/=0/-0 | +27/=0/-2 | **+83/=0/-4** |
| HSES | Unimodal | +0/=2/-0 | +2/=0/-0 | +0/=0/-2 | +2/=2/-2 |
| | Multimodal | +2/=1/-4 | +1/=0/-6 | +0/=0/-7 | +3/=1/-17 |
| | Hybrid | +10/=0/-0 | +8/=0/-2 | +3/=0/-7 | +21/=0/-9 |
| | Composition | +6/=0/-4 | +9/=0/-1 | +10/=0/-0 | +25/=0/-5 |
| | Total | +18/=3/-8 | +20/=0/-9 | +13/=0/-16 | **+51/=3/-33** |
| MadDE | Unimodal | +2/=0/-0 | +2/=0/-0 | +2/=0/-0 | +6/=0/-0 |
| | Multimodal | +7/=0/-0 | +7/=0/-0 | +7/=0/-0 | +21/=0/-0 |
| | Hybrid | +10/=0/-0 | +10/=0/-0 | +10/=0/-0 | +30/=0/-0 |
| | Composition | +8/=0/-2 | +10/=0/-0 | +10/=0/-0 | +28/=0/-2 |
| | Total | +27/=0/-2 | +29/=0/-0 | +29/=0/-0 | **+85/=0/-2** |
| IMODE | Unimodal | +2/=0/-0 | +2/=0/-0 | +2/=0/-0 | +6/=0/-0 |
| | Multimodal | +7/=0/-0 | +7/=0/-0 | +6/=0/-1 | +20/=0/-1 |
| | Hybrid | +10/=0/-0 | +9/=0/-1 | +7/=0/-3 | +26/=0/-4 |
| | Composition | +8/=0/-2 | +10/=0/-0 | +8/=0/-2 | +26/=0/-4 |
| | Total | +27/=0/-2 | +28/=0/-1 | +23/=0/-6 | **+78/=0/-9** |
| ALSHADE | Unimodal | +0/=2/-0 | +0/=2/-0 | +1/=0/-1 | +1/=4/-1 |
| | Multimodal | +2/=1/-4 | +2/=0/-5 | +2/=0/-5 | +6/=1/-14 |
| | Hybrid | +5/=0/-5 | +6/=0/-4 | +5/=0/-5 | +16/=0/-14 |
| | Composition | +5/=0/-5 | +7/=0/-3 | +7/=0/-3 | +19/=0/-11 |
| | Total | +12/=3/-14 | +15/=2/-12 | +15/=0/-14 | **+42/=5/-40** |
| EA4eig | Unimodal | +2/=0/-0 | +2/=0/-0 | +2/=0/-0 | +6/=0/-0 |
| | Multimodal | +7/=0/-0 | +7/=0/-0 | +7/=0/-0 | +21/=0/-0 |
| | Hybrid | +10/=0/-0 | +10/=0/-0 | +10/=0/-0 | +30/=0/-0 |
| | Composition | +10/=0/-0 | +10/=0/-0 | +10/=0/-0 | +30/=0/-0 |
| | Total | +29/=0/-0 | +29/=0/-0 | +29/=0/-0 | **+87/=0/-0** |
| APGSK_ IMODE | Unimodal | +2/=0/-0 | +2/=0/-0 | +2/=0/-0 | +6/=0/-0 |
| | Multimodal | +7/=0/-0 | +7/=0/-0 | +6/=0/-1 | +20/=0/-1 |
| | Hybrid | +10/=0/-0 | +10/=0/-0 | +10/=0/-0 | +30/=0/-0 |
| | Composition | +9/=0/-1 | +10/=0/-0 | +10/=0/-0 | +29/=0/-1 |
| | Total | +28/=0/-1 | +29/=0/-0 | +28/=0/-1 | **+85/=0/-2** |

Remarkably, it achieved this with 8457 function evaluations, which is fewer than the 12,000 evaluations required by the other algorithms.

### *10.4. Design of welded beam*

The welded beam design problem aims to minimize the total fabrication cost, which includes the cost of welding and the cost of the beam material, as defined in Appendix J.4. The four design variables include weld width $x_1$, weld length $x_2$, beam depth $x_3$, and beam thickness $x_4$. These variables are subject to multiple structural and fabrication constraints, including limits on shear stress, normal stress, deflection, and buckling load. A schematic representation of the beam setup is provided in Fig. 33.

Table 21 presents the welded beam design problem results, where several algorithms achieved the optimal median cost of 1.7248523086 while maintaining feasibility. Among them, DA2MODE and ALSHADE exhibited the highest success rate of 100%, with DA2MODE requiring only 9304 function evaluations, fewer than ALSHADE and the other contenders. APGSKIMODE and EODE also reached the same cost with a moderate success rate of 66.67%.

## 11. Discussion and summary of experimental results

This section consolidates the experimental findings across all benchmark groups and engineering tasks, providing evidence of the effectiveness and adaptability of the proposed DA2MODE algorithm.

*Parameter tuning*

A factorial sensitivity study on CEC2017 functions (10–100 D) showed that performance is stable once the *minimum fraction of the non-elite solutions* is fixed at $p_{A,\min} = 0.5$ and the *exponential smoothing*

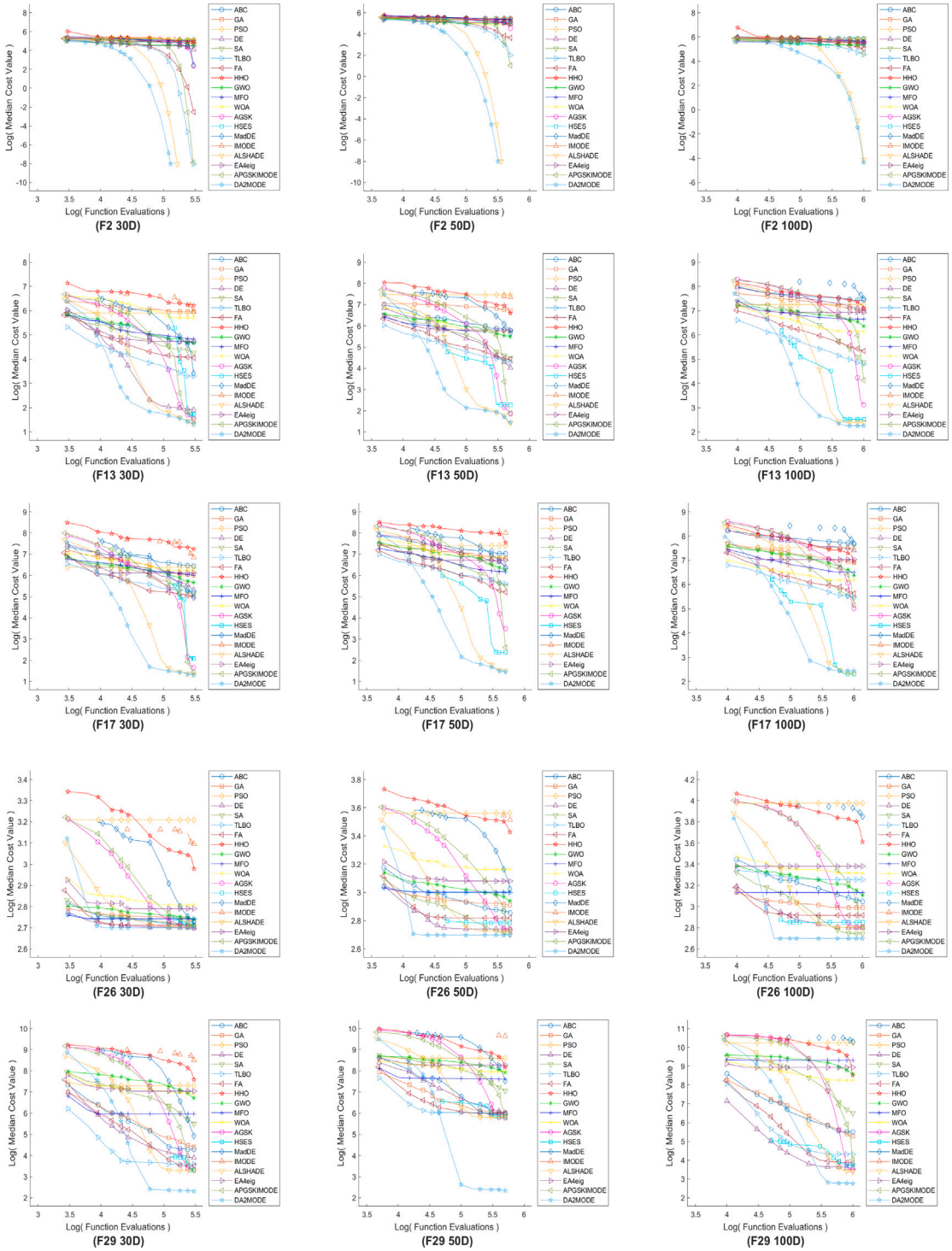



**Fig. 21.** Median convergence plots for all the algorithms for selective 30D, 50D, and 100D 10D CEC2017-2018 benchmark functions.

*factor* at $\alpha_{\mathrm{EMA}} = 0.6$. Lower diversity thresholds ($p_{A,\min} \leq 0.3$) or more aggressive smoothing ($\alpha_{\mathrm{EMA}} \geq 0.7$) systematically increased the mean error and the risk of premature convergence. All subsequent benchmarks used these two defaults without retuning, demonstrating that DA2MODE is essentially parameter-free in practice.

*Baseline comparison with classical and CEC-winning algorithms*

In the CEC2020-2022 suite (10D/20D), DA2MODE ranked first by achieving the highest total FE-based rank (420.5), exceeding ALSHADE by (+2.6%), APGSKIMODE by (+5.0%), MadDE by (+10.5%),

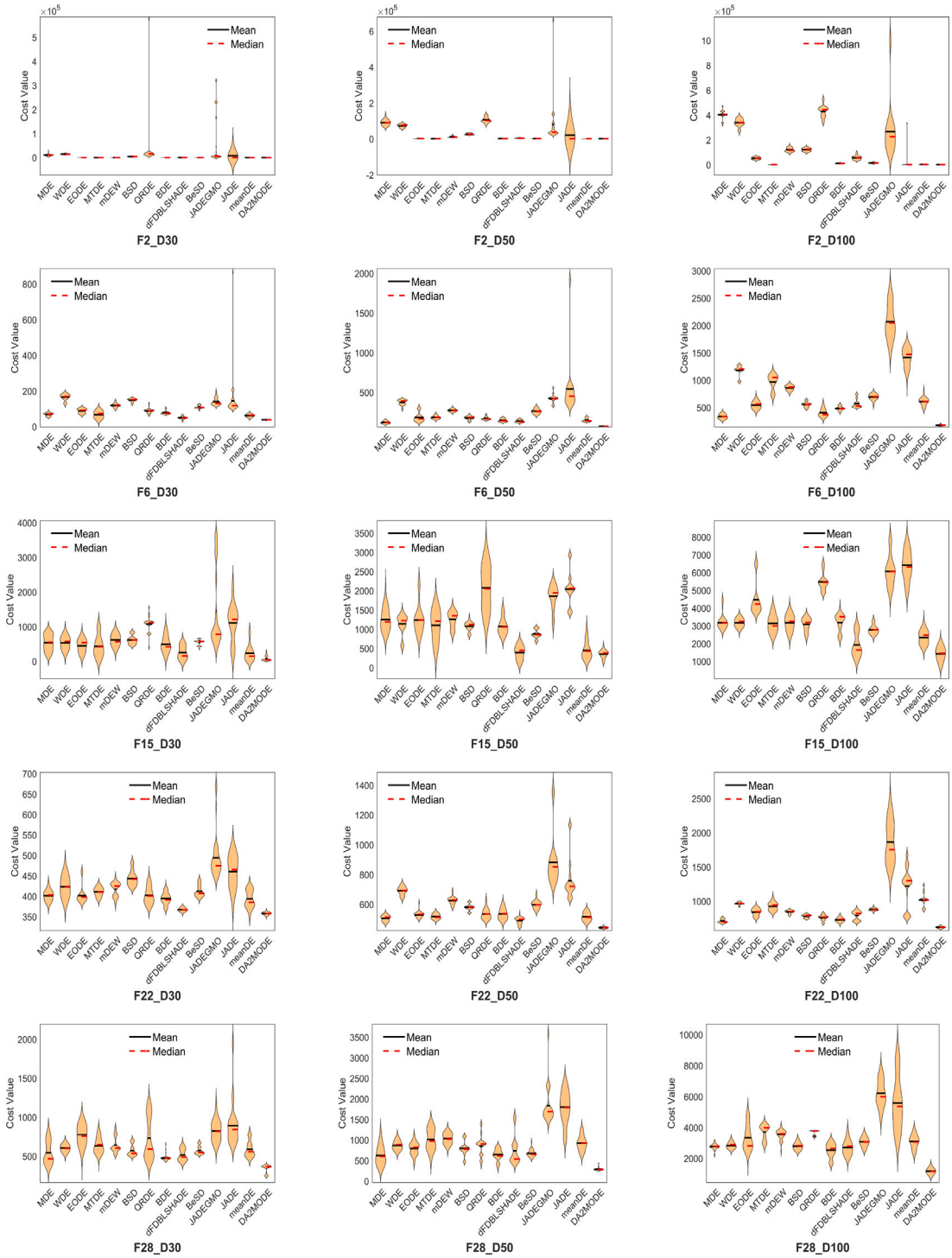



**Fig. 22.** Violin plots for the 14 DE variants for selective 30D, 50D, and 100D CEC2017-2018 benchmark functions.

HSES by (+19.7%), and AGSK by (+19.4%). In paired comparisons, DA2MODE records 44/0/0 perfect wins against PSO, BAS, HHO, WOA, GWO, and MFO, and more than 40 wins against ABC, GA, and SA. Compared with stronger competitors, DA2MODE remains favorable (e.g.,20/0/15 versus MadDE). A minor shortfall appears only against ALSHADE in a small subset of 20D multimodal cases, but DA2MODE recovers on composition functions and overall FE-based rank. Convergence trend analyses indicate faster progress for DA2MODE than AGSK, APGSKIMODE, IMODE, MadDE, and ALSHADE.

On the more complex CEC2017–2018 suite (30D–100D), DA2MODE achieved the highest SNE-SR accuracy score (93.94), surpassing HSES by (+6.72%), ALSHADE by (+11.13%), APGSKIMODE by (+54.52%), SA by (+55.22%), and FA by (+56.56%). It also ranks first in Friedman analyses across 30D/50D/100D with mean ranks 2.21, 1.93, and 2.62, which are all statistically significant ($p < 0.05$). In paired tests, DA2MODE achieves 87/0/0 against eleven classical algorithms, performs comparably to ALSHADE (42/5/40), and holds a clear advantage over HSES (51/3/33). Despite minor losses in some multimodal cases

**Table 13**
Detailed ranking of the 14 DE variants based on SNE-SR ranking and FE-based score (CEC2017–2018). Best or top-ranked results are shown in bold.

| Algorithm | SNE-SR-based ranking | | | | | | Median FE-based ranking | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | SNE | Score1 | SR | Score2 | total | Place | SR 30D | SR 50D | SR 100D | SR | Place |
| MDE | 11.3720 | 23.3973 | 189.4 | 9.3849 | 32.7822 | 8 | 215 | 221 | 264 | 241.3 | 3 |
| WDE | 15.0803 | 17.6438 | 240.4 | 7.3939 | 25.0377 | 11 | 166 | 187 | 174 | 176.3 | 11 |
| EODE | 10.1026 | 26.3373 | 202.3 | 8.7865 | 35.1237 | 5 | 252.5 | 215 | 237 | 233.5 | 6 |
| MTDE | 10.7405 | 24.7729 | 205.25 | 8.6602 | 33.4331 | 6 | 263 | 237 | 198 | 222.7 | 8 |
| mDEW | 12.0740 | 22.0370 | 206.9 | 8.5911 | 30.6281 | 9 | 249 | 226 | 199 | 217.1 | 9 |
| BSD | 12.1216 | 21.9505 | 215.65 | 8.2425 | 30.1930 | 10 | 143 | 197 | 246 | 210.7 | 10 |
| QRDE | 15.4921 | 17.1748 | 271.4 | 6.5494 | 23.7242 | 13 | 142 | 162 | 190 | 172 | 12 |
| BDE | 8.9136 | 29.8503 | 152.75 | 11.6367 | 41.4870 | 2 | 268 | 256 | 289 | 274.9 | 2 |
| dFDBLSHADE | 10.0837 | 26.3864 | 190.1 | 9.3503 | 35.7368 | 4 | 234 | 254 | 228 | 237 | 4 |
| BeSD | 11.2242 | 23.7054 | 188.8 | 9.4147 | 33.1202 | 7 | 237 | 227 | 227 | 229 | 7 |
| JADEGMO | 23.5071 | 11.3189 | 378.9 | 4.6912 | 16.0101 | 14 | 77 | 75 | 46 | 60.9 | 14 |
| JADE | 13.9528 | 19.0696 | 368.9 | 4.8184 | 23.8880 | 12 | 157.5 | 134 | 126 | 134.7 | 13 |
| meanDE | 9.3389 | 28.4909 | 198.7 | 8.9456 | 37.4366 | 3 | 248 | 252 | 222 | 236.2 | 5 |
| DA2MODE | 5.3215 | 50.0000 | 35.55 | 50.0000 | **100.0000** | **1** | 393 | 402 | 399 | **398.7** | **1** |

**Table 14**
Detailed ranking of the 14 DE variants based on Friedman test for mean error (30D, 50D, and 100D) (CEC2017–2018). Best or top-ranked results are shown in bold.

| Algorithm | Friedman test (30D) | | | Friedman test (50D) | | | Friedman test (100D) | | |
|---|---|---|---|---|---|---|---|---|---|
| | SumRanks | MeanRanks | Rank | SumRanks | MeanRanks | Rank | SumRanks | MeanRanks | Rank |
| MDE | 165 | 5.6897 | 3 | 201 | 6.9310 | 8 | 165 | 5.6897 | 3 |
| WDE | 244 | 8.4138 | 11 | 234 | 8.0690 | 11 | 244 | 8.4138 | 11 |
| EODE | 203 | 7.0000 | 7 | 214 | 7.3793 | 9 | 203 | 7.0000 | 7 |
| MTDE | 230 | 7.9310 | 10 | 191.5 | 6.6034 | 6 | 230 | 7.9310 | 10 |
| mDEW | 226 | 7.7931 | 9 | 197 | 6.7931 | 7 | 226 | 7.7931 | 9 |
| BSD | 184 | 6.3448 | 4 | 229.5 | 7.9138 | 10 | 184 | 6.3448 | 4 |
| QRDE | 251 | 8.6552 | 12 | 285 | 9.8276 | 12 | 251 | 8.6552 | 12 |
| BDE | 136 | 4.6897 | 2 | 170.5 | 5.8793 | 2 | 136 | 4.6897 | 2 |
| dFDBLSHADE | 202 | 6.9655 | 6 | 175 | 6.0345 | 3 | 202 | 6.9655 | 6 |
| BeSD | 196 | 6.7586 | 5 | 184 | 6.3448 | 4 | 196 | 6.7586 | 5 |
| JADEGMO | 387 | 13.3448 | 14 | 368 | 12.6897 | 13 | 387 | 13.3448 | 14 |
| JADE | 369 | 12.7241 | 13 | 376 | 12.9655 | 14 | 369 | 12.7241 | 13 |
| meanDE | 216 | 7.4483 | 8 | 187 | 6.4483 | 5 | 216 | 7.4483 | 8 |
| DA2MODE | 36 | **1.2414** | **1** | 32.5 | **1.1207** | **1** | 36 | **1.2414** | **1** |
| | Friedman $p$-value = **2.9474E−35** | | | Friedman $p$-value = **9.7496E−33** | | | Friedman $p$-value = **3.1948E−34** | | |

at lower dimension, DA2MODE showed dominance in hybrid and composition functions and gained strength with increasing dimensionality.

*Comparison with advanced DE variants*

To assess competitiveness against recent DE designs, we evaluated DA2MODE against 13 modern variants such as BDE, mDEW, and dFDBLSHADE. On CEC2020-2022 (10D/20D), it achieved the best FE-based rank (268.7), exceeding mDEW by (+22.5%), BDE by (+36.3%), MTDE by (+41.9%), dFDBLSHADE by (+46.1%), and BeSD by (+55.1%). It also ranked first in the Friedman test with highly significant mean ranks of 3.70 (10D) and 2.89 (20D), and $p$-values under $10^{-13}$. Wilcoxon tests confirmed superiority, with at least 30 wins per algorithm, including perfect 44/0/0 wins over JADE and JADEGMO.

On CEC2017–2018 (30D–100D), DA2MODE achieved a perfect SNE–SR score of 100.0%, ahead of BDE by (+58.51%), meanDE by (+62.56%), dFDBLSHADE by (+64.26%), EODE by (+64.88%), and MTDE by (+66.57%). Paired comparisons showed that DA2MODE achieved at least 82 wins out of 87 for all algorithms, including top contenders like dFDBLSHADE and BDE. Dimension-wise, it consistently won $\geq 90\%$ of all the cases. The algorithm's superiority in hybrid and composition functions underscores its scalability and versatility. These results indicate a wide performance gap between DA2MODE and the closest competitors.

*Large-scale performance on CEC2013 (1000d)*

In the CEC2013 LSGO benchmark (1000D), DA2MODE demonstrated excellent scalability. It recorded the best Friedman rank (2.73) and the top FE-based rank(153), exceeding BDE by (+11.7%), EODE by (+21.4%), BSD by (+21.4%), SA by (+22.4%), and ALSHADE by (+26.4%). DA2MODE dominated all function categories, specifically the separable, partially separable, and fully non-separable functions, confirming its robustness in ultra-high-dimensional spaces.

*Performance on engineering design problems*

Across all four engineering case studies, DA2MODE achieved the best median cost and highest success rate. DA2MODE reached high-quality solutions with around 25% less computational effort than others. For instance, it solved the cantilever and welded beam problems with the same quality solutions as ALSHADE and APGSKIMODE, but with significantly less computational effort. These results confirm the method's real-world applicability and efficiency.

*Design factors that yield the DA2MODE advantages*

Three design choices consistently map to the observed advantages. First, the Progressive Adaptive Selector with Exponential Smoothing

**Table 15**
Detailed sign test results between the DA2MODE and every other DE variant for the 30D, 50D, and 100D CEC2017–2018 benchmark functions. Best results are shown in bold, highlighting cases where DA2MODE outperforms the competing algorithms.

| Alg. | Category | 30D | 50D | 100D | Total |
|---|---|---|---|---|---|
| MDE | Unimodal | +2/=0/-0 | +2/=0/-0 | +2/=0/-0 | +6/=0/-0 |
| | Multimodal | +7/=0/-0 | +7/=0/-0 | +7/=0/-0 | +21/=0/-0 |
| | Hybrid | +10/=0/-0 | +10/=0/-0 | +10/=0/-0 | +30/=0/-0 |
| | Composition | +10/=0/-0 | +10/=0/-0 | +10/=0/-0 | +30/=0/-0 |
| | Total | +29/=0/-0 | +29/=0/-0 | +29/=0/-0 | **+87/=0/-0** |
| WDE | Unimodal | +2/=0/-0 | +2/=0/-0 | +2/=0/-0 | +6/=0/-0 |
| | Multimodal | +7/=0/-0 | +7/=0/-0 | +7/=0/-0 | +21/=0/-0 |
| | Hybrid | +10/=0/-0 | +10/=0/-0 | +9/=0/-1 | +29/=0/-1 |
| | Composition | +9/=0/-1 | +10/=0/-0 | +10/=0/-0 | +29/=0/-1 |
| | Total | +28/=0/-1 | +29/=0/-0 | +28/=0/-1 | **+85/=0/-2** |
| EODE | Unimodal | +2/=0/-0 | +2/=0/-0 | +2/=0/-0 | +6/=0/-0 |
| | Multimodal | +7/=0/-0 | +7/=0/-0 | +7/=0/-0 | +21/=0/-0 |
| | Hybrid | +10/=0/-0 | +10/=0/-0 | +10/=0/-0 | +30/=0/-0 |
| | Composition | +9/=0/-1 | +10/=0/-0 | +10/=0/-0 | +29/=0/-1 |
| | Total | +28/=0/-1 | +29/=0/-0 | +29/=0/-0 | **+86/=0/-1** |
| MTDE | Unimodal | +0/=2/-0 | +1/=1/-0 | +2/=0/-0 | +3/=3/-0 |
| | Multimodal | +7/=0/-0 | +7/=0/-0 | +7/=0/-0 | +21/=0/-0 |
| | Hybrid | +10/=0/-0 | +10/=0/-0 | +10/=0/-0 | +30/=0/-0 |
| | Composition | +10/=0/-0 | +10/=0/-0 | +10/=0/-0 | +30/=0/-0 |
| | Total | +27/=2/-0 | +28/=1/-0 | +29/=0/-0 | **+84/=3/-0** |
| mDEW | Unimodal | +2/=0/-0 | +2/=0/-0 | +2/=0/-0 | +6/=0/-0 |
| | Multimodal | +6/=0/-1 | +7/=0/-0 | +6/=0/-1 | +19/=0/-2 |
| | Hybrid | +10/=0/-0 | +10/=0/-0 | +10/=0/-0 | +30/=0/-0 |
| | Composition | +9/=0/-1 | +10/=0/-0 | +10/=0/-0 | +29/=0/-1 |
| | Total | +27/=0/-2 | +29/=0/-0 | +28/=0/-1 | **+84/=0/-3** |
| BSD | Unimodal | +2/=0/-0 | +2/=0/-0 | +2/=0/-0 | +6/=0/-0 |
| | Multimodal | +7/=0/-0 | +6/=0/-1 | +6/=0/-1 | +19/=0/-2 |
| | Hybrid | +10/=0/-0 | +10/=0/-0 | +10/=0/-0 | +30/=0/-0 |
| | Composition | +10/=0/-0 | +10/=0/-0 | +10/=0/-0 | +30/=0/-0 |
| | Total | +29/=0/-0 | +28/=0/-1 | +28/=0/-1 | **+85/=0/-2** |
| QRDE | Unimodal | +2/=0/-0 | +2/=0/-0 | +2/=0/-0 | +6/=0/-0 |
| | Multimodal | +7/=0/-0 | +7/=0/-0 | +6/=0/-1 | +20/=0/-1 |
| | Hybrid | +10/=0/-0 | +10/=0/-0 | +10/=0/-0 | +30/=0/-0 |
| | Composition | +10/=0/-0 | +10/=0/-0 | +10/=0/-0 | +30/=0/-0 |
| | Total | +29/=0/-0 | +29/=0/-0 | +28/=0/-1 | **+86/=0/-1** |
| BDE | Unimodal | +2/=0/-0 | +2/=0/-0 | +2/=0/-0 | +6/=0/-0 |
| | Multimodal | +6/=0/-1 | +6/=0/-1 | +6/=0/-1 | +18/=0/-3 |
| | Hybrid | +10/=0/-0 | +10/=0/-0 | +9/=0/-1 | +29/=0/-1 |
| | Composition | +9/=0/-1 | +10/=0/-0 | +10/=0/-0 | +29/=0/-1 |
| | Total | +27/=0/-2 | +28/=0/-1 | +27/=0/-2 | **+82/=0/-5** |
| dFDBLSHADE | Unimodal | +2/=0/-0 | +2/=0/-0 | +2/=0/-0 | +6/=0/-0 |
| | Multimodal | +6/=0/-1 | +7/=0/-0 | +7/=0/-0 | +20/=0/-1 |
| | Hybrid | +8/=0/-2 | +10/=0/-0 | +10/=0/-0 | +28/=0/-2 |
| | Composition | +10/=0/-0 | +10/=0/-0 | +10/=0/-0 | +30/=0/-0 |
| | Total | +26/=0/-3 | +29/=0/-0 | +29/=0/-0 | **+84/=0/-3** |
| BeSD | Unimodal | +2/=0/-0 | +2/=0/-0 | +2/=0/-0 | +6/=0/-0 |
| | Multimodal | +7/=0/-0 | +6/=0/-1 | +6/=0/-1 | +19/=0/-2 |
| | Hybrid | +10/=0/-0 | +10/=0/-0 | +10/=0/-0 | +30/=0/-0 |
| | Composition | +10/=0/-0 | +10/=0/-0 | +10/=0/-0 | +30/=0/-0 |
| | Total | +29/=0/-0 | +28/=0/-1 | +28/=0/-1 | **+85/=0/-2** |
| JADEGMO | Unimodal | +2/=0/-0 | +2/=0/-0 | +2/=0/-0 | +6/=0/-0 |
| | Multimodal | +7/=0/-0 | +7/=0/-0 | +7/=0/-0 | +21/=0/-0 |
| | Hybrid | +10/=0/-0 | +10/=0/-0 | +10/=0/-0 | +30/=0/-0 |
| | Composition | +10/=0/-0 | +10/=0/-0 | +10/=0/-0 | +30/=0/-0 |
| | Total | +29/=0/-0 | +29/=0/-0 | +29/=0/-0 | **+87/=0/-0** |
| JADE | Unimodal | +2/=0/-0 | +2/=0/-0 | +2/=0/-0 | +6/=0/-0 |
| | Multimodal | +7/=0/-0 | +7/=0/-0 | +7/=0/-0 | +21/=0/-0 |
| | Hybrid | +10/=0/-0 | +10/=0/-0 | +10/=0/-0 | +30/=0/-0 |
| | Composition | +10/=0/-0 | +10/=0/-0 | +10/=0/-0 | +30/=0/-0 |
| | Total | +29/=0/-0 | +29/=0/-0 | +29/=0/-0 | **+87/=0/-0** |
| meanDE | Unimodal | +2/=0/-0 | +2/=0/-0 | +2/=0/-0 | +6/=0/-0 |
| | Multimodal | +7/=0/-0 | +7/=0/-0 | +7/=0/-0 | +21/=0/-0 |
| | Hybrid | +10/=0/-0 | +10/=0/-0 | +10/=0/-0 | +30/=0/-0 |
| | Composition | +10/=0/-0 | +10/=0/-0 | +10/=0/-0 | +30/=0/-0 |
| | Total | +29/=0/-0 | +29/=0/-0 | +29/=0/-0 | **+87/=0/-0** |

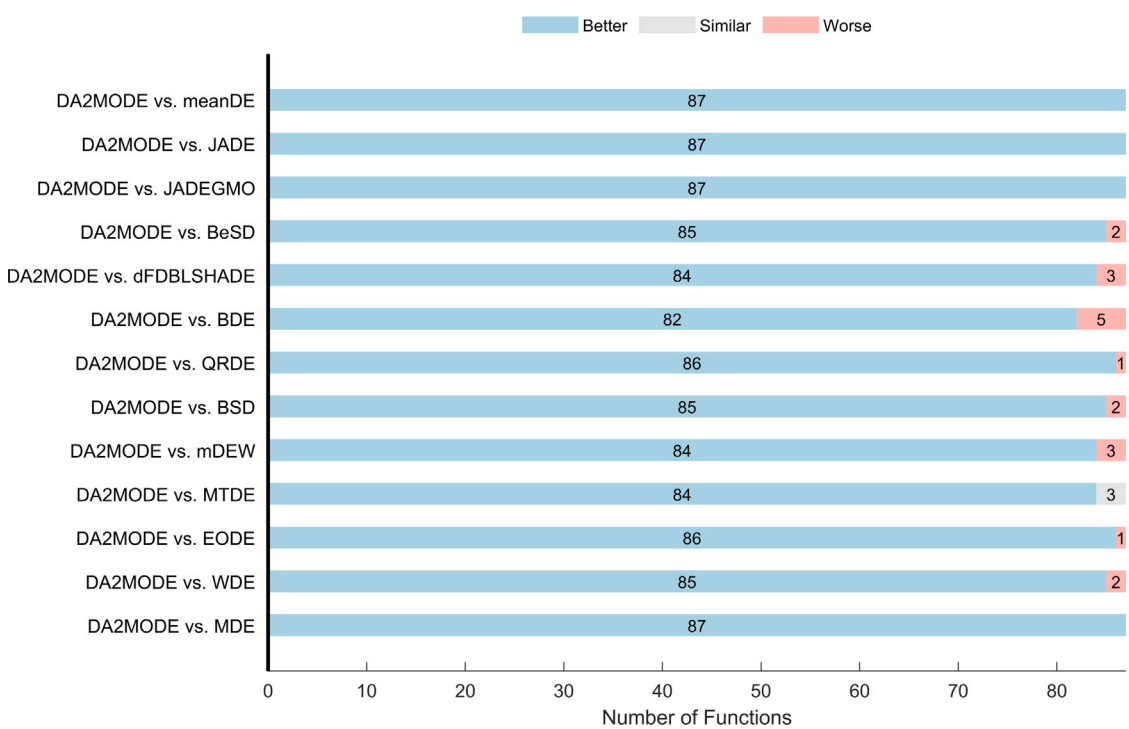



**Fig. 23.** Detailed Wilcoxon Signed-rank test results distributions for all the function of CEC2017-2018 benchmark functions, where the DA2MODE is the reference among 14 DE variants. (Algorithm perspective).

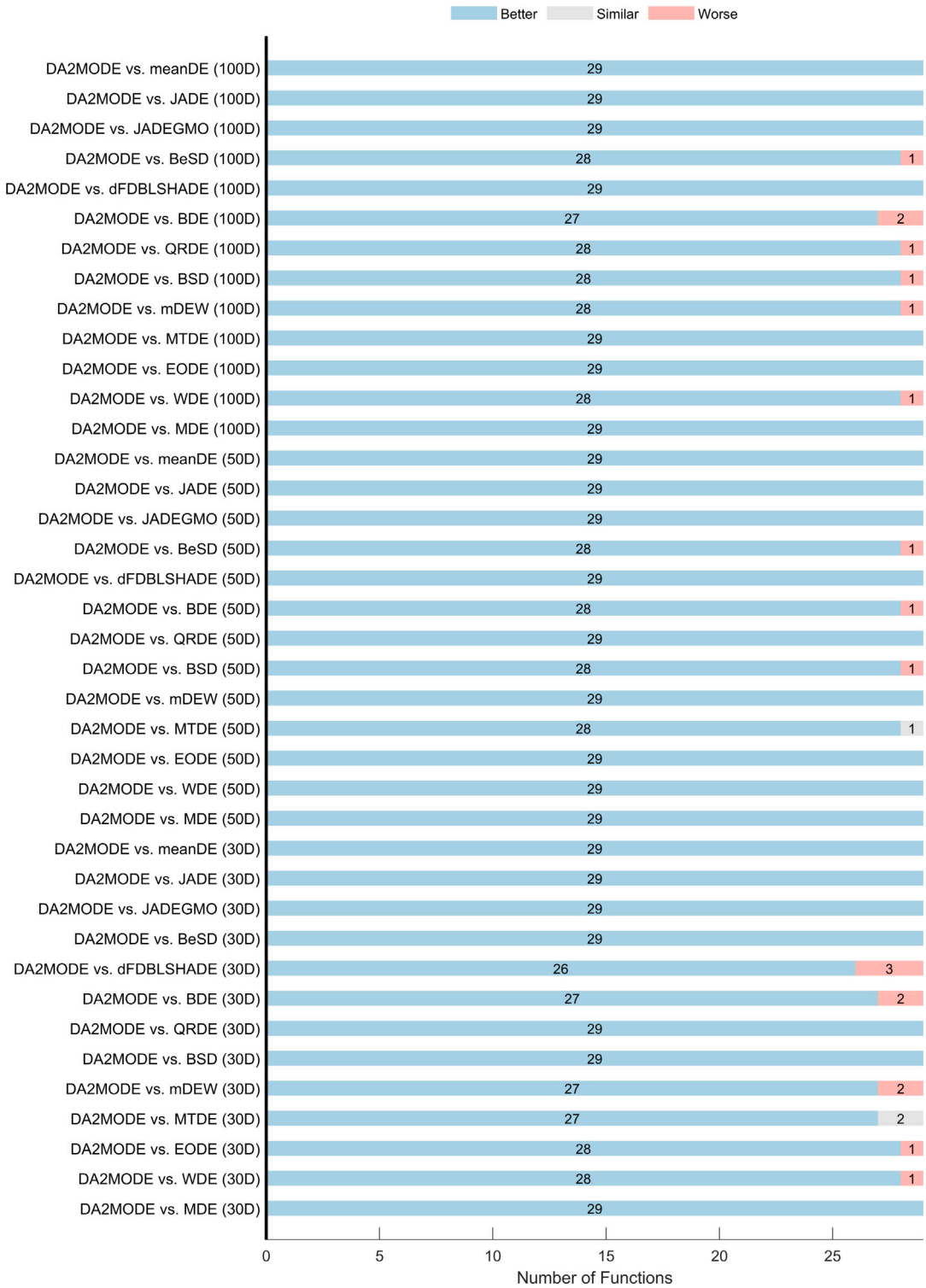



**Fig. 24.** Detailed Wilcoxon Signed-rank test results distributions for all the 30D, 50D, and 100D function of CEC2017-2018 benchmark functions, where the DA2MODE is the reference among 14 DE variants. (Dimensions perspective).

(PASES) blends short-term improvements with the long-term performance, yielding stable yet responsive operator selection. This mechanism likely explains the strong outcomes on hybrid/composition classes and the Page-verified convergence speed-ups.

Second, the Adaptive Non-Elite Archive Update (ANEAU) preserves non-elite diversity late in the run, which reduces stagnation and supports high-dimensional wins (i.e., 1000D) where diversity tends to collapse. Third, the memory-based $(CR, F)$ with stochastic sampling in no-improvement phases prevents parameter lock-in, improving recovery on complex landscapes. These components produce faster early descent and better end-of-run accuracy across dimensions.

*Final insights*

In summary, DA2MODE combines statistical superiority, rapid convergence, and low parameter dependence across diverse benchmarks

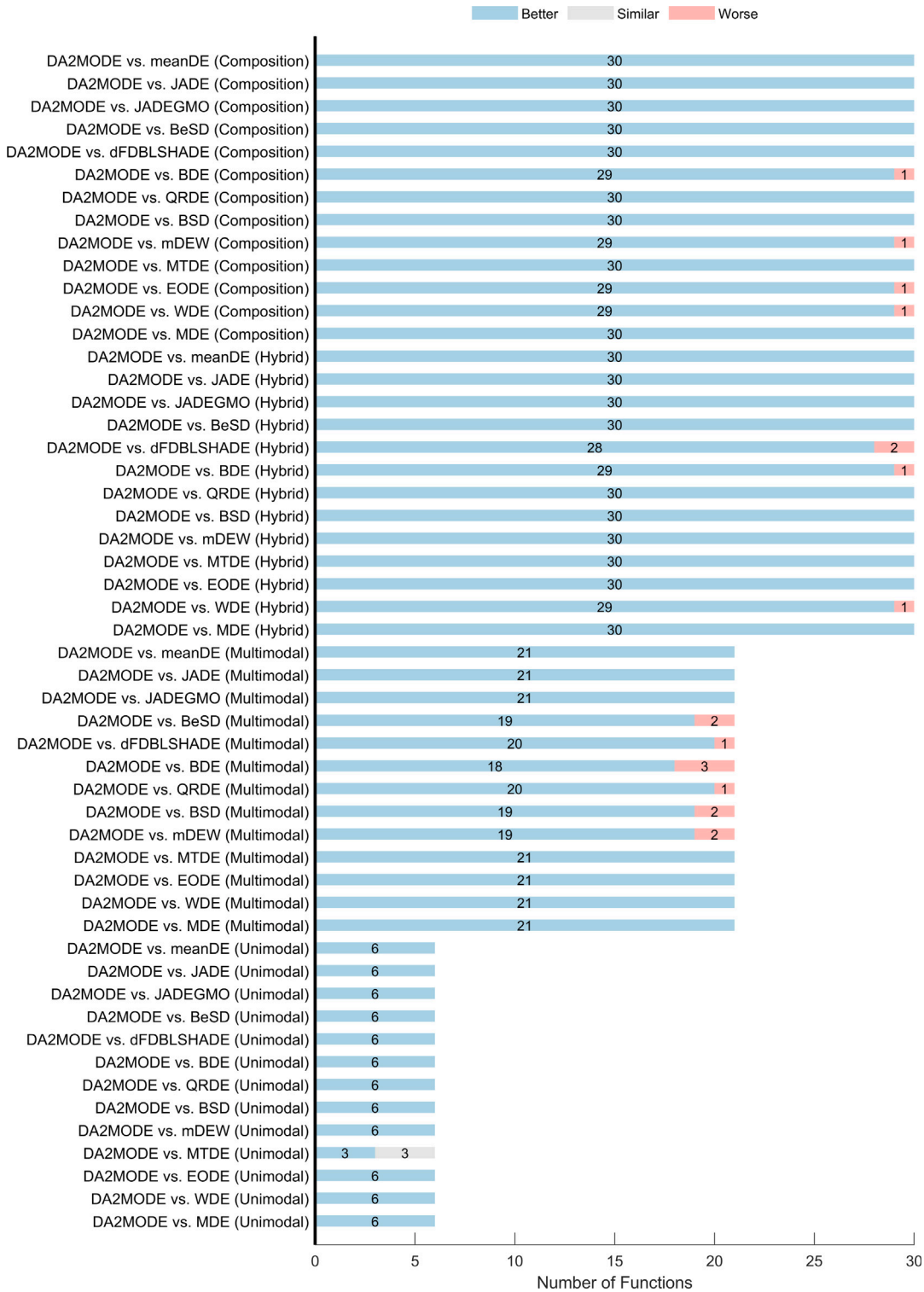



**Fig. 25.** Detailed Wilcoxon Signed-rank test results distributions for all the 30D, 50D, and 100D of CEC2017-2018 benchmark functions, where the DA2MODE is the reference among 14 DE variants. (Categories perspective).

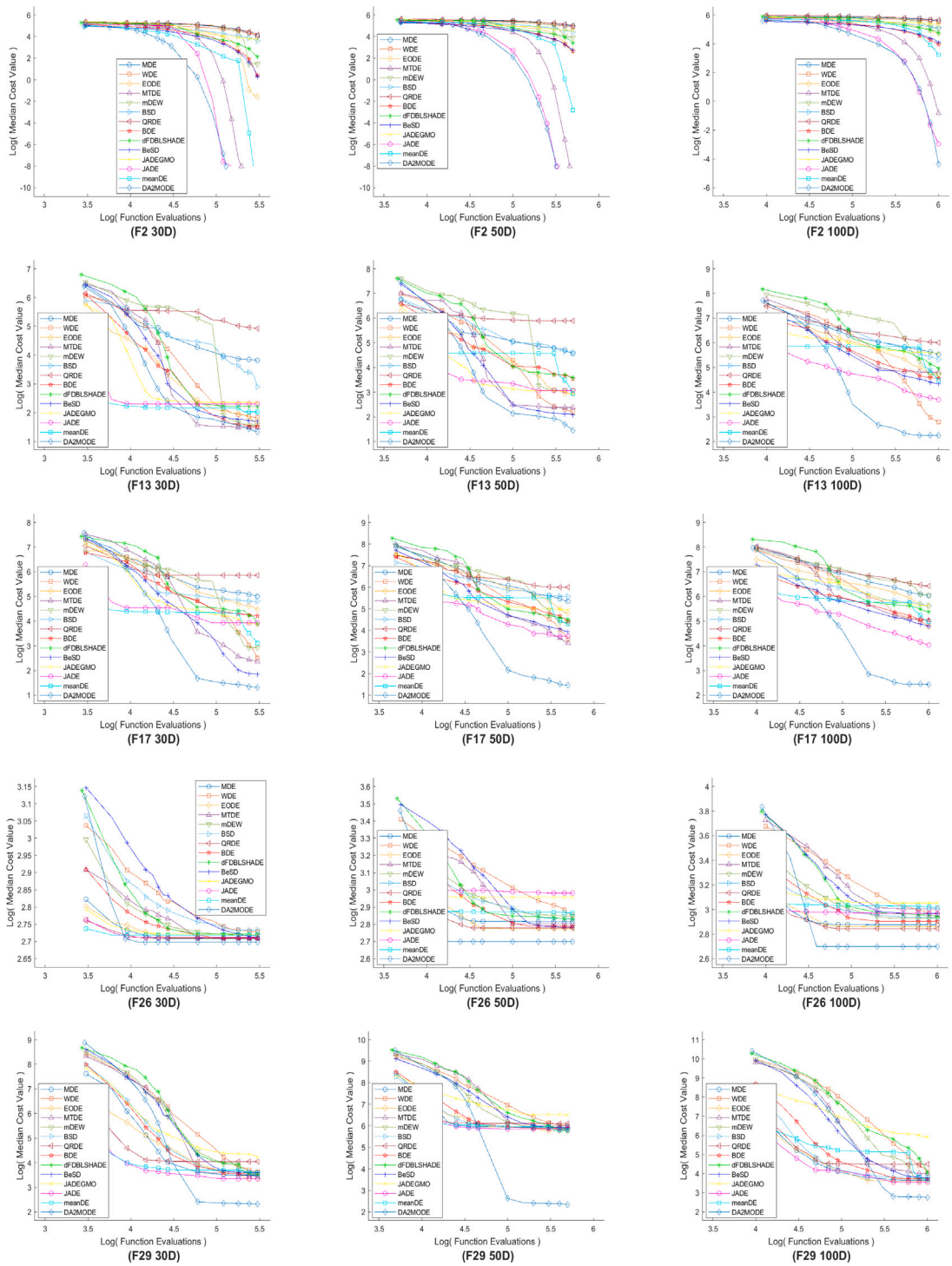



**Fig. 26.** Median convergence plots for 14 DE variants for selective 30D, 50D, and 100D 10D CEC2017-2018 benchmark functions.

from 10D to 1000D. Its dominance spans classical baselines, recent DE variants, CEC winners, and practical design problems, making it a scalable solution for numerical optimization. The clear performance gap, especially in high and large-scale dimensions, confirms that the proposed adaptation methods contribute meaningful advances over existing algorithms.

## 12. Conclusion

This paper introduced DA2MODE, a new multi-operator DE variant designed to tackle numerical optimization challenges across a broad spectrum of problem dimensionalities. DA2MODE integrates a dynamic population, an innovative archive strategy for non-elite solutions (ANEAU), and the progressive PASES selection method for both mutation and crossover. The algorithm was evaluated on diverse benchmarks including CEC2017–2018 (30D–100D), CEC2020-2022 (10D and 20D), CEC2013-LSGO (1000D), and real-world engineering problems.

Experimental results confirmed that DA2MODE consistently outperforms 33 state-of-the-art competitors across all test groups, achieving first place in all statistical methods. It demonstrated superior accuracy, faster convergence, and robustness across all dimensions, achieving the highest SNE–SR scores and winning the majority of pairwise statistical

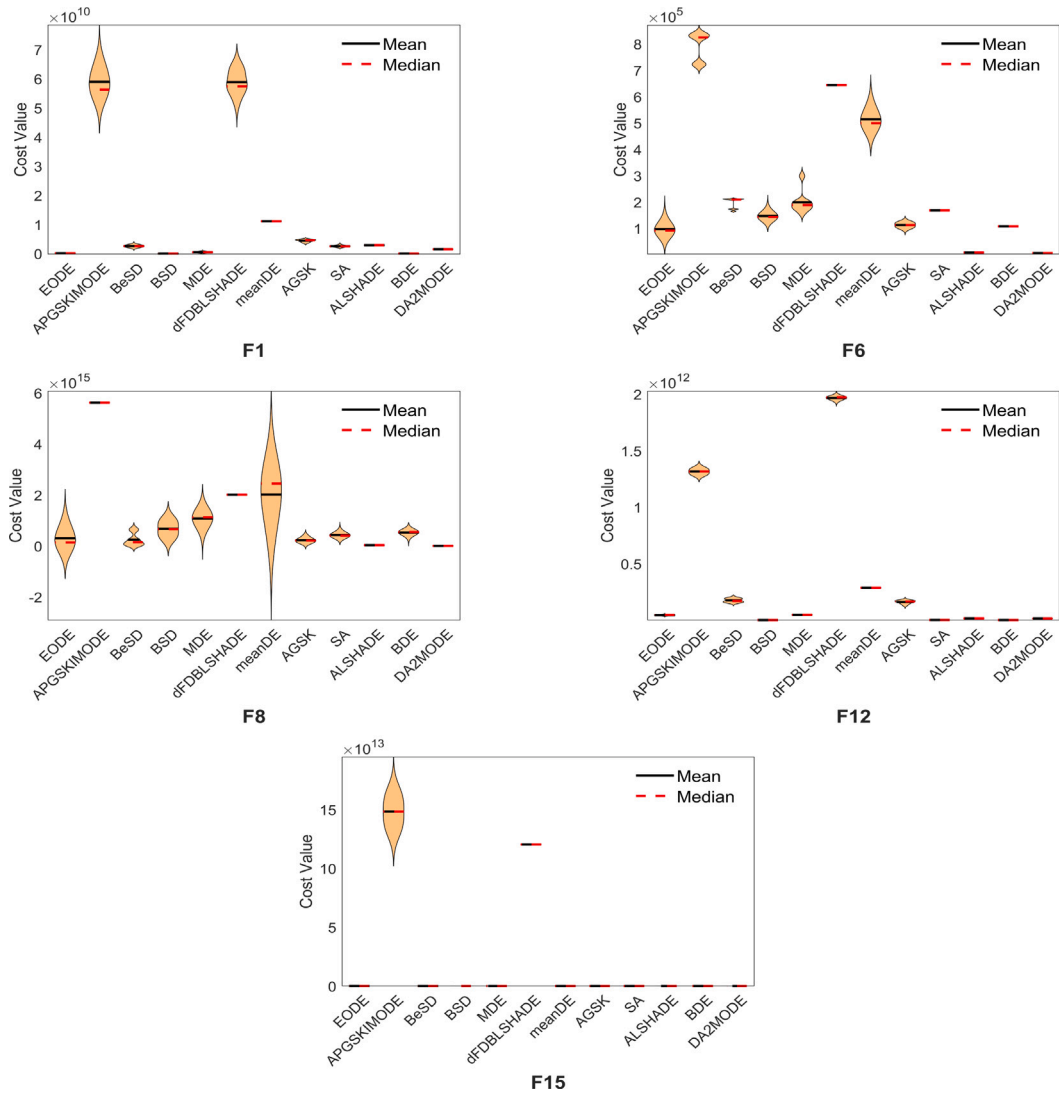



**Fig. 27.** Violin plots for selective 1000D CEC2013-LSGO benchmark functions.

**Table 16**
Detailed ranking of the algorithms based on Friedman test, FE-based, and SNE-SR-based ranking (CEC2013-LSGO, 1000D). Best or top-ranked results are shown in bold.

| Algorithm | SNE-SR-based ranking | | | | | | Median FE-based | | Friedman test (1000D) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | SNE | Score1 | SR | Score2 | total | Place | SR | Place | SumRanks | MeanRanks | Rank |
| EODE | 2.4785 | 33.9617 | 75 | 27.3333 | 61.2950 | 7 | 126 | 3 | 75 | 5.0000 | 6 |
| APGSKIMODE | 14.4601 | 5.8212 | 177 | 11.5819 | 17.4031 | 12 | 20 | 12 | 177 | 11.8000 | 12 |
| BeSD | 3.2132 | 26.1970 | 113 | 18.1416 | 44.3386 | 9 | 82 | 9 | 113 | 7.5333 | 9 |
| BSD | 2.2555 | 37.3196 | 72 | 28.4722 | 65.7918 | 3 | 126 | 4 | 72 | 4.8000 | 4 |
| MDE | 2.1895 | 38.4443 | 79 | 25.9494 | 64.3936 | 5 | 112 | 7 | 79 | 5.2667 | 7 |
| dFDBLSHADE | 11.7557 | 7.1604 | 165 | 12.4242 | 19.5847 | 11 | 27 | 11 | 165 | 11.0000 | 11 |
| meanDE | 4.7249 | 17.8151 | 139 | 14.7482 | 32.5633 | 10 | 57 | 10 | 139 | 9.2667 | 10 |
| AGSK | 3.0864 | 27.2729 | 108 | 18.9815 | 46.2544 | 8 | 84 | 8 | 108 | 7.2000 | 8 |
| SA | 2.4666 | 34.1255 | 68 | 30.1471 | 64.2726 | 6 | 125 | 5 | 68 | 4.5333 | 3 |
| ALSHADE | 2.2389 | 37.5964 | 73 | 28.0822 | 65.6786 | 4 | 121 | 6 | 73 | 4.8667 | 5 |
| BDE | 1.6835 | 50.0000 | 60 | 34.1667 | 84.1667 | 2 | 137 | 2 | 60 | 4.0000 | 2 |
| DA2MODE | 2.2548 | 37.3315 | 41 | 50.0000 | **87.3315** | **1** | **153** | **1** | 41 | **2.7333** | **1** |
| | | | | | | | | | Friedman $p$-value = **1.6469E−17** | | |

**Table 17**
Detailed sign test results between the DA2MODE and every other algorithm for the 1000D CEC2013-LSGO benchmark functions. Best results are shown in bold, highlighting cases where DA2MODE outperforms the competing algorithms.

| Algorithm | Fully-separable | Partially separable I | Partially separable II | Overlapping | Fully non-separable | Total |
|---|---|---|---|---|---|---|
| EODE | +2/=0/-1 | +3/=0/-1 | +3/=0/-1 | +3/=0/-0 | +1/=0/-0 | +12/=0/-3 |
| APGSKIMODE | +3/=0/-0 | +4/=0/-0 | +4/=0/-0 | +3/=0/-0 | +1/=0/-0 | +15/=0/-0 |
| BeSD | +3/=0/-0 | +4/=0/-0 | +3/=0/-1 | +3/=0/-0 | +1/=0/-0 | +14/=0/-1 |
| BSD | +0/=0/-3 | +4/=0/-0 | +4/=0/-0 | +2/=0/-1 | +1/=0/-0 | +11/=0/-4 |
| MDE | +1/=0/-2 | +3/=0/-1 | +2/=0/-2 | +3/=0/-0 | +1/=0/-0 | +10/=0/-5 |
| dFDBLSHADE | +3/=0/-0 | +4/=0/-0 | +4/=0/-0 | +3/=0/-0 | +1/=0/-0 | +15/=0/-0 |
| meanDE | +3/=0/-0 | +4/=0/-0 | +4/=0/-0 | +3/=0/-0 | +1/=0/-0 | +15/=0/-0 |
| AGSK | +3/=0/-0 | +4/=0/-0 | +3/=0/-1 | +3/=0/-0 | +1/=0/-0 | +14/=0/-1 |
| SA | +2/=0/-1 | +3/=0/-1 | +3/=0/-1 | +2/=0/-1 | +1/=0/-0 | +11/=0/-4 |
| ALSHADE | +1/=0/-2 | +4/=0/-0 | +4/=0/-0 | +3/=0/-0 | +1/=0/-0 | +13/=0/-2 |
| BDE | +0/=0/-3 | +4/=0/-0 | +2/=0/-2 | +2/=0/-1 | +1/=0/-0 | +9/=0/-6 |


**Fig. 28.** Detailed Wilcoxon Signed-rank test results distributions for all the function of CEC2013-LSGO benchmark functions, where the DA2MODE is the reference. (Algorithm perspective).

**Table 18**
Median results of the tension/compression spring design problem. Best results are shown in bold.

| Algorithm | Median cost | Succ. Rate | Sol FEs | $x_1$ | $x_2$ | $x_3$ |
|---|---|---|---|---|---|---|
| EODE | 0.0126947830 | 0.00 | 12 000 | 0.053339 | 0.397608 | 9.248811 |
| APGSKIMODE | 0.0126658022 | 37.50 | 12 000 | 0.051930 | 0.362552 | 10.954932 |
| BeSD | 0.0131114826 | 0.00 | 12 000 | 0.054566 | 0.429775 | 8.398979 |
| BSD | 0.0131174746 | 0.00 | 12 000 | 0.060980 | 0.610352 | 4.380861 |
| MDE | 0.0140998749 | 0.00 | 12 000 | 0.062829 | 0.688620 | 3.425623 |
| dFDBLSHADE | 0.0126659614 | 0.00 | 12 000 | 0.052624 | 0.379631 | 10.062031 |
| meanDE | 0.0136312892 | 0.00 | 12 000 | 0.059380 | 0.546168 | 5.490775 |
| AGSK | 0.0126666457 | 0.00 | 12 000 | 0.051440 | 0.350649 | 11.659799 |
| SA | 0.0130846812 | 0.00 | 12 000 | 0.064166 | 0.716887 | 3.310312 |
| ALSHADE | 0.0126652585 | 37.50 | 12 000 | 0.051763 | 0.358493 | 11.185671 |
| BDE | 0.0127927368 | 0.00 | 12 000 | 0.055905 | 0.465903 | 6.938420 |
| DA2MODE | **0.0126652328** | **75.00** | **7848** | 0.052380 | 0.373573 | 10.365278 |

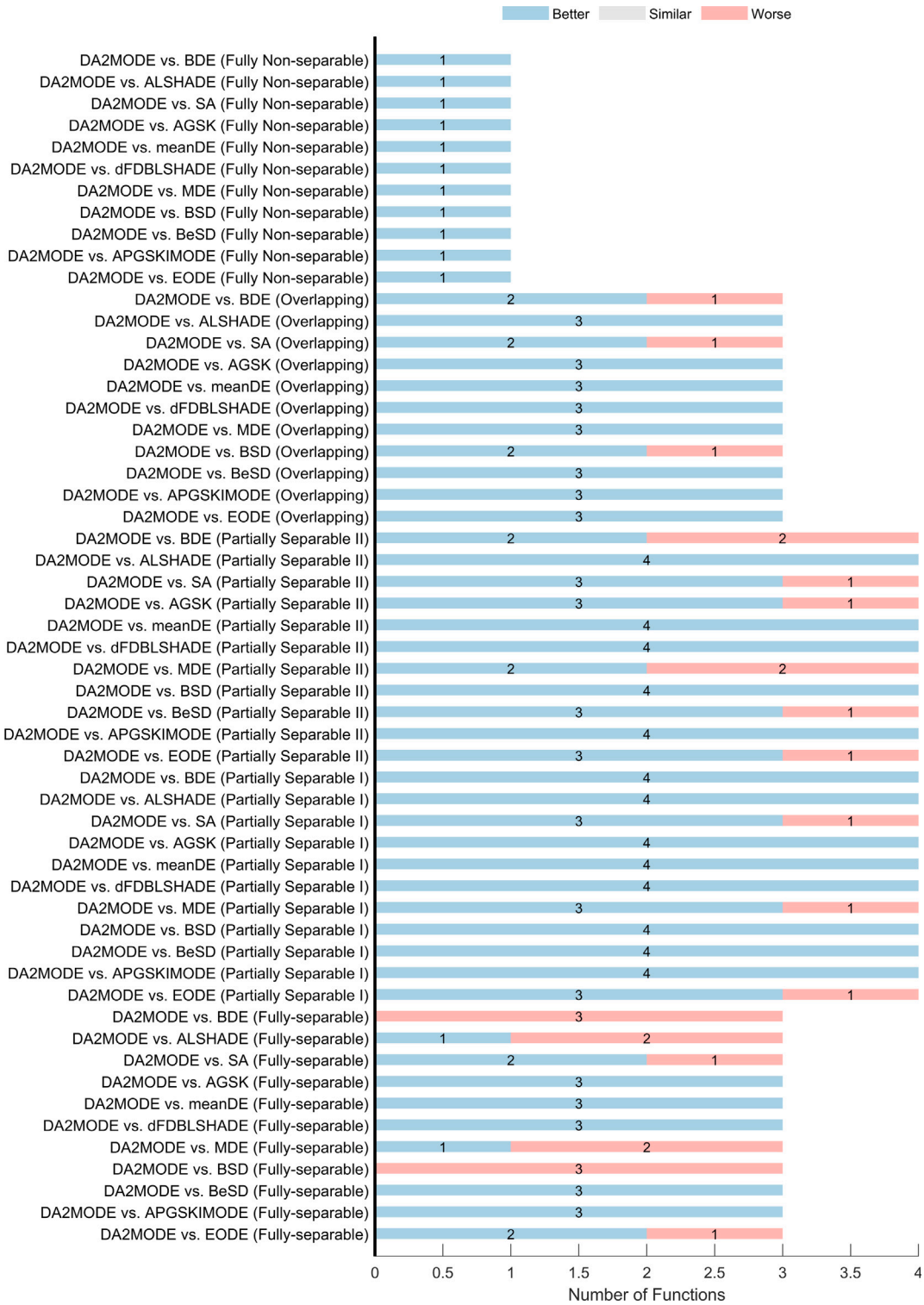



**Fig. 29.** Detailed Wilcoxon Signed-rank test results distributions for all the 1000D of CEC2013-LSGO benchmark functions, where the DA2MODE is the reference. (Categories perspective).

**Table 19**
Median results of the cantilever beam design problem. Best results are shown in bold.

| Algorithm | Median Cost | Succ. Rate | Sol FEs | $x_1$ | $x_2$ | $x_3$ | $x_4$ | $x_5$ |
|---|---|---|---|---|---|---|---|---|
| EODE | 1.3399577244 | 20.83 | 12 000 | 6.019308 | 5.307639 | 4.497918 | 3.499033 | 2.149783 |
| APGSKIMODE | 1.3399739512 | 33.33 | 12 000 | 6.006425 | 5.296584 | 4.495816 | 3.519379 | 2.155739 |
| BeSD | 1.4646629908 | 0.00 | 12 000 | 5.108140 | 7.769389 | 4.154848 | 4.053347 | 2.386439 |
| BSD | 1.3417536471 | 0.00 | 12 000 | 5.892062 | 5.319763 | 4.435833 | 3.547082 | 2.306807 |

(*continued on next page*)

**Table 19** (*continued*).

| Algorithm | Median Cost | Succ. Rate | Sol FEs | $x_1$ | $x_2$ | $x_3$ | $x_4$ | $x_5$ |
|---|---|---|---|---|---|---|---|---|
| MDE | 1.3402370479 | 0.00 | 12 000 | 6.057879 | 5.329928 | 4.499783 | 3.489274 | 2.101293 |
| dFDBLSHADE | 1.3399608631 | 33.33 | 12 000 | 6.022240 | 5.300671 | 4.492697 | 3.508044 | 2.150081 |
| meanDE | 1.3399723734 | 0.00 | 12 000 | 6.026019 | 5.294916 | 4.487431 | 3.501561 | 2.163988 |
| AGSK | 1.3400136609 | 0.00 | 12 000 | 6.031549 | 5.285082 | 4.491689 | 3.491475 | 2.174780 |
| SA | 1.4056609990 | 0.00 | 12 000 | 7.419527 | 5.523391 | 3.753339 | 3.259404 | 2.570958 |
| ALSHADE | **1.3399576000** | **100.00** | 8532 | 6.017032 | 5.309745 | 4.491426 | 3.503439 | 2.152034 |
| BDE | 1.3410510309 | 0.00 | 12 000 | 5.930661 | 5.312495 | 4.460897 | 3.578980 | 2.208170 |
| DA2MODE | **1.3399576000** | **100.00** | **6523** | 6.016882 | 5.311336 | 4.494346 | 3.499258 | 2.151843 |

**Table 20**
Median results of the I-shaped beam design problem. Best results are shown in bold.

| Algorithm | Median cost | Succ. rate | Sol FEs | $x_1$ | $x_2$ | $x_3$ | $x_4$ |
|---|---|---|---|---|---|---|---|
| EODE | 0.0130741189 | 0.00 | 12 000 | 79.9999999995 | 50.0000000000 | 0.9000000000 | 2.3217922607 |
| APGSKIMODE | 0.0130741198 | 0.00 | 12 000 | 80.0000000000 | 49.9999998785 | 0.9000002821 | 2.3217920171 |
| BeSD | 0.0134788381 | 0.00 | 12 000 | 79.6668883571 | 43.3633914452 | 0.9184379362 | 2.6374825631 |
| BSD | 0.0135848816 | 0.00 | 12 000 | 79.1530037873 | 46.8510132087 | 0.9785480344 | 2.4254775432 |
| MDE | 0.0130741190 | 0.00 | 12 000 | 80.0000000000 | 50.0000000000 | 0.9001536495 | 2.3216743532 |
| dFDBLSHADE | 0.0130741190 | 0.00 | 12 000 | 80.0000000000 | 49.9999966835 | 0.9000000000 | 2.3217924175 |
| meanDE | 0.0130741197 | 0.00 | 12 000 | 79.9999999207 | 49.9999910985 | 0.9000000859 | 2.3217925284 |
| AGSK | 0.0130741200 | 0.00 | 12 000 | 79.9999998774 | 49.9999753320 | 0.9000000387 | 2.3217932781 |
| SA | 0.0130751845 | 0.00 | 12 000 | 80.0000000000 | 50.0000000000 | 0.9000000000 | 2.3215687037 |
| ALSHADE | 0.0130741189 | 0.00 | 12 000 | 80.0000000000 | 50.0000000000 | 0.9000000000 | 2.3217922607 |
| BDE | 0.0131285688 | 0.00 | 12 000 | 79.9650476122 | 48.7543586659 | 0.9093159283 | 2.3746368813 |
| DA2MODE | **0.0130741000** | **100.00** | **8457** | 80.0000000000 | 50.0000000000 | 0.1500248127 | 2.6680416526 |

**Table 21**
Median results of the welded beam design problem. Best results are shown in bold.

| Algorithm | Median cost | Succ. rate | Sol FEs | $x_1$ | $x_2$ | $x_3$ | $x_4$ |
|---|---|---|---|---|---|---|---|
| EODE | **1.7248523086** | 66.67 | 9900 | 0.20572964 | 3.47048863 | 9.03662390 | 0.20572964 |
| APGSKIMODE | **1.7248523086** | 66.67 | 11 860 | 0.20572964 | 3.47048867 | 9.03662398 | 0.20572964 |
| BeSD | 1.8783979946 | 0.00 | 12 000 | 0.19722337 | 4.68262551 | 9.07271589 | 0.20566983 |
| BSD | 2.0491255497 | 0.00 | 12 000 | 0.29879617 | 2.44094003 | 8.03249274 | 0.26054792 |
| MDE | 1.7368318603 | 0.00 | 12 000 | 0.20593366 | 3.43741086 | 9.11546296 | 0.20606427 |
| dFDBLSHADE | 1.7248526401 | 33.33 | 12 000 | 0.20572940 | 3.47049381 | 9.03662398 | 0.20572964 |
| meanDE | 1.7248920671 | 0.00 | 12 000 | 0.20572207 | 3.47071134 | 9.03657404 | 0.20573331 |
| AGSK | 1.7249273042 | 0.00 | 12 000 | 0.20568904 | 3.47145911 | 9.03664392 | 0.20572996 |
| SA | 1.7609354468 | 0.00 | 12 000 | 0.19909394 | 3.54884682 | 9.26675946 | 0.20521448 |
| ALSHADE | **1.7248523086** | **100.00** | 10 352 | 0.20572964 | 3.47048871 | 9.03662392 | 0.20572964 |
| BDE | 1.7343878130 | 0.00 | 12 000 | 0.20176216 | 3.57501182 | 9.03606294 | 0.20596291 |
| DA2MODE | **1.7248523086** | **100.00** | **9304** | 0.20572964 | 3.47048868 | 9.03662396 | 0.20572964 |

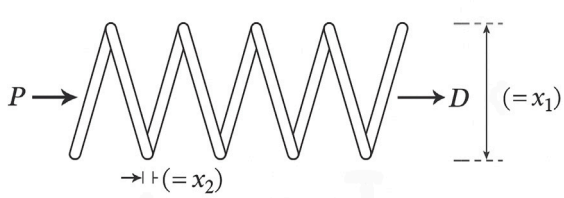



**Fig. 30.** Tension/compression spring schematic diagram.

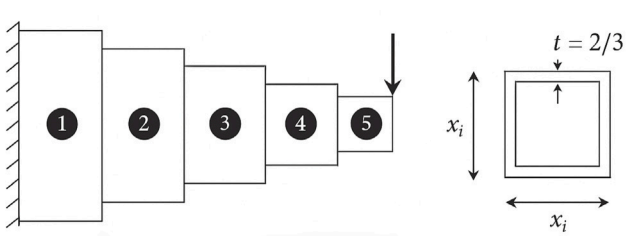



**Fig. 31.** Cantilever beam schematic diagram.

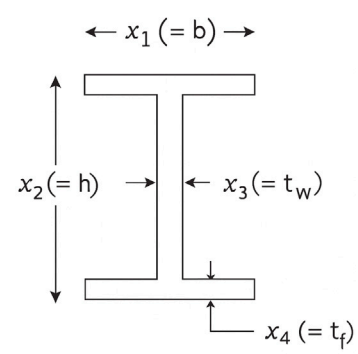



**Fig. 32.** I-shaped beam schematic diagram.

tests. Importantly, it remained stable without parameter tuning and scaled well to ultra-high dimensions.

Several directions remain open for future research. First, more mutation operators could be tested within the DA2MODE framework, and their performance could be compared to the current version. Second, DA2MODE can be hybridized with other successful optimizers or local-search strategies to exploit complementary strengths, potentially creating an enhanced DA2MODE. Finally, exploring domains beyond single-objective optimization, such as multi-objective optimization problems, would further demonstrate DA2MODE's versatility and scalability.

**Table A.1**
CEC2020 and CEC2021 benchmark functions Test Suites [18].

| Type | No. | Symbol | Functions | $F_i^*$ |
|---|---|---|---|---|
| Unimodal Functions | 1 | F1 | Shifted and Rotated Bent Cigar Function (CEC 2017 F1) | 100 |
| Basic Functions | 2 | F2 | Shifted and Rotated Schwefel's Function (CEC 2014 F11) | 1100 |
| | 3 | F3 | Shifted and Rotated Lunacek Bi-Rastrigin Function (CEC 2017 F7) | 700 |
| | 4 | F4 | Expanded Rosenbrock's plus Griewank's Function (CEC2017 F9) | 1900 |
| Hybrid Functions | 5 | F5 | Hybrid Function 1 (N=3) (CEC 2014 F17) | 1700 |
| | 6 | F6 | Hybrid Function 2 (N=4) (CEC 2017 F16) | 1600 |
| | 7 | F7 | Hybrid Function 3 (N=5) (CEC 2014 F21) | 2100 |
| Composition Functions | 8 | F8 | Composition Function 1 (N=3) (CEC 2017 F22) | 2200 |
| | 9 | F9 | Composition Function 2 (N=4) (CEC 2017 F24) | 2400 |
| | 10 | F10 | Composition Function 3 (N=5) (CEC 2017 F25) | 2500 |

**Table A.2**
CEC2022 benchmark functions Test Suite [37].

| Type | No. | Symbol | Functions | $F_i^*$ |
|---|---|---|---|---|
| Unimodal Function | 1 | F11 | Shifted and full Rotated Zakharov Function | 300 |
| Basic Functions | 2 | F12 | Shifted and full Rotated Rosenbrock's Function | 400 |
| | 3 | F13 | Shifted and full Rotated Expanded Schaffer's f6 Function | 600 |
| | 4 | F14 | Shifted and full Rotated Non-Continuous Rastrigin's Function | 800 |
| | 5 | F15 | Shifted and full Rotated Levy Function | 900 |
| Hybrid Functions | 6 | F16 | Hybrid Function 1 (N=3) | 1800 |
| | 7 | F17 | Hybrid Function 2 (N=6) | 2000 |
| | 8 | F18 | Hybrid Function 3 (N=5) | 2200 |
| Composition Functions | 9 | F19 | Composition Function 1 (N=5) | 2300 |
| | 10 | F20 | Composition Function 2 (N=4) | 2400 |
| | 11 | F21 | Composition Function 3 (N=5) | 2600 |
| | 12 | F22 | Composition Function 4 (N=6) | 2700 |

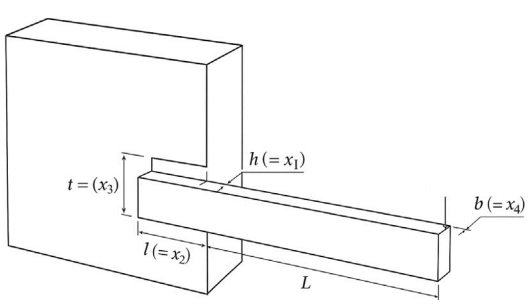



**Fig. 33.** Welded beam schematic diagram.

## CRediT authorship contribution statement

**Mohamed Reda:** Writing – review & editing, Writing – original draft, Visualization, Validation, Software, Resources, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Ahmed Onsy:** Supervision, Resources, Project administration, Funding acquisition. **Amira Y. Haikal:** Supervision, Project administration, Funding acquisition. **Ali Ghanbari:** Supervision, Project administration, Funding acquisition.

## Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

## Acknowledgment

All authors approved the final version of the manuscript.

## Appendix A. CEC benchmark functions

See Tables A.1–A.4

**Table A.3**
CEC2017 benchmark functions [57].

| Type | Number | Function Name | $f_i(x^*)$ |
|---|---|---|---|
| Unimodal | 1 | Shifted and Rotated Bent Cigar Function | 100 |
| | 2 | Shifted and Rotated Sum of Different Power Function* | 200 |
| | 3 | Shifted and Rotated Zakharov Function | 300 |
| Multimodal | 4 | Shifted and Rotated Rosenbrock's Function | 400 |
| | 5 | Shifted and Rotated Rastrigin's Function | 500 |
| | 6 | Shifted and Rotated Expanded Scaffer's F6 Function | 600 |
| | 7 | Shifted and Rotated Lunacek Bi_Rastrigin Function | 700 |
| | 8 | Shifted and Rotated Non-Continuous Rastrigin's Function | 800 |
| | 9 | Shifted and Rotated Levy Function | 900 |
| | 10 | Shifted and Rotated Schwefel's Function | 1000 |
| Hybrid | 11 | Hybrid Function 1 (N=3) | 1100 |
| | 12 | Hybrid Function 2 (N=3) | 1200 |
| | 13 | Hybrid Function 3 (N=3) | 1300 |
| | 14 | Hybrid Function 4 (N=4) | 1400 |
| | 15 | Hybrid Function 5 (N=4) | 1500 |
| | 16 | Hybrid Function 6 (N=4) | 1600 |
| | 17 | Hybrid Function 6 (N=5) | 1700 |
| | 18 | Hybrid Function 6 (N=5) | 1800 |
| | 19 | Hybrid Function 6 (N=5) | 1900 |
| | 20 | Hybrid Function 6 (N=6) | 2000 |
| Composition | 21 | Composition Function 1 (N=3) | 2100 |
| | 22 | Composition Function 2 (N=3) | 2200 |
| | 23 | Composition Function 3 (N=4) | 2300 |
| | 24 | Composition Function 4 (N=4) | 2400 |
| | 25 | Composition Function 5 (N=5) | 2500 |
| | 26 | Composition Function 6 (N=5) | 2600 |
| | 27 | Composition Function 7 (N=6) | 2700 |
| | 28 | Composition Function 8 (N=6) | 2800 |
| | 29 | Composition Function 9 (N=3) | 2900 |
| | 30 | Composition Function 10 (N=3) | 3000 |

**Table A.4**
CEC2013 LSGO Benchmark Functions [58].

| No. | Function name | Group | Dim. | Bounds |
|---|---|---|---|---|
| F1 | Shifted Elliptic Function | Separable | 1000 | [−100, 100] |
| F2 | Shifted Rastrigin's Function | Separable | 1000 | [−5, 5] |
| F3 | Shifted Ackley's Function | Separable | 1000 | [−32, 32] |
| F4 | Shifted and Rotated Elliptic Function (7 non-sep, 1 sep) | Partially Separable I | 1000 | [−100, 100] |
| F5 | Shifted and Rotated Rastrigin's Function (7 non-sep, 1 sep) | Partially Separable I | 1000 | [−5, 5] |
| F6 | Shifted and Rotated Ackley's Function (7 non-sep, 1 sep) | Partially Separable I | 1000 | [−32, 32] |
| F7 | Shifted Schwefel's Function (7 non-sep, 1 sep) | Partially Separable I | 1000 | [−100, 100] |
| F8 | Shifted and Rotated Elliptic Function (20 non-sep) | Partially Separable II | 1000 | [−100, 100] |
| F9 | Shifted and Rotated Rastrigin's Function (20 non-sep) | Partially Separable II | 1000 | [−5, 5] |
| F10 | Shifted and Rotated Ackley's Function (20 non-sep) | Partially Separable II | 1000 | [−32, 32] |
| F11 | Shifted Schwefel's Function (20 non-sep) | Partially Separable II | 1000 | [−100, 100] |
| F12 | Shifted Rosenbrock's Function | Overlapping (non-grouped) | 1000 | [−100, 100] |
| F13 | Shifted Schwefel's Function (Conforming Overlap) | Overlapping | 905 | [−100, 100] |
| F14 | Shifted Schwefel's Function (Conflicting Overlap) | Overlapping | 905 | [−100, 100] |
| F15 | Shifted Schwefel's Function | Fully Non-separable | 1000 | [−100, 100] |
| Global Optimum: $F_i^* = 0$ for all functions | | | | |

## Appendix B. CEC2020-2022 benchmark results tables

### B.1. Part 1: Meta-heuristic algorithms and CEC winners

See Tables B.5 and B.6

### B.2. Part 2: Advanced DE variants

See Tables B.7 and B.8

## Appendix C. CEC2020-2022 violin plots

### C.1. Part 1: Meta-heuristic algorithms and CEC winners

See Figs. C.1a–C.1d and Figs. C.2a–C.2d.

### C.2. Part 2: Advanced DE variants

See Figs. C.3a–C.3d and Figs. C.4a–C.4d.

## Appendix D. CEC2020-2022 convergence plots

### D.1. Part 1: Meta-heuristic algorithms and CEC winners

See Figs. D.5a–D.5d and Figs. D.6a–D.6d.

### D.2. Part 2: Advanced DE variants

See Figs. D.7a–D.7d and Figs. D.8a–D.8d.

**Table B.5**
The results metrics for the error and function evaluation metrics for 21 algorithms, CEC2020-2022 (F1–F3), (10 Dim).

| Fun | Alg. | Error | | | | | Function evaluations | | | | | SR (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No. | Name | Best | Worst | Median | Mean | SD | Best | Worst | Median | Mean | SD | |
| F1 | ABC | 2.27E+01 | 2.65E+03 | 3.18E+02 | 6.24E+02 | 6.78E+02 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | GA | 1.50E+04 | 1.78E+06 | 3.66E+05 | 5.05E+05 | 4.37E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | PSO | 1.42E+06 | 2.04E+09 | 3.04E+08 | 5.82E+08 | 6.12E+08 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | DE | 0.00E+00 | 0.00E+00 | 0.00E+00 | **0.00E+00** | 0.00E+00 | 3.77E+04 | 8.56E+04 | 4.06E+04 | 4.26E+04 | 9.30E+03 | 100.00 |
| | SA | 1.45E+06 | 8.04E+06 | 4.07E+06 | 4.24E+06 | 1.80E+06 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | TLBO | 1.98E+01 | 5.85E+03 | 7.77E+02 | 1.69E+03 | 1.79E+03 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | BAS | 8.55E+09 | 3.84E+10 | 2.04E+10 | 2.25E+10 | 7.55E+09 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | FA | 8.79E−01 | 5.84E+03 | 1.49E+03 | 2.01E+03 | 1.98E+03 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | HHO | 1.16E+07 | 8.49E+08 | 1.05E+08 | 1.87E+08 | 2.08E+08 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | GWO | 3.37E+02 | 4.88E+08 | 1.15E+04 | 4.29E+07 | 1.21E+08 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | MFO | 1.55E+00 | 1.60E+09 | 5.53E+03 | 1.97E+08 | 4.95E+08 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | WOA | 3.10E+03 | 2.01E+05 | 9.25E+03 | 1.80E+04 | 3.55E+04 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | CMAES | 1.68E+03 | 8.42E+09 | 4.33E+09 | 4.07E+09 | 1.98E+09 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | AGSK | 0.00E+00 | 0.00E+00 | 0.00E+00 | **0.00E+00** | 0.00E+00 | 1.36E+05 | 1.43E+05 | 1.38E+05 | 1.39E+05 | 1.55E+03 | 100.00 |
| | HSES | 0.00E+00 | 0.00E+00 | 0.00E+00 | **0.00E+00** | 0.00E+00 | 3.34E+04 | 5.02E+04 | 3.52E+04 | 3.57E+04 | 2.85E+03 | 100.00 |
| | MadDE | 0.00E+00 | 0.00E+00 | 0.00E+00 | **0.00E+00** | 0.00E+00 | 9.77E+04 | 1.04E+05 | 1.01E+05 | 1.00E+05 | 1.63E+03 | 100.00 |
| | IMODE | 0.00E+00 | 0.00E+00 | 0.00E+00 | **0.00E+00** | 0.00E+00 | 1.74E+05 | 1.77E+05 | 1.76E+05 | 1.76E+05 | 6.18E+02 | 100.00 |
| | ALSHADE | 0.00E+00 | 0.00E+00 | 0.00E+00 | **0.00E+00** | 0.00E+00 | 5.35E+04 | 5.90E+04 | 5.76E+04 | 5.73E+04 | 1.22E+03 | 100.00 |
| | EA4eig | 5.72E+03 | 1.98E+08 | 1.88E+07 | 3.66E+07 | 4.55E+07 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | APGSKIMODE | 0.00E+00 | 0.00E+00 | 0.00E+00 | **0.00E+00** | 0.00E+00 | 8.99E+04 | 9.28E+04 | 9.13E+04 | 9.13E+04 | 8.56E+02 | 100.00 |
| | DA2MODE | 0.00E+00 | 0.00E+00 | 0.00E+00 | **0.00E+00** | 0.00E+00 | 4.45E+04 | 4.62E+04 | 4.56E+04 | 4.56E+04 | 4.12E+02 | 100.00 |
| F2 | ABC | 1.15E+03 | 1.65E+03 | 1.40E+03 | 1.43E+03 | 1.13E+02 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | GA | 1.91E+01 | 8.24E+02 | 3.57E+02 | 3.89E+02 | 2.10E+02 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | PSO | 2.46E+02 | 1.46E+03 | 1.04E+03 | 1.02E+03 | 3.21E+02 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | DE | 1.04E+01 | 4.69E+02 | 2.46E+02 | 2.28E+02 | 1.42E+02 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | SA | 3.33E+01 | 3.53E+02 | 1.69E+02 | 1.66E+02 | 9.10E+01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | TLBO | 7.02E+00 | 4.30E+02 | 1.32E+02 | 1.54E+02 | 1.45E+02 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | BAS | 1.66E+03 | 2.90E+03 | 2.40E+03 | 2.39E+03 | 2.46E+02 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | FA | 3.72E+00 | 9.95E+02 | 3.62E+02 | 3.50E+02 | 2.97E+02 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | HHO | 5.56E+02 | 2.01E+03 | 1.17E+03 | 1.18E+03 | 2.89E+02 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | GWO | 4.49E−01 | 7.98E+02 | 4.24E+02 | 4.04E+02 | 2.32E+02 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | MFO | 3.32E+02 | 1.51E+03 | 9.23E+02 | 8.97E+02 | 3.24E+02 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | WOA | 3.52E+02 | 1.34E+03 | 9.93E+02 | 9.60E+02 | 2.55E+02 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | CMAES | 1.29E+03 | 2.14E+03 | 1.81E+03 | 1.78E+03 | 1.90E+02 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | AGSK | 2.96E+01 | 2.63E+02 | 1.43E+02 | 1.29E+02 | 6.61E+01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | HSES | 3.60E+00 | 1.85E+01 | 6.92E+00 | 8.83E+00 | 4.45E+00 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | MadDE | 3.75E−01 | 1.30E+02 | 1.03E+01 | 1.98E+01 | 2.99E+01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | IMODE | 2.50E−01 | 1.40E+02 | 2.02E+01 | 2.63E+01 | 2.58E+01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | ALSHADE | 1.25E−01 | 1.52E+01 | 3.76E+00 | 5.39E+00 | 3.98E+00 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | EA4eig | 1.10E+01 | 1.35E+03 | 7.80E+02 | 7.36E+02 | 3.04E+02 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | APGSKIMODE | 3.60E+00 | 1.26E+02 | 1.52E+01 | 1.94E+01 | 2.15E+01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | DA2MODE | 3.43E−01 | 1.54E+01 | 3.86E+00 | **4.79E+00** | 3.75E+00 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| F3 | ABC | 2.76E+01 | 4.70E+01 | 4.14E+01 | 4.03E+01 | 4.80E+00 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | GA | 1.50E+01 | 5.23E+01 | 3.16E+01 | 3.20E+01 | 8.54E+00 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | PSO | 2.26E+01 | 9.78E+01 | 4.30E+01 | 4.85E+01 | 2.02E+01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | DE | 1.76E+01 | 2.43E+01 | 2.09E+01 | 2.09E+01 | 1.84E+00 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | SA | 1.99E+01 | 4.02E+01 | 3.24E+01 | 3.12E+01 | 4.88E+00 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | TLBO | 1.28E+01 | 2.60E+01 | 1.82E+01 | 1.89E+01 | 3.70E+00 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | BAS | 2.36E+02 | 6.66E+02 | 4.27E+02 | 4.28E+02 | 1.16E+02 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | FA | 1.24E+01 | 2.68E+01 | 1.70E+01 | 1.73E+01 | 3.47E+00 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | HHO | 5.58E+01 | 1.37E+02 | 1.11E+02 | 1.05E+02 | 1.92E+01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | GWO | 1.31E+01 | 4.77E+01 | 2.81E+01 | 2.77E+01 | 8.70E+00 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | MFO | 1.70E+01 | 7.93E+01 | 3.86E+01 | 4.20E+01 | 1.45E+01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | WOA | 3.21E+01 | 1.23E+02 | 7.09E+01 | 7.47E+01 | 2.72E+01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | CMAES | 1.20E+01 | 3.23E+01 | 1.42E+01 | 1.51E+01 | 3.82E+00 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | AGSK | 1.23E+01 | 1.83E+01 | 1.44E+01 | 1.49E+01 | 1.62E+00 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | HSES | 1.04E+01 | 1.34E+01 | 1.11E+01 | 1.14E+01 | 7.27E−01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | MadDE | 1.14E+01 | 1.59E+01 | 1.36E+01 | 1.37E+01 | 1.14E+00 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | IMODE | 1.21E+01 | 1.65E+01 | 1.46E+01 | 1.46E+01 | 1.11E+00 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | ALSHADE | 1.05E+01 | 1.50E+01 | 1.16E+01 | 1.19E+01 | 1.03E+00 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | EA4eig | 2.81E+01 | 6.08E+01 | 4.25E+01 | 4.42E+01 | 7.68E+00 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | APGSKIMODE | 1.11E+01 | 1.60E+01 | 1.34E+01 | 1.34E+01 | 1.17E+00 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | DA2MODE | 1.04E+01 | 1.24E+01 | 1.13E+01 | **1.14E+01** | 5.30E−01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| F4 | ABC | 1.17E+00 | 2.54E+00 | 1.86E+00 | 1.89E+00 | 3.43E−01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | GA | 1.19E+00 | 1.38E+01 | 5.53E+00 | 6.17E+00 | 3.69E+00 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | PSO | 2.38E+01 | 2.03E+04 | 8.30E+02 | 2.58E+03 | 4.60E+03 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | DE | 9.75E−01 | 1.88E+00 | 1.51E+00 | 1.49E+00 | 2.33E−01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | SA | 1.52E+00 | 3.14E+00 | 2.34E+00 | 2.34E+00 | 3.49E−01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | TLBO | 1.29E−01 | 2.87E+00 | 1.04E+00 | 1.09E+00 | 6.79E−01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | BAS | 2.85E+04 | 1.98E+07 | 3.48E+06 | 4.72E+06 | 5.20E+06 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | FA | 3.66E−01 | 1.64E+00 | 7.65E−01 | 8.41E−01 | 3.02E−01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | HHO | 5.13E+00 | 6.02E+02 | 1.75E+01 | 4.91E+01 | 1.18E+02 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | GWO | 5.04E−01 | 2.68E+00 | 1.80E+00 | 1.59E+00 | 7.41E−01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | MFO | 7.73E−01 | 3.61E+02 | 1.93E+00 | 1.60E+01 | 6.57E+01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | WOA | 1.95E+00 | 8.75E+00 | 4.65E+00 | 4.82E+00 | 1.63E+00 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | CMAES | 2.24E+02 | 4.68E+03 | 1.13E+03 | 1.45E+03 | 1.15E+03 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | AGSK | 3.37E−01 | 7.41E−01 | 6.31E−01 | 6.05E−01 | 9.92E−02 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | HSES | 2.21E−01 | 1.26E+00 | 5.88E−01 | 6.42E−01 | 2.41E−01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | MadDE | 6.91E−02 | 4.80E−01 | 2.27E−01 | 2.27E−01 | 1.14E−01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | IMODE | 0.00E+00 | 1.40E−01 | 2.00E−02 | **3.12E−02** | 3.30E−02 | 1.82E+05 | 2.00E+05 | 2.00E+05 | 1.99E+05 | 3.80E+03 | 10.00 |
| | ALSHADE | 2.32E−01 | 5.98E−01 | 3.60E−01 | 3.71E−01 | 1.10E−01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | EA4eig | 1.95E+00 | 8.44E+00 | 3.70E+00 | 4.02E+00 | 1.36E+00 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | APGSKIMODE | 2.37E−01 | 6.06E−01 | 3.77E−01 | 4.07E−01 | 9.81E−02 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | DA2MODE | 2.49E−01 | 4.70E−01 | 3.23E−01 | 3.36E−01 | 6.72E−02 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |

(*continued on next page*)

## Appendix E. CEC2017-2018 benchmark results tables

### *E.1. Part 1: Meta-heuristic algorithms and CEC winners*

See Tables E.9–E.11

**Table B.5** (*continued*).

| Fun | Alg. | Error | | | | | Function evaluations | | | | | SR (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No. | Name | Best | Worst | Median | Mean | SD | Best | Worst | Median | Mean | SD | |
| | ABC | 2.31E+04 | 2.37E+05 | 9.33E+04 | 9.82E+04 | 5.13E+04 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | GA | 1.62E+04 | 3.89E+06 | 5.69E+05 | 1.16E+06 | 1.18E+06 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | PSO | 1.18E+03 | 1.80E+06 | 4.05E+05 | 5.37E+05 | 4.99E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | DE | 0.00E+00 | 5.02E+01 | 2.12E+00 | 6.43E+00 | 1.11E+01 | 1.73E+05 | 2.00E+05 | 2.00E+05 | 1.99E+05 | 5.14E+03 | 6.67 |
| | SA | 2.73E+02 | 1.86E+04 | 3.28E+03 | 5.16E+03 | 5.06E+03 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | TLBO | 2.54E+02 | 1.93E+03 | 5.28E+02 | 7.18E+02 | 4.94E+02 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | BAS | 8.84E+05 | 1.29E+08 | 9.33E+06 | 2.01E+07 | 2.93E+07 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | FA | 2.83E+01 | 7.31E+03 | 1.60E+03 | 2.50E+03 | 2.27E+03 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | HHO | 5.66E+03 | 7.36E+05 | 1.41E+05 | 2.96E+05 | 2.87E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | GWO | 8.77E+02 | 3.45E+05 | 2.67E+03 | 1.53E+04 | 6.24E+04 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| F5 | MFO | 8.08E+02 | 2.94E+06 | 6.57E+03 | 1.18E+05 | 5.34E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | WOA | 1.29E+03 | 3.70E+05 | 2.63E+04 | 7.63E+04 | 1.09E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | CMAES | 3.18E+04 | 1.60E+06 | 1.25E+05 | 2.47E+05 | 3.25E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | AGSK | 5.01E−02 | 7.72E+00 | 1.52E+00 | 2.05E+00 | 1.87E+00 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | HSES | 1.44E+01 | 6.92E+02 | 1.60E+02 | 2.12E+02 | 1.89E+02 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | MadDE | 0.00E+00 | 2.20E+00 | 4.16E−01 | **6.91E−01** | 5.71E−01 | 1.76E+05 | 2.00E+05 | 2.00E+05 | 1.99E+05 | 4.35E+03 | 3.33 |
| | IMODE | 1.19E−04 | 6.18E+00 | 1.41E+00 | 1.91E+00 | 1.51E+00 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | ALSHADE | 2.08E−01 | 2.61E+00 | 6.24E−01 | 9.52E−01 | 6.81E−01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | EA4eig | 3.12E+02 | 1.63E+04 | 3.90E+03 | 5.02E+03 | 4.14E+03 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | APGSKIMODE | 1.66E−07 | 2.20E+00 | 6.24E−01 | 8.25E−01 | 6.14E−01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | DA2MODE | 0.00E+00 | 2.41E+00 | 5.20E−01 | 8.83E−01 | 7.22E−01 | 1.46E+05 | 2.00E+05 | 2.00E+05 | 1.97E+05 | 1.24E+04 | 6.67 |
| | ABC | 3.53E+01 | 1.53E+02 | 9.52E+01 | 9.12E+01 | 3.13E+01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | GA | 1.76E+00 | 4.22E+02 | 1.23E+02 | 1.33E+02 | 1.07E+02 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | PSO | 3.21E+00 | 6.40E+02 | 3.12E+02 | 3.20E+02 | 1.81E+02 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | DE | 7.77E−02 | 1.50E+02 | 6.56E−01 | 1.13E+01 | 3.41E+01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | SA | 1.21E+00 | 3.12E+02 | 1.23E+02 | 9.93E+01 | 8.44E+01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | TLBO | 7.29E−01 | 2.41E+02 | 6.15E+01 | 6.94E+01 | 7.23E+01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | BAS | 5.27E+02 | 3.72E+03 | 1.26E+03 | 1.37E+03 | 6.33E+02 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | FA | 8.06E−01 | 3.44E+02 | 6.69E+01 | 7.92E+01 | 8.76E+01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | HHO | 5.43E+01 | 6.13E+02 | 3.50E+02 | 3.55E+02 | 1.40E+02 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | GWO | 1.51E+01 | 4.17E+02 | 1.53E+02 | 1.73E+02 | 9.92E+01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| F6 | MFO | 2.82E+00 | 4.34E+02 | 2.60E+02 | 2.32E+02 | 1.11E+02 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | WOA | 1.53E+01 | 3.44E+02 | 1.73E+02 | 2.02E+02 | 8.91E+01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | CMAES | 9.23E+01 | 6.09E+02 | 3.91E+02 | 4.08E+02 | 1.21E+02 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | AGSK | 2.09E−02 | 1.22E+00 | 4.14E−01 | 4.63E−01 | 3.60E−01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | HSES | 2.04E−02 | 1.20E+02 | 8.11E−01 | 8.73E+00 | 3.01E+01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | MadDE | 1.96E−02 | 5.54E−01 | 9.42E−02 | 1.76E−01 | 1.66E−01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | IMODE | 2.83E−02 | 1.21E+00 | 3.68E−01 | 4.12E−01 | 3.71E−01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | ALSHADE | 1.96E−02 | 7.27E−01 | 2.47E−01 | 2.85E−01 | 1.94E−01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | EA4eig | 5.68E+00 | 1.47E+02 | 3.79E+01 | 5.15E+01 | 4.04E+01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | APGSKIMODE | 1.77E−04 | 5.16E−01 | 4.25E−02 | **1.05E−01** | 1.34E−01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | DA2MODE | 2.53E−02 | 1.21E+00 | 3.24E−01 | 3.96E−01 | 3.19E−01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | ABC | 3.76E+03 | 6.91E+04 | 2.44E+04 | 2.69E+04 | 1.50E+04 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | GA | 4.63E+02 | 4.20E+06 | 2.16E+05 | 5.15E+05 | 9.87E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | PSO | 1.28E+02 | 1.01E+06 | 1.68E+04 | 1.32E+05 | 2.68E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | DE | 5.86E−04 | 1.75E+01 | 3.16E−01 | 8.91E−01 | 3.15E+00 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | SA | 2.77E+01 | 8.39E+02 | 3.25E+02 | 3.84E+02 | 2.57E+02 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | TLBO | 1.33E−01 | 4.19E+02 | 6.81E+01 | 8.66E+01 | 8.82E+01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | BAS | 9.91E+03 | 1.35E+08 | 5.25E+06 | 1.84E+07 | 3.30E+07 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | FA | 8.38E−02 | 6.78E+02 | 5.88E+01 | 1.11E+02 | 1.61E+02 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | HHO | 4.05E+03 | 1.06E+06 | 3.91E+04 | 1.53E+05 | 2.73E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | GWO | 4.87E+02 | 1.21E+04 | 5.20E+03 | 5.63E+03 | 4.28E+03 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| F7 | MFO | 2.32E+02 | 3.06E+04 | 6.47E+03 | 8.22E+03 | 8.16E+03 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | WOA | 1.38E+03 | 8.77E+04 | 1.20E+04 | 1.55E+04 | 1.70E+04 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | CMAES | 3.66E+03 | 3.35E+06 | 3.00E+05 | 5.39E+05 | 7.61E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | AGSK | 4.16E−04 | 7.86E−01 | 8.34E−02 | 2.15E−01 | 2.37E−01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | HSES | 1.29E−03 | 1.19E+02 | 1.72E+01 | 2.75E+01 | 3.65E+01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | MadDE | 3.06E−06 | 1.12E+00 | 2.66E−02 | **1.47E−01** | 2.41E−01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | IMODE | 5.69E−03 | 8.07E−01 | 4.55E−02 | 2.03E−01 | 2.33E−01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | ALSHADE | 2.34E−04 | 8.00E−01 | 3.15E−01 | 2.93E−01 | 2.32E−01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | EA4eig | 1.22E+02 | 7.25E+03 | 1.81E+03 | 2.15E+03 | 1.81E+03 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | APGSKIMODE | 3.63E−04 | 8.03E−01 | 1.58E−02 | 1.73E−01 | 2.27E−01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | DA2MODE | 3.38E−05 | 8.12E−01 | 1.09E−01 | 2.40E−01 | 2.62E−01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | ABC | 1.07E+02 | 1.23E+02 | 1.13E+02 | 1.13E+02 | 3.92E+00 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | GA | 1.04E+02 | 1.24E+02 | 1.09E+02 | 1.10E+02 | 5.43E+00 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | PSO | 1.06E+02 | 2.14E+03 | 1.31E+02 | 2.13E+02 | 3.65E+02 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | DE | 1.00E+02 | 1.00E+02 | 1.00E+02 | 1.00E+02 | 1.48E−01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | SA | 4.45E+00 | 1.14E+02 | 1.12E+02 | 1.06E+02 | 2.61E+01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | TLBO | 2.18E+01 | 1.09E+02 | 1.02E+02 | 9.96E+01 | 1.48E+01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | BAS | 5.75E+02 | 3.09E+03 | 2.05E+03 | 2.07E+03 | 6.42E+02 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | FA | 1.80E+01 | 1.02E+02 | 1.01E+02 | 9.29E+01 | 2.45E+01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | HHO | 6.02E+01 | 1.36E+03 | 1.26E+02 | 2.02E+02 | 2.82E+02 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | GWO | 1.01E+02 | 1.31E+02 | 1.02E+02 | 1.07E+02 | 7.64E+00 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| F8 | MFO | 5.03E+01 | 1.54E+02 | 1.04E+02 | 1.09E+02 | 1.97E+01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | WOA | 3.97E+01 | 7.12E+02 | 1.13E+02 | 1.32E+02 | 1.11E+02 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | CMAES | 1.16E+01 | 2.20E+03 | 1.00E+02 | 4.48E+02 | 6.91E+02 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | AGSK | 0.00E+00 | 1.00E+02 | 2.04E+01 | **4.47E+01** | 4.74E+01 | 1.46E+05 | 2.00E+05 | 2.00E+05 | 1.82E+05 | 2.16E+04 | 43.33 |
| | HSES | 1.00E+02 | 1.00E+02 | 1.00E+02 | 1.00E+02 | 3.16E−10 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | MadDE | 1.70E+01 | 1.00E+02 | 1.00E+02 | 8.91E+01 | 2.33E+01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | IMODE | 4.82E+01 | 1.00E+02 | 1.00E+02 | 9.83E+01 | 9.45E+00 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | ALSHADE | 0.00E+00 | 1.00E+02 | 1.00E+02 | 9.67E+01 | 1.83E+01 | 6.59E+04 | 2.00E+05 | 2.00E+05 | 1.96E+05 | 2.45E+04 | 3.33 |
| | EA4eig | 4.95E+01 | 1.18E+02 | 1.10E+02 | 1.08E+02 | 1.17E+01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | APGSKIMODE | 0.00E+00 | 1.00E+02 | 1.00E+02 | 6.36E+01 | 4.45E+01 | 1.23E+05 | 2.00E+05 | 2.00E+05 | 1.91E+05 | 2.09E+04 | 20.00 |
| | DA2MODE | 1.00E+02 | 1.00E+02 | 1.00E+02 | 1.00E+02 | 0.00E+00 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | ABC | 2.99E+02 | 3.69E+02 | 3.58E+02 | 3.52E+02 | 1.79E+01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | GA | 1.01E+02 | 4.05E+02 | 3.56E+02 | 3.52E+02 | 4.95E+01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | PSO | 1.18E+02 | 5.21E+02 | 4.33E+02 | 3.98E+02 | 1.28E+02 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | DE | 3.35E+02 | 3.51E+02 | 3.43E+02 | 3.44E+02 | 3.62E+00 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | SA | 1.09E+02 | 3.48E+02 | 3.18E+02 | 2.87E+02 | 9.09E+01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | TLBO | 1.00E+02 | 3.47E+02 | 3.37E+02 | 3.15E+02 | 7.29E+01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | BAS | 5.05E+02 | 1.05E+03 | 6.28E+02 | 6.57E+02 | 1.15E+02 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | FA | 1.00E+02 | 3.67E+02 | 3.44E+02 | 2.97E+02 | 1.01E+02 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | HHO | 1.67E+02 | 5.30E+02 | 4.21E+02 | 4.11E+02 | 7.39E+01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | GWO | 1.18E+02 | 3.59E+02 | 3.40E+02 | 3.33E+02 | 4.28E+01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| F9 | MFO | 3.43E+02 | 3.86E+02 | 3.66E+02 | 3.66E+02 | 1.08E+01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | WOA | 1.01E+02 | 4.54E+02 | 3.81E+02 | 3.65E+02 | 7.57E+01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | CMAES | 2.95E+02 | 4.30E+02 | 4.15E+02 | 4.10E+02 | 2.34E+01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | AGSK | 1.00E+02 | 1.00E+02 | 1.00E+02 | 1.00E+02 | 1.66E−13 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | HSES | 3.24E+02 | 3.31E+02 | 3.29E+02 | 3.28E+02 | 1.07E+00 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | MadDE | 0.00E+00 | 1.00E+02 | 1.00E+02 | 9.67E+01 | 1.83E+01 | 1.52E+05 | 2.00E+05 | 2.00E+05 | 1.98E+05 | 8.70E+03 | 3.33 |
| | IMODE | 0.00E+00 | 1.00E+02 | 1.00E+02 | **9.33E+01** | 2.54E+01 | 1.97E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 6.67E+02 | 6.67 |
| | ALSHADE | 1.00E+02 | 3.33E+02 | 3.30E+02 | 3.06E+02 | 7.02E+01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | EA4eig | 1.27E+02 | 3.40E+02 | 2.66E+02 | 2.66E+02 | 4.90E+01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | APGSKIMODE | 0.00E+00 | 1.00E+02 | 1.00E+02 | 9.67E+01 | 1.83E+01 | 1.95E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 9.39E+02 | 3.33 |
| | DA2MODE | 1.00E+02 | 3.30E+02 | 3.00E+02 | 2.39E+02 | 1.08E+02 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |

(*continued on next page*)

**Table B.5** (*continued*).

| Fun | Alg. | Error | | | | | Function evaluations | | | | | SR (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No. | Name | Best | Worst | Median | Mean | SD | Best | Worst | Median | Mean | SD | |
| | ABC | 3.98E+02 | 4.46E+02 | 4.39E+02 | 4.33E+02 | 1.54E+01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | GA | 3.99E+02 | 4.62E+02 | 4.48E+02 | 4.41E+02 | 1.87E+01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | PSO | 4.01E+02 | 6.99E+02 | 4.61E+02 | 4.71E+02 | 6.10E+01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | DE | 3.98E+02 | 4.46E+02 | 4.46E+02 | 4.30E+02 | 2.27E+01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | SA | 3.99E+02 | 4.46E+02 | 4.01E+02 | 4.06E+02 | 1.30E+01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | TLBO | 3.98E+02 | 4.71E+02 | 4.43E+02 | 4.25E+02 | 2.50E+01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | BAS | 8.33E+02 | 3.87E+03 | 2.04E+03 | 1.99E+03 | 7.15E+02 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | FA | 3.98E+02 | 4.46E+02 | 4.43E+02 | 4.26E+02 | 2.31E+01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | HHO | 4.22E+02 | 6.75E+02 | 4.65E+02 | 4.81E+02 | 4.98E+01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | GWO | 3.98E+02 | 4.50E+02 | 4.34E+02 | 4.31E+02 | 1.56E+01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| F10 | MFO | 3.98E+02 | 4.97E+02 | 4.50E+02 | 4.42E+02 | 2.74E+01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | WOA | 1.04E+02 | 4.58E+02 | 4.48E+02 | 4.24E+02 | 6.46E+01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | CMAES | 4.43E+02 | 8.74E+02 | 5.97E+02 | 6.07E+02 | 1.07E+02 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | AGSK | 1.00E+02 | 3.98E+02 | 3.98E+02 | 3.08E+02 | 1.39E+02 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | HSES | 4.44E+02 | 4.48E+02 | 4.46E+02 | 4.46E+02 | 1.18E+00 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | MadDE | 3.98E+02 | 4.00E+02 | 3.98E+02 | 3.98E+02 | 3.36E−01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | IMODE | 3.98E+02 | 4.00E+02 | 3.98E+02 | 3.98E+02 | 8.83E−01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | ALSHADE | 3.98E+02 | 4.43E+02 | 3.98E+02 | 4.12E+02 | 2.11E+01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | EA4eig | 3.98E+02 | 4.52E+02 | 4.44E+02 | 4.30E+02 | 2.32E+01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | APGSKIMODE | 1.00E+02 | 3.98E+02 | 3.98E+02 | **2.98E+02** | 1.43E+02 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | DA2MODE | 3.98E+02 | 4.43E+02 | 3.98E+02 | 4.08E+02 | 1.96E+01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | ABC | 3.52E+03 | 1.97E+04 | 1.05E+04 | 1.11E+04 | 3.98E+03 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | GA | 1.61E+03 | 2.45E+04 | 6.05E+03 | 7.79E+03 | 5.86E+03 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | PSO | 3.32E+02 | 1.65E+04 | 5.73E+03 | 5.69E+03 | 3.64E+03 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | DE | 0.00E+00 | 0.00E+00 | 0.00E+00 | **0.00E+00** | 0.00E+00 | 4.69E+04 | 6.06E+04 | 5.54E+04 | 5.51E+04 | 3.03E+03 | 100.00 |
| | SA | 1.04E+01 | 5.47E+01 | 3.68E+01 | 3.52E+01 | 1.18E+01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | TLBO | 0.00E+00 | 0.00E+00 | 0.00E+00 | **0.00E+00** | 0.00E+00 | 2.00E+04 | 2.87E+04 | 2.40E+04 | 2.40E+04 | 2.24E+03 | 100.00 |
| | BAS | 1.22E+04 | 1.03E+08 | 4.21E+04 | 3.80E+06 | 1.88E+07 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | FA | 0.00E+00 | 7.33E−08 | 4.70E−08 | 4.72E−08 | 1.55E−08 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 5.57E+01 | 3.33 |
| | HHO | 4.24E+03 | 1.88E+04 | 7.96E+03 | 8.15E+03 | 2.74E+03 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | GWO | 7.50E−02 | 3.85E+03 | 1.80E+02 | 8.34E+02 | 1.18E+03 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| F11 | MFO | 0.00E+00 | 2.76E+04 | 3.74E+03 | 7.22E+03 | 7.43E+03 | 3.30E+04 | 2.00E+05 | 2.00E+05 | 1.52E+05 | 7.51E+04 | 30.00 |
| | WOA | 1.52E+03 | 1.04E+04 | 4.21E+03 | 4.56E+03 | 2.17E+03 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | CMAES | 1.08E+04 | 5.24E+04 | 2.39E+04 | 2.57E+04 | 8.41E+03 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | AGSK | 0.00E+00 | 0.00E+00 | 0.00E+00 | **0.00E+00** | 0.00E+00 | 1.33E+05 | 1.41E+05 | 1.36E+05 | 1.37E+05 | 2.09E+03 | 100.00 |
| | HSES | 0.00E+00 | 0.00E+00 | 0.00E+00 | **0.00E+00** | 0.00E+00 | 2.95E+04 | 3.95E+04 | 3.04E+04 | 3.10E+04 | 2.31E+03 | 100.00 |
| | MadDE | 0.00E+00 | 0.00E+00 | 0.00E+00 | **0.00E+00** | 0.00E+00 | 6.28E+04 | 6.88E+04 | 6.55E+04 | 6.55E+04 | 1.51E+03 | 100.00 |
| | IMODE | 0.00E+00 | 0.00E+00 | 0.00E+00 | **0.00E+00** | 0.00E+00 | 1.21E+05 | 1.27E+05 | 1.24E+05 | 1.24E+05 | 1.46E+03 | 100.00 |
| | ALSHADE | 0.00E+00 | 0.00E+00 | 0.00E+00 | **0.00E+00** | 0.00E+00 | 4.07E+04 | 4.71E+04 | 4.53E+04 | 4.49E+04 | 1.46E+03 | 100.00 |
| | EA4eig | 1.82E−06 | 3.99E+02 | 1.21E+02 | 1.11E+02 | 9.68E+01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | APGSKIMODE | 0.00E+00 | 0.00E+00 | 0.00E+00 | **0.00E+00** | 0.00E+00 | 6.22E+04 | 6.57E+04 | 6.35E+04 | 6.36E+04 | 8.37E+02 | 100.00 |
| | DA2MODE | 0.00E+00 | 0.00E+00 | 0.00E+00 | **0.00E+00** | 0.00E+00 | 3.39E+04 | 3.56E+04 | 3.46E+04 | 3.47E+04 | 4.29E+02 | 100.00 |
| | ABC | 2.11E+00 | 4.66E+00 | 2.88E+00 | 2.82E+00 | 5.03E−01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | GA | 1.93E−01 | 9.13E+01 | 5.37E+00 | 2.02E+01 | 3.11E+01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | PSO | 4.42E+00 | 2.64E+02 | 9.78E+01 | 1.01E+02 | 6.67E+01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | DE | 0.00E+00 | 8.92E+00 | 8.92E+00 | 7.28E+00 | 2.48E+00 | 1.74E+05 | 2.00E+05 | 2.00E+05 | 1.99E+05 | 4.66E+03 | 3.33 |
| | SA | 9.87E−01 | 9.66E+00 | 9.17E+00 | 8.02E+00 | 2.19E+00 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | TLBO | 1.29E−03 | 7.08E+01 | 1.29E−01 | 6.92E+00 | 1.77E+01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | BAS | 7.64E+02 | 9.09E+03 | 3.24E+03 | 4.04E+03 | 2.49E+03 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | FA | 9.87E−05 | 8.92E+00 | 4.36E+00 | 4.89E+00 | 3.91E+00 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | HHO | 5.38E−01 | 5.08E+02 | 9.13E+01 | 1.18E+02 | 1.15E+02 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | GWO | 1.70E+00 | 6.24E+01 | 1.09E+01 | 1.85E+01 | 1.78E+01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| F12 | MFO | 4.07E+00 | 7.08E+01 | 8.92E+00 | 1.46E+01 | 1.62E+01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | WOA | 4.02E−02 | 8.85E+01 | 7.46E+00 | 1.80E+01 | 2.73E+01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | CMAES | 7.58E+01 | 3.92E+02 | 2.27E+02 | 2.41E+02 | 9.07E+01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | AGSK | 0.00E+00 | 3.99E+00 | 0.00E+00 | 3.99E−01 | 1.22E+00 | 1.39E+05 | 2.00E+05 | 1.48E+05 | 1.53E+05 | 1.63E+04 | 90.00 |
| | HSES | 0.00E+00 | 0.00E+00 | 0.00E+00 | **0.00E+00** | 0.00E+00 | 2.86E+04 | 3.08E+04 | 2.99E+04 | 2.98E+04 | 5.99E+02 | 100.00 |
| | MadDE | 0.00E+00 | 0.00E+00 | 0.00E+00 | **0.00E+00** | 0.00E+00 | 7.82E+04 | 9.18E+04 | 8.16E+04 | 8.23E+04 | 2.93E+03 | 100.00 |
| | IMODE | 0.00E+00 | 0.00E+00 | 0.00E+00 | **0.00E+00** | 0.00E+00 | 1.66E+05 | 1.69E+05 | 1.68E+05 | 1.67E+05 | 8.72E+02 | 100.00 |
| | ALSHADE | 3.99E+00 | 8.92E+00 | 3.99E+00 | 4.32E+00 | 1.25E+00 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | EA4eig | 1.79E+00 | 6.56E+01 | 2.50E+01 | 2.58E+01 | 1.52E+01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | APGSKIMODE | 0.00E+00 | 0.00E+00 | 0.00E+00 | **0.00E+00** | 0.00E+00 | 7.85E+04 | 1.72E+05 | 8.13E+04 | 8.77E+04 | 2.07E+04 | 100.00 |
| | DA2MODE | 0.00E+00 | 0.00E+00 | 0.00E+00 | **0.00E+00** | 0.00E+00 | 5.03E+04 | 6.28E+04 | 5.96E+04 | 5.90E+04 | 2.87E+03 | 100.00 |
| | ABC | 2.89E−03 | 1.09E−02 | 6.36E−03 | 6.42E−03 | 1.97E−03 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | GA | 7.56E−03 | 8.01E−01 | 1.05E−01 | 1.96E−01 | 2.18E−01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | PSO | 9.83E+00 | 4.53E+01 | 3.13E+01 | 2.96E+01 | 9.45E+00 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | DE | 0.00E+00 | 0.00E+00 | 0.00E+00 | **0.00E+00** | 0.00E+00 | 1.47E+04 | 1.67E+04 | 1.57E+04 | 1.57E+04 | 4.52E+02 | 100.00 |
| | SA | 6.66E−01 | 1.93E+00 | 1.38E+00 | 1.36E+00 | 3.10E−01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | TLBO | 3.55E−07 | 4.14E+00 | 1.86E−02 | 4.27E−01 | 1.05E+00 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | BAS | 5.47E+01 | 9.70E+01 | 7.84E+01 | 7.72E+01 | 1.25E+01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | FA | 9.20E−05 | 1.53E−04 | 1.33E−04 | 1.28E−04 | 1.69E−05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | HHO | 2.42E+01 | 6.92E+01 | 3.99E+01 | 4.17E+01 | 1.17E+01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | GWO | 3.02E−03 | 1.35E+01 | 1.85E−01 | 1.12E+00 | 2.84E+00 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| F13 | MFO | 0.00E+00 | 1.52E+01 | 1.34E+00 | 2.92E+00 | 3.59E+00 | 2.42E+04 | 2.00E+05 | 2.00E+05 | 1.71E+05 | 6.60E+04 | 16.67 |
| | WOA | 8.86E+00 | 6.30E+01 | 2.50E+01 | 2.69E+01 | 1.29E+01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | CMAES | 0.00E+00 | 5.66E+01 | 0.00E+00 | 1.27E+01 | 2.16E+01 | 1.63E+04 | 2.00E+05 | 1.78E+04 | 1.02E+05 | 9.29E+04 | 53.33 |
| | AGSK | 0.00E+00 | 1.42E−06 | 0.00E+00 | 1.42E−07 | 4.34E−07 | 1.57E+05 | 2.00E+05 | 1.62E+05 | 1.65E+05 | 1.20E+04 | 90.00 |
| | HSES | 0.00E+00 | 0.00E+00 | 0.00E+00 | **0.00E+00** | 0.00E+00 | 3.44E+04 | 5.00E+04 | 3.51E+04 | 3.56E+04 | 2.75E+03 | 100.00 |
| | MadDE | 0.00E+00 | 0.00E+00 | 0.00E+00 | **0.00E+00** | 0.00E+00 | 1.49E+05 | 1.56E+05 | 1.51E+05 | 1.52E+05 | 1.84E+03 | 100.00 |
| | IMODE | 0.00E+00 | 0.00E+00 | 0.00E+00 | **0.00E+00** | 0.00E+00 | 1.91E+05 | 1.94E+05 | 1.93E+05 | 1.93E+05 | 6.68E+02 | 100.00 |
| | ALSHADE | 0.00E+00 | 0.00E+00 | 0.00E+00 | **0.00E+00** | 0.00E+00 | 7.98E+04 | 8.67E+04 | 8.41E+04 | 8.38E+04 | 1.67E+03 | 100.00 |
| | EA4eig | 2.21E−02 | 1.03E+01 | 1.86E+00 | 2.81E+00 | 2.46E+00 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | APGSKIMODE | 0.00E+00 | 0.00E+00 | 0.00E+00 | **0.00E+00** | 0.00E+00 | 1.24E+05 | 1.31E+05 | 1.29E+05 | 1.29E+05 | 1.68E+03 | 100.00 |
| | DA2MODE | 0.00E+00 | 0.00E+00 | 0.00E+00 | **0.00E+00** | 0.00E+00 | 7.32E+04 | 7.74E+04 | 7.50E+04 | 7.52E+04 | 1.00E+03 | 100.00 |

(*continued on next page*)

**Table B.5** (*continued*).

| Fun | Alg. | Error | | | | | Function evaluations | | | | | SR (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No. | Name | Best | Worst | Median | Mean | SD | Best | Worst | Median | Mean | SD | |
| | ABC | 2.23E+01 | 3.64E+01 | 3.10E+01 | 3.00E+01 | 3.53E+00 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | GA | 4.99E+00 | 4.08E+01 | 2.64E+01 | 2.27E+01 | 1.05E+01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | PSO | 1.19E+01 | 6.57E+01 | 2.49E+01 | 2.67E+01 | 1.19E+01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | DE | 9.60E+00 | 2.21E+01 | 1.74E+01 | 1.73E+01 | 3.08E+00 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | SA | 4.08E+00 | 1.40E+01 | 9.14E+00 | 9.17E+00 | 2.64E+00 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | TLBO | 2.98E+00 | 1.30E+01 | 7.96E+00 | 7.80E+00 | 2.97E+00 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | BAS | 7.70E+01 | 1.55E+02 | 1.16E+02 | 1.15E+02 | 1.72E+01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | FA | 3.98E+00 | 3.62E+01 | 1.19E+01 | 1.28E+01 | 6.47E+00 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | HHO | 1.09E+01 | 6.12E+01 | 3.05E+01 | 3.12E+01 | 1.04E+01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | GWO | 5.98E+00 | 2.79E+01 | 1.31E+01 | 1.40E+01 | 5.86E+00 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| F14 | MFO | 5.97E+00 | 5.27E+01 | 2.94E+01 | 3.15E+01 | 1.25E+01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | WOA | 1.60E+01 | 7.66E+01 | 3.73E+01 | 3.87E+01 | 1.54E+01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | CMAES | 1.99E+00 | 2.66E+01 | 3.98E+00 | 4.97E+00 | 4.48E+00 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | AGSK | 3.09E+00 | 1.01E+01 | 6.05E+00 | 6.25E+00 | 1.58E+00 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | HSES | 0.00E+00 | 1.99E+00 | 4.97E−01 | **5.97E−01** | 6.71E−01 | 2.56E+04 | 2.00E+05 | 2.00E+05 | 1.48E+05 | 8.12E+04 | 30.00 |
| | MadDE | 0.00E+00 | 4.97E+00 | 2.98E+00 | 2.92E+00 | 1.04E+00 | 1.58E+05 | 2.00E+05 | 2.00E+05 | 1.99E+05 | 7.61E+03 | 3.33 |
| | IMODE | 1.99E+00 | 7.96E+00 | 5.40E+00 | 5.52E+00 | 1.34E+00 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | ALSHADE | 0.00E+00 | 3.98E+00 | 1.99E+00 | 1.79E+00 | 1.32E+00 | 7.81E+04 | 2.00E+05 | 2.00E+05 | 1.81E+05 | 3.94E+04 | 20.00 |
| | EA4eig | 4.01E+00 | 3.57E+01 | 2.19E+01 | 2.18E+01 | 7.27E+00 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | APGSKIMODE | 9.95E−01 | 4.97E+00 | 2.98E+00 | 3.12E+00 | 8.95E−01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | DA2MODE | 0.00E+00 | 1.99E+00 | 9.95E−01 | 6.63E−01 | 6.58E−01 | 1.43E+05 | 2.00E+05 | 2.00E+05 | 1.79E+05 | 2.60E+04 | 40.00 |
| | ABC | 2.44E−03 | 1.91E−01 | 5.56E−02 | 6.62E−02 | 5.20E−02 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | GA | 1.60E+01 | 1.06E+03 | 1.30E+02 | 2.23E+02 | 2.39E+02 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | PSO | 5.44E+01 | 4.20E+02 | 1.80E+02 | 2.05E+02 | 1.07E+02 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | DE | 0.00E+00 | 0.00E+00 | 0.00E+00 | **0.00E+00** | 0.00E+00 | 1.13E+04 | 1.87E+04 | 1.22E+04 | 1.25E+04 | 1.35E+03 | 100.00 |
| | SA | 6.65E−01 | 3.09E+00 | 1.97E+00 | 1.88E+00 | 5.92E−01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | TLBO | 0.00E+00 | 1.33E+01 | 6.33E−01 | 1.73E+00 | 2.63E+00 | 2.01E+04 | 2.00E+05 | 2.00E+05 | 1.94E+05 | 3.28E+04 | 3.33 |
| | BAS | 6.48E+02 | 2.69E+03 | 1.47E+03 | 1.56E+03 | 4.24E+02 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | FA | 0.00E+00 | 2.01E−08 | 1.28E−08 | 1.22E−08 | 5.48E−09 | 1.94E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 1.17E+03 | 13.33 |
| | HHO | 1.28E+02 | 1.09E+03 | 5.17E+02 | 5.62E+02 | 2.28E+02 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | GWO | 1.16E−02 | 5.43E+01 | 1.54E+00 | 9.46E+00 | 1.59E+01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| F15 | MFO | 0.00E+00 | 1.09E+03 | 6.32E+01 | 1.39E+02 | 2.18E+02 | 2.02E+04 | 2.00E+05 | 2.00E+05 | 1.94E+05 | 3.28E+04 | 3.33 |
| | WOA | 2.78E+01 | 2.06E+03 | 4.09E+02 | 4.71E+02 | 4.05E+02 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | CMAES | 0.00E+00 | 0.00E+00 | 0.00E+00 | **0.00E+00** | 0.00E+00 | 7.38E+03 | 8.77E+03 | 8.06E+03 | 8.05E+03 | 3.23E+02 | 100.00 |
| | AGSK | 0.00E+00 | 0.00E+00 | 0.00E+00 | **0.00E+00** | 0.00E+00 | 1.24E+05 | 1.33E+05 | 1.28E+05 | 1.28E+05 | 2.27E+03 | 100.00 |
| | HSES | 0.00E+00 | 5.63E−09 | 0.00E+00 | 8.34E−10 | 1.92E−09 | 2.56E+04 | 2.00E+05 | 2.60E+04 | 9.55E+04 | 8.68E+04 | 60.00 |
| | MadDE | 0.00E+00 | 0.00E+00 | 0.00E+00 | **0.00E+00** | 0.00E+00 | 7.83E+04 | 8.56E+04 | 8.26E+04 | 8.28E+04 | 1.80E+03 | 100.00 |
| | IMODE | 0.00E+00 | 0.00E+00 | 0.00E+00 | **0.00E+00** | 0.00E+00 | 1.66E+05 | 1.71E+05 | 1.68E+05 | 1.68E+05 | 1.12E+03 | 100.00 |
| | ALSHADE | 0.00E+00 | 0.00E+00 | 0.00E+00 | **0.00E+00** | 0.00E+00 | 3.87E+04 | 4.29E+04 | 4.15E+04 | 4.13E+04 | 1.03E+03 | 100.00 |
| | EA4eig | 5.19E−06 | 1.97E+01 | 2.05E+00 | 4.11E+00 | 5.18E+00 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | APGSKIMODE | 0.00E+00 | 0.00E+00 | 0.00E+00 | **0.00E+00** | 0.00E+00 | 7.55E+04 | 7.83E+04 | 7.67E+04 | 7.66E+04 | 7.90E+02 | 100.00 |
| | DA2MODE | 0.00E+00 | 0.00E+00 | 0.00E+00 | **0.00E+00** | 0.00E+00 | 3.21E+04 | 3.44E+04 | 3.32E+04 | 3.33E+04 | 6.02E+02 | 100.00 |
| | ABC | 3.97E+04 | 1.83E+06 | 5.30E+05 | 5.53E+05 | 4.27E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | GA | 8.50E+00 | 4.20E+04 | 2.08E+03 | 4.55E+03 | 8.56E+03 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | PSO | 3.19E+01 | 6.12E+03 | 8.70E+02 | 1.53E+03 | 1.66E+03 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | DE | 3.13E−01 | 6.48E−01 | 5.04E−01 | 4.96E−01 | 7.19E−02 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | SA | 5.28E+02 | 7.47E+03 | 4.16E+03 | 4.22E+03 | 2.22E+03 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | TLBO | 7.57E+01 | 5.12E+03 | 1.12E+03 | 1.69E+03 | 1.67E+03 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | BAS | 1.57E+07 | 4.31E+09 | 1.10E+09 | 1.34E+09 | 8.78E+08 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | FA | 3.25E+01 | 6.09E+03 | 2.80E+03 | 2.74E+03 | 2.16E+03 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | HHO | 3.55E+02 | 1.99E+05 | 7.71E+03 | 2.72E+04 | 5.02E+04 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | GWO | 7.73E+01 | 6.31E+03 | 6.23E+03 | 4.33E+03 | 2.51E+03 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| F16 | MFO | 1.40E+01 | 6.35E+03 | 2.18E+03 | 2.92E+03 | 2.46E+03 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | WOA | 1.04E+02 | 6.22E+03 | 1.20E+03 | 1.86E+03 | 2.02E+03 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | CMAES | 4.83E+05 | 1.58E+08 | 8.69E+06 | 3.25E+07 | 4.53E+07 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | AGSK | 1.92E−02 | 4.86E−01 | 2.31E−01 | **2.46E−01** | 1.23E−01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | HSES | 3.73E−03 | 2.09E+00 | 3.02E−01 | 6.34E−01 | 6.14E−01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | MadDE | 2.78E−02 | 4.97E−01 | 2.69E−01 | 2.47E−01 | 1.56E−01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | IMODE | 2.35E−02 | 5.00E−01 | 4.15E−01 | 3.23E−01 | 1.86E−01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | ALSHADE | 1.31E−02 | 4.98E−01 | 2.37E−01 | 2.64E−01 | 1.61E−01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | EA4eig | 8.77E+01 | 1.56E+06 | 3.81E+04 | 1.91E+05 | 3.67E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | APGSKIMODE | 2.48E−03 | 4.76E−01 | 3.56E−01 | 2.79E−01 | 1.78E−01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | DA2MODE | 5.27E−02 | 4.98E−01 | 4.67E−01 | 4.22E−01 | 1.11E−01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | ABC | 2.24E+01 | 2.71E+01 | 2.44E+01 | 2.44E+01 | 9.28E−01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | GA | 6.89E−01 | 2.41E+01 | 2.03E+01 | 1.65E+01 | 7.70E+00 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | PSO | 3.52E+01 | 1.28E+02 | 6.03E+01 | 6.66E+01 | 2.26E+01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | DE | 0.00E+00 | 9.95E−01 | 0.00E+00 | 8.71E−02 | 2.72E−01 | 3.35E+04 | 2.00E+05 | 5.42E+04 | 6.85E+04 | 4.56E+04 | 90.00 |
| | SA | 4.46E+00 | 2.59E+01 | 2.21E+01 | 1.64E+01 | 8.28E+00 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | TLBO | 7.96E−07 | 3.03E+01 | 2.06E+01 | 1.44E+01 | 9.93E+00 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | BAS | 7.86E+01 | 2.69E+02 | 1.46E+02 | 1.57E+02 | 5.35E+01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | FA | 6.25E−01 | 2.46E+01 | 2.07E+01 | 1.45E+01 | 1.00E+01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | HHO | 3.10E+01 | 1.45E+02 | 8.43E+01 | 8.34E+01 | 3.06E+01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | GWO | 8.99E+00 | 5.80E+01 | 2.95E+01 | 3.09E+01 | 1.15E+01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| F17 | MFO | 2.01E+01 | 1.05E+02 | 2.44E+01 | 3.66E+01 | 2.10E+01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | WOA | 2.16E+01 | 8.93E+01 | 4.51E+01 | 4.84E+01 | 1.67E+01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | CMAES | 2.40E+01 | 2.26E+02 | 1.04E+02 | 1.06E+02 | 6.09E+01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | AGSK | 0.00E+00 | 0.00E+00 | 0.00E+00 | **0.00E+00** | 0.00E+00 | 1.70E+05 | 1.87E+05 | 1.77E+05 | 1.78E+05 | 4.32E+03 | 100.00 |
| | HSES | 0.00E+00 | 2.06E+01 | 6.24E−01 | 4.29E+00 | 7.65E+00 | 4.92E+04 | 2.00E+05 | 2.00E+05 | 1.64E+05 | 6.16E+04 | 26.67 |
| | MadDE | 0.00E+00 | 9.95E−01 | 0.00E+00 | 3.32E−02 | 1.82E−01 | 1.65E+05 | 2.00E+05 | 1.76E+05 | 1.80E+05 | 1.12E+04 | 90.00 |
| | IMODE | 0.00E+00 | 2.12E−02 | 8.00E−08 | 7.11E−04 | 3.87E−03 | 1.98E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 6.47E+02 | 36.67 |
| | ALSHADE | 0.00E+00 | 9.95E−01 | 0.00E+00 | 3.32E−02 | 1.82E−01 | 1.34E+05 | 2.00E+05 | 1.66E+05 | 1.65E+05 | 1.39E+04 | 96.67 |
| | EA4eig | 1.76E+01 | 4.91E+01 | 3.65E+01 | 3.59E+01 | 6.48E+00 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | APGSKIMODE | 0.00E+00 | 0.00E+00 | 0.00E+00 | **0.00E+00** | 0.00E+00 | 1.72E+05 | 1.88E+05 | 1.81E+05 | 1.81E+05 | 4.17E+03 | 100.00 |
| | DA2MODE | 0.00E+00 | 9.95E−01 | 0.00E+00 | 1.12E−01 | 2.95E−01 | 1.52E+05 | 2.00E+05 | 1.81E+05 | 1.84E+05 | 1.30E+04 | 70.00 |
| | ABC | 2.31E+01 | 2.94E+01 | 2.56E+01 | 2.58E+01 | 1.45E+00 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | GA | 1.80E+01 | 2.20E+01 | 2.08E+01 | 2.08E+01 | 7.45E−01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | PSO | 1.71E+01 | 2.56E+02 | 2.84E+01 | 5.11E+01 | 5.63E+01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | DE | 4.06E−04 | 2.01E+01 | 1.76E−02 | 8.79E−01 | 3.64E+00 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | SA | 3.03E+00 | 2.46E+01 | 2.38E+01 | 2.13E+01 | 6.43E+00 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | TLBO | 4.82E−01 | 2.70E+01 | 2.11E+01 | 1.64E+01 | 9.27E+00 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | BAS | 2.00E+01 | 5.75E+03 | 3.84E+02 | 6.97E+02 | 1.09E+03 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | FA | 6.49E−02 | 2.24E+01 | 2.02E+01 | 1.60E+01 | 8.56E+00 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | HHO | 2.76E+01 | 6.65E+01 | 3.62E+01 | 3.86E+01 | 9.65E+00 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | GWO | 5.79E+00 | 2.82E+01 | 2.28E+01 | 2.29E+01 | 3.75E+00 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| F18 | MFO | 2.06E+01 | 3.47E+01 | 2.26E+01 | 2.44E+01 | 3.91E+00 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | WOA | 2.23E+01 | 3.99E+01 | 3.02E+01 | 3.01E+01 | 3.97E+00 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | CMAES | 2.86E+01 | 1.77E+02 | 5.55E+01 | 6.83E+01 | 3.50E+01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | AGSK | 1.98E−02 | 1.14E+00 | 3.88E−01 | 4.33E−01 | 2.73E−01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | HSES | 2.00E+01 | 2.18E+01 | 2.04E+01 | 2.05E+01 | 4.12E−01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | MadDE | 1.68E−03 | 7.06E−01 | 1.02E−01 | 1.46E−01 | 1.74E−01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | IMODE | 1.02E−02 | 9.88E−01 | 2.72E−01 | 3.86E−01 | 3.04E−01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | ALSHADE | 6.87E−05 | 6.46E−01 | 3.48E−02 | **9.60E−02** | 1.61E−01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | EA4eig | 1.57E+01 | 3.30E+01 | 2.79E+01 | 2.71E+01 | 3.35E+00 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | APGSKIMODE | 3.77E−04 | 1.02E+00 | 5.01E−02 | 1.41E−01 | 2.50E−01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | DA2MODE | 2.84E−02 | 5.92E−01 | 2.24E−01 | 2.31E−01 | 1.30E−01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |

(*continued on next page*)

**Table B.5** (*continued*).

| Fun | Alg. | Error | | | | | Function evaluations | | | | | SR (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No. | Name | Best | Worst | Median | Mean | SD | Best | Worst | Median | Mean | SD | |
| | ABC | 1.90E+02 | 2.08E+02 | 1.99E+02 | 1.99E+02 | 4.24E+00 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | GA | 2.35E+02 | 3.76E+02 | 2.47E+02 | 2.52E+02 | 2.57E+01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | PSO | 2.74E+02 | 4.02E+02 | 3.31E+02 | 3.31E+02 | 2.97E+01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | DE | 2.29E+02 | 2.29E+02 | 2.29E+02 | 2.29E+02 | 0.00E+00 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | SA | 2.29E+02 | 2.30E+02 | 2.30E+02 | 2.30E+02 | 1.01E−01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | TLBO | 2.29E+02 | 2.29E+02 | 2.29E+02 | 2.29E+02 | 3.68E−13 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | BAS | 5.11E+02 | 1.08E+03 | 6.79E+02 | 7.14E+02 | 1.43E+02 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | FA | 2.29E+02 | 2.29E+02 | 2.29E+02 | 2.29E+02 | 4.10E−10 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | HHO | 2.32E+02 | 4.35E+02 | 3.86E+02 | 3.75E+02 | 4.60E+01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | GWO | 2.29E+02 | 3.42E+02 | 2.54E+02 | 2.60E+02 | 3.01E+01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| F19 | MFO | 2.29E+02 | 3.27E+02 | 2.30E+02 | 2.41E+02 | 2.97E+01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | WOA | 2.29E+02 | 3.76E+02 | 2.29E+02 | 2.36E+02 | 2.77E+01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | CMAES | 2.31E+02 | 3.99E+02 | 2.37E+02 | 2.55E+02 | 4.35E+01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | AGSK | 2.29E+02 | 2.29E+02 | 2.29E+02 | 2.29E+02 | 0.00E+00 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | HSES | 2.29E+02 | 2.29E+02 | 2.29E+02 | 2.29E+02 | 1.11E−04 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | MadDE | 2.29E+02 | 2.29E+02 | 2.29E+02 | 2.29E+02 | 0.00E+00 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | IMODE | 2.29E+02 | 2.29E+02 | 2.29E+02 | 2.29E+02 | 0.00E+00 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | ALSHADE | 2.29E+02 | 2.29E+02 | 2.29E+02 | 2.29E+02 | 0.00E+00 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | EA4eig | 2.04E+02 | 2.47E+02 | 2.29E+02 | 2.25E+02 | 1.27E+01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | APGSKIMODE | 2.29E+02 | 2.29E+02 | 2.29E+02 | 2.29E+02 | 0.00E+00 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | DA2MODE | 1.86E+02 | 1.86E+02 | 1.86E+02 | **1.86E+02** | 0.00E+00 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | ABC | 1.01E+02 | 1.22E+02 | 1.08E+02 | 1.09E+02 | 4.85E+00 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | GA | 1.00E+02 | 2.40E+02 | 1.01E+02 | 1.39E+02 | 5.94E+01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | PSO | 1.01E+02 | 1.03E+03 | 2.23E+02 | 2.41E+02 | 1.85E+02 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | DE | 1.00E+02 | 2.04E+02 | 1.00E+02 | 1.07E+02 | 2.60E+01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | SA | 1.00E+02 | 2.18E+02 | 1.00E+02 | 1.27E+02 | 4.96E+01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | TLBO | 1.00E+02 | 2.31E+02 | 1.00E+02 | 1.30E+02 | 5.06E+01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | BAS | 1.25E+02 | 2.58E+03 | 1.19E+03 | 1.23E+03 | 6.90E+02 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | FA | 1.00E+02 | 2.21E+02 | 1.00E+02 | 1.12E+02 | 3.54E+01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | HHO | 1.01E+02 | 1.05E+03 | 1.02E+02 | 1.90E+02 | 1.77E+02 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | GWO | 1.00E+02 | 2.19E+02 | 2.10E+02 | 1.68E+02 | 5.60E+01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| F20 | MFO | 1.00E+02 | 2.39E+02 | 1.01E+02 | 1.34E+02 | 5.59E+01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | WOA | 1.00E+02 | 6.50E+02 | 1.01E+02 | 1.80E+02 | 1.13E+02 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | CMAES | 1.22E+02 | 1.86E+03 | 4.20E+02 | 7.64E+02 | 6.55E+02 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | AGSK | 1.00E+02 | 1.00E+02 | 1.00E+02 | 1.00E+02 | 3.22E−02 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | HSES | 1.00E+02 | 2.07E+02 | 1.37E+02 | 1.48E+02 | 4.84E+01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | MadDE | 1.00E+02 | 1.00E+02 | 1.00E+02 | 1.00E+02 | 3.60E−02 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | IMODE | 1.00E+02 | 1.00E+02 | 1.00E+02 | 1.00E+02 | 3.39E−02 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | ALSHADE | 1.00E+02 | 1.00E+02 | 1.00E+02 | **1.00E+02** | 3.05E−02 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | EA4eig | 1.00E+02 | 1.09E+02 | 1.01E+02 | 1.01E+02 | 1.48E+00 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | APGSKIMODE | 1.00E+02 | 1.00E+02 | 1.00E+02 | 1.00E+02 | 2.70E−02 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | DA2MODE | 1.00E+02 | 1.00E+02 | 1.00E+02 | 1.00E+02 | 3.28E−02 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | ABC | 6.26E−02 | 9.89E+00 | 4.26E−01 | 1.08E+00 | 1.98E+00 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | GA | 2.76E+00 | 3.19E+02 | 1.51E+02 | 1.49E+02 | 1.17E+02 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | PSO | 1.18E+02 | 7.39E+02 | 1.76E+02 | 2.76E+02 | 1.85E+02 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | DE | 0.00E+00 | 3.00E+02 | 0.00E+00 | 4.56E+01 | 8.12E+01 | 1.46E+04 | 2.00E+05 | 1.58E+04 | 6.47E+04 | 8.30E+04 | 73.33 |
| | SA | 1.39E+01 | 3.63E+01 | 2.35E+01 | 2.48E+01 | 5.78E+00 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | TLBO | 0.00E+00 | 4.00E+02 | 0.00E+00 | 8.43E+01 | 1.15E+02 | 1.85E+04 | 2.00E+05 | 2.95E+04 | 1.05E+05 | 9.07E+04 | 53.33 |
| | BAS | 7.84E+02 | 4.11E+03 | 2.52E+03 | 2.53E+03 | 9.41E+02 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | FA | 1.03E−03 | 4.00E+02 | 1.79E−03 | 3.84E+01 | 8.88E+01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | HHO | 6.15E+01 | 6.70E+02 | 1.56E+02 | 2.43E+02 | 1.75E+02 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | GWO | 1.07E−01 | 7.58E+02 | 1.50E+02 | 2.27E+02 | 1.88E+02 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| F21 | MFO | 0.00E+00 | 6.68E+02 | 1.67E+02 | 2.00E+02 | 1.56E+02 | 2.75E+04 | 2.00E+05 | 2.00E+05 | 1.83E+05 | 5.22E+04 | 10.00 |
| | WOA | 3.92E−01 | 6.04E+02 | 1.51E+02 | 2.06E+02 | 1.53E+02 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | CMAES | 2.19E+02 | 1.02E+03 | 3.00E+02 | 4.24E+02 | 2.48E+02 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | AGSK | 0.00E+00 | 0.00E+00 | 0.00E+00 | **0.00E+00** | 0.00E+00 | 1.22E+05 | 1.25E+05 | 1.23E+05 | 1.23E+05 | 8.71E+02 | 100.00 |
| | HSES | 0.00E+00 | 3.00E+02 | 0.00E+00 | 3.00E+01 | 9.15E+01 | 3.34E+04 | 2.00E+05 | 3.57E+04 | 5.18E+04 | 5.02E+04 | 90.00 |
| | MadDE | 0.00E+00 | 0.00E+00 | 0.00E+00 | **0.00E+00** | 0.00E+00 | 1.04E+05 | 1.10E+05 | 1.07E+05 | 1.07E+05 | 1.48E+03 | 100.00 |
| | IMODE | 0.00E+00 | 0.00E+00 | 0.00E+00 | **0.00E+00** | 0.00E+00 | 1.79E+05 | 1.81E+05 | 1.80E+05 | 1.80E+05 | 6.44E+02 | 100.00 |
| | ALSHADE | 0.00E+00 | 0.00E+00 | 0.00E+00 | **0.00E+00** | 0.00E+00 | 5.82E+04 | 6.23E+04 | 6.06E+04 | 6.05E+04 | 9.51E+02 | 100.00 |
| | EA4eig | 2.75E−03 | 1.57E+02 | 5.44E+01 | 6.36E+01 | 5.08E+01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | APGSKIMODE | 0.00E+00 | 0.00E+00 | 0.00E+00 | **0.00E+00** | 0.00E+00 | 9.64E+04 | 1.01E+05 | 9.83E+04 | 9.87E+04 | 1.28E+03 | 100.00 |
| | DA2MODE | 0.00E+00 | 0.00E+00 | 0.00E+00 | **0.00E+00** | 0.00E+00 | 5.26E+04 | 5.52E+04 | 5.36E+04 | 5.37E+04 | 6.09E+02 | 100.00 |
| | ABC | 1.83E+02 | 2.00E+02 | 2.00E+02 | 1.98E+02 | 4.53E+00 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | GA | 1.65E+02 | 1.94E+02 | 1.72E+02 | 1.74E+02 | 7.77E+00 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | PSO | 2.02E+02 | 4.33E+02 | 2.97E+02 | 3.07E+02 | 6.58E+01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | DE | 1.59E+02 | 1.64E+02 | 1.63E+02 | 1.62E+02 | 1.10E+00 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | SA | 1.61E+02 | 1.64E+02 | 1.63E+02 | 1.62E+02 | 8.61E−01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | TLBO | 1.59E+02 | 1.76E+02 | 1.65E+02 | 1.65E+02 | 2.79E+00 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | BAS | 2.77E+02 | 1.07E+03 | 4.93E+02 | 5.25E+02 | 1.65E+02 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | FA | 1.59E+02 | 1.67E+02 | 1.64E+02 | 1.64E+02 | 1.89E+00 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | HHO | 1.84E+02 | 4.27E+02 | 2.50E+02 | 2.58E+02 | 5.24E+01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | GWO | 1.60E+02 | 1.97E+02 | 1.64E+02 | 1.68E+02 | 9.41E+00 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| F22 | MFO | 1.61E+02 | 1.74E+02 | 1.64E+02 | 1.65E+02 | 2.69E+00 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | WOA | 1.61E+02 | 2.72E+02 | 1.70E+02 | 1.81E+02 | 2.68E+01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | CMAES | 1.71E+02 | 1.92E+02 | 1.76E+02 | 1.78E+02 | 6.00E+00 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | AGSK | 1.59E+02 | 1.60E+02 | 1.59E+02 | 1.59E+02 | 3.68E−01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | HSES | 1.65E+02 | 1.68E+02 | 1.67E+02 | 1.67E+02 | 6.39E−01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | MadDE | 1.59E+02 | 1.63E+02 | 1.59E+02 | 1.60E+02 | 1.34E+00 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | IMODE | 1.59E+02 | 1.64E+02 | 1.63E+02 | 1.62E+02 | 1.28E+00 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | ALSHADE | 1.59E+02 | 1.65E+02 | 1.61E+02 | 1.61E+02 | 1.58E+00 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | EA4eig | 1.58E+02 | 1.72E+02 | 1.65E+02 | 1.65E+02 | 3.47E+00 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | APGSKIMODE | 1.59E+02 | 1.63E+02 | 1.59E+02 | 1.60E+02 | 1.57E+00 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | DA2MODE | 1.45E+02 | 1.46E+02 | 1.46E+02 | **1.46E+02** | 1.40E−01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |

**Table B.6**
The results metrics for the error and function evaluation metrics for 21 algorithms, CEC2020-2022 (F1-F3), (20 Dim).

| Fun | Alg. | Error | | | | | Function evaluations | | | | | SR (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No. | Name | Best | Worst | Median | Mean | SD | Best | Worst | Median | Mean | SD | |
| | ABC | 9.46E+00 | 1.11E+04 | 2.06E+03 | 2.89E+03 | 2.78E+03 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | GA | 1.24E+04 | 2.66E+05 | 5.38E+04 | 7.44E+04 | 6.42E+04 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | PSO | 2.18E+09 | 1.54E+10 | 6.59E+09 | 7.57E+09 | 3.60E+09 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | DE | 0.00E+00 | 0.00E+00 | 0.00E+00 | **0.00E+00** | 0.00E+00 | 7.04E+04 | 9.95E+04 | 7.64E+04 | 7.80E+04 | 5.99E+03 | 100.00 |
| | SA | 6.52E+05 | 2.40E+06 | 1.62E+06 | 1.60E+06 | 4.76E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | TLBO | 8.13E−01 | 3.02E+03 | 2.92E+02 | 5.56E+02 | 7.58E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | BAS | 3.82E+10 | 8.64E+10 | 6.37E+10 | 6.46E+10 | 1.12E+10 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | FA | 4.41E+00 | 1.17E+04 | 1.88E+03 | 3.09E+03 | 3.57E+03 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | HHO | 2.44E+07 | 4.97E+08 | 1.59E+08 | 1.70E+08 | 1.05E+08 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | GWO | 1.98E+02 | 3.07E+09 | 4.63E+08 | 7.00E+08 | 8.51E+08 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| F1 | MFO | 1.21E+04 | 1.64E+10 | 1.71E+09 | 2.73E+09 | 3.32E+09 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | WOA | 6.02E+03 | 3.33E+04 | 1.36E+04 | 1.42E+04 | 5.30E+03 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | CMAES | 2.13E+02 | 2.17E+10 | 9.82E+09 | 8.46E+09 | 7.70E+09 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | AGSK | 0.00E+00 | 0.00E+00 | 0.00E+00 | **0.00E+00** | 0.00E+00 | 3.36E+05 | 3.43E+05 | 3.40E+05 | 3.40E+05 | 1.84E+03 | 100.00 |
| | HSES | 0.00E+00 | 0.00E+00 | 0.00E+00 | **0.00E+00** | 0.00E+00 | 4.70E+04 | 5.04E+04 | 4.86E+04 | 4.86E+04 | 7.72E+02 | 100.00 |
| | MadDE | 0.00E+00 | 0.00E+00 | 0.00E+00 | **0.00E+00** | 0.00E+00 | 3.89E+05 | 3.96E+05 | 3.93E+05 | 3.93E+05 | 1.73E+03 | 100.00 |
| | IMODE | 4.19E−06 | 1.32E−04 | 2.26E−05 | 3.03E−05 | 2.69E−05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | ALSHADE | 0.00E+00 | 0.00E+00 | 0.00E+00 | **0.00E+00** | 0.00E+00 | 1.23E+05 | 1.34E+05 | 1.28E+05 | 1.28E+05 | 2.93E+03 | 100.00 |
| | EA4eig | 2.03E+06 | 5.32E+08 | 1.50E+08 | 1.91E+08 | 1.54E+08 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | APGSKIMODE | 0.00E+00 | 0.00E+00 | 0.00E+00 | **0.00E+00** | 0.00E+00 | 2.78E+05 | 2.82E+05 | 2.80E+05 | 2.80E+05 | 1.10E+03 | 100.00 |
| | DA2MODE | 0.00E+00 | 0.00E+00 | 0.00E+00 | **0.00E+00** | 0.00E+00 | 9.34E+04 | 1.04E+05 | 9.77E+04 | 9.79E+04 | 2.63E+03 | 100.00 |
| | ABC | 3.51E+03 | 4.49E+03 | 4.17E+03 | 4.16E+03 | 2.37E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | GA | 1.12E+01 | 7.65E+02 | 4.08E+02 | 4.11E+02 | 2.14E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | PSO | 1.38E+03 | 3.11E+03 | 2.35E+03 | 2.26E+03 | 5.07E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | DE | 2.68E+01 | 1.59E+03 | 1.17E+03 | 1.06E+03 | 4.18E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | SA | 4.84E+01 | 8.39E+02 | 3.39E+02 | 3.85E+02 | 2.26E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | TLBO | 4.89E+02 | 2.03E+03 | 9.30E+02 | 9.85E+02 | 3.02E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | BAS | 4.68E+03 | 6.21E+03 | 5.81E+03 | 5.71E+03 | 3.43E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | FA | 3.56E+02 | 2.30E+03 | 1.28E+03 | 1.26E+03 | 4.38E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | HHO | 1.67E+03 | 3.83E+03 | 2.89E+03 | 2.86E+03 | 5.31E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | GWO | 5.11E+02 | 2.16E+03 | 1.40E+03 | 1.36E+03 | 3.92E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| F2 | MFO | 5.87E+02 | 3.00E+03 | 2.14E+03 | 2.05E+03 | 5.65E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | WOA | 1.35E+03 | 3.43E+03 | 2.56E+03 | 2.42E+03 | 5.25E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | CMAES | 3.96E+03 | 5.10E+03 | 4.67E+03 | 4.64E+03 | 2.67E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | AGSK | 4.89E+01 | 2.78E+02 | 1.53E+02 | 1.53E+02 | 5.78E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | HSES | 3.63E+00 | 5.96E+02 | 1.76E+02 | 1.79E+02 | 1.66E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | MadDE | 1.56E−01 | 1.26E+02 | 5.15E+00 | 2.13E+01 | 4.15E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | IMODE | 1.27E+02 | 6.71E+02 | 3.84E+02 | 4.15E+02 | 1.48E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | ALSHADE | 9.37E−02 | 1.34E+01 | 3.51E+00 | 3.84E+00 | 2.90E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | EA4eig | 2.86E+03 | 3.78E+03 | 3.50E+03 | 3.46E+03 | 2.34E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | APGSKIMODE | 2.81E−01 | 1.30E+02 | 8.77E+00 | 1.80E+01 | 3.06E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | DA2MODE | 1.59E−01 | 7.82E+00 | 2.10E+00 | **2.26E+00** | 1.83E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | ABC | 1.10E+02 | 1.44E+02 | 1.30E+02 | 1.29E+02 | 8.00E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | GA | 2.51E+01 | 5.25E+01 | 3.77E+01 | 3.92E+01 | 5.78E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | PSO | 8.41E+01 | 2.26E+02 | 1.45E+02 | 1.53E+02 | 3.30E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | DE | 4.62E+01 | 6.56E+01 | 5.88E+01 | 5.89E+01 | 5.23E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | SA | 3.50E+01 | 7.45E+01 | 5.84E+01 | 5.63E+01 | 8.62E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | TLBO | 5.30E+01 | 1.32E+02 | 7.92E+01 | 8.10E+01 | 1.72E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | BAS | 1.07E+03 | 1.84E+03 | 1.41E+03 | 1.46E+03 | 2.07E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | FA | 3.23E+01 | 7.49E+01 | 4.41E+01 | 4.57E+01 | 1.04E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | HHO | 2.00E+02 | 3.60E+02 | 2.91E+02 | 2.85E+02 | 3.91E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | GWO | 4.25E+01 | 9.62E+01 | 6.62E+01 | 6.80E+01 | 1.39E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| F3 | MFO | 4.81E+01 | 2.67E+02 | 9.53E+01 | 1.23E+02 | 6.54E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | WOA | 1.43E+02 | 3.36E+02 | 2.04E+02 | 2.12E+02 | 4.32E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | CMAES | 1.33E+01 | 4.31E+01 | 3.13E+01 | 3.21E+01 | 5.83E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | AGSK | 2.20E+01 | 2.85E+01 | 2.51E+01 | 2.54E+01 | 1.53E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | HSES | 2.05E+01 | 2.68E+01 | 2.35E+01 | 2.34E+01 | 1.58E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | MadDE | 2.12E+01 | 3.07E+01 | 2.49E+01 | 2.56E+01 | 2.37E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | IMODE | 2.65E+01 | 4.28E+01 | 3.74E+01 | 3.66E+01 | 4.36E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | ALSHADE | 2.04E+01 | 2.24E+01 | 2.10E+01 | **2.11E+01** | 4.86E−01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | EA4eig | 1.20E+02 | 1.69E+02 | 1.47E+02 | 1.45E+02 | 1.07E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | APGSKIMODE | 2.18E+01 | 2.51E+01 | 2.33E+01 | 2.33E+01 | 9.10E−01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | DA2MODE | 2.04E+01 | 2.51E+01 | 2.13E+01 | 2.18E+01 | 1.32E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | ABC | 7.80E+00 | 1.18E+01 | 1.03E+01 | 1.00E+01 | 1.13E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | GA | 1.03E+00 | 4.20E+01 | 5.31E+00 | 7.53E+00 | 8.11E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | PSO | 4.65E+02 | 6.93E+04 | 6.67E+03 | 1.39E+04 | 1.53E+04 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | DE | 4.17E+00 | 6.92E+00 | 5.72E+00 | 5.70E+00 | 6.61E−01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | SA | 2.77E+00 | 5.30E+00 | 4.08E+00 | 4.09E+00 | 6.57E−01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | TLBO | 2.84E+00 | 4.99E+01 | 1.28E+01 | 1.47E+01 | 9.18E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | BAS | 1.47E+06 | 4.35E+07 | 1.02E+07 | 1.24E+07 | 9.64E+06 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | FA | 8.78E−01 | 3.14E+00 | 1.79E+00 | 1.95E+00 | 5.83E−01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | HHO | 2.07E+01 | 2.10E+03 | 6.68E+01 | 1.77E+02 | 4.00E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | GWO | 1.76E+00 | 1.33E+03 | 8.13E+00 | 6.15E+01 | 2.40E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| F4 | MFO | 7.03E+00 | 3.74E+05 | 3.02E+03 | 2.42E+04 | 7.14E+04 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | WOA | 5.79E+00 | 9.07E+01 | 2.37E+01 | 2.92E+01 | 1.75E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | CMAES | 3.67E+03 | 1.46E+05 | 3.21E+04 | 4.94E+04 | 3.86E+04 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | AGSK | 1.29E+00 | 2.08E+00 | 1.66E+00 | 1.64E+00 | 1.96E−01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | HSES | 1.23E+00 | 2.76E+00 | 1.81E+00 | 1.87E+00 | 4.02E−01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | MadDE | 7.06E−01 | 1.86E+00 | 1.17E+00 | 1.19E+00 | 2.46E−01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | IMODE | 1.23E+00 | 3.70E+00 | 1.94E+00 | 2.05E+00 | 5.75E−01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | ALSHADE | 2.99E−01 | 6.94E−01 | 6.05E−01 | **5.93E−01** | 8.00E−02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | EA4eig | 1.23E+01 | 2.26E+01 | 1.51E+01 | 1.59E+01 | 2.93E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | APGSKIMODE | 8.18E−01 | 1.42E+00 | 1.05E+00 | 1.06E+00 | 1.49E−01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | DA2MODE | 5.46E−01 | 8.23E−01 | 6.77E−01 | 6.79E−01 | 7.27E−02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |

(*continued on next page*)

**Table B.6** (*continued*).

| Fun | Alg. | Error | | | | | Function evaluations | | | | | SR (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No. | Name | Best | Worst | Median | Mean | SD | Best | Worst | Median | Mean | SD | |
| | ABC | 5.43E+05 | 5.69E+06 | 2.45E+06 | 2.59E+06 | 1.14E+06 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | GA | 3.68E+05 | 9.12E+06 | 1.46E+06 | 2.00E+06 | 1.80E+06 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | PSO | 2.25E+05 | 6.28E+06 | 1.51E+06 | 1.80E+06 | 1.45E+06 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | DE | 1.12E+03 | 2.64E+04 | 2.12E+03 | 3.90E+03 | 4.70E+03 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | SA | 4.98E+03 | 1.51E+05 | 3.13E+04 | 4.56E+04 | 3.50E+04 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | TLBO | 1.03E+03 | 7.39E+04 | 2.27E+04 | 2.53E+04 | 1.91E+04 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | BAS | 9.40E+06 | 3.38E+08 | 1.58E+08 | 1.59E+08 | 9.31E+07 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | FA | 2.11E+03 | 2.40E+05 | 5.29E+04 | 7.47E+04 | 6.60E+04 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | HHO | 1.88E+05 | 3.42E+06 | 1.23E+06 | 1.39E+06 | 7.74E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | GWO | 3.54E+04 | 2.34E+06 | 2.44E+05 | 5.31E+05 | 6.53E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| F5 | MFO | 4.59E+03 | 1.61E+07 | 3.57E+05 | 1.54E+06 | 3.39E+06 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | WOA | 2.90E+04 | 2.13E+06 | 3.64E+05 | 5.54E+05 | 5.26E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | CMAES | 1.27E+06 | 3.88E+07 | 1.05E+07 | 1.25E+07 | 8.94E+06 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | AGSK | 1.27E+01 | 4.33E+02 | 2.53E+02 | 2.39E+02 | 1.17E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | HSES | 1.55E+02 | 1.03E+03 | 6.23E+02 | 5.99E+02 | 2.27E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | MadDE | 9.26E+00 | 1.53E+02 | 2.58E+01 | 3.27E+01 | 3.21E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | IMODE | 1.46E+02 | 3.87E+02 | 2.10E+02 | 2.29E+02 | 6.96E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | ALSHADE | 1.20E+00 | 1.41E+02 | 1.79E+01 | 4.56E+01 | 5.26E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | EA4eig | 2.45E+03 | 5.81E+05 | 2.54E+05 | 2.61E+05 | 1.57E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | APGSKIMODE | 1.10E+00 | 1.43E+02 | 1.00E+01 | **1.72E+01** | 3.25E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | DA2MODE | 3.40E+00 | 1.65E+02 | 2.37E+01 | 3.96E+01 | 4.51E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | ABC | 4.53E+02 | 9.58E+02 | 7.91E+02 | 7.71E+02 | 1.14E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | GA | 7.34E−01 | 7.74E+00 | 2.84E+00 | 3.27E+00 | 1.68E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | PSO | 4.71E+02 | 1.68E+03 | 9.87E+02 | 9.56E+02 | 3.01E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | DE | 8.06E−01 | 7.42E+01 | 1.60E+01 | 2.21E+01 | 1.93E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | SA | 3.29E+00 | 1.56E+02 | 2.88E+01 | 5.28E+01 | 5.62E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | TLBO | 1.94E+00 | 4.76E+02 | 1.41E+02 | 1.74E+02 | 1.13E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | BAS | 2.04E+03 | 5.11E+03 | 3.05E+03 | 3.23E+03 | 7.82E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | FA | 3.11E+00 | 4.40E+02 | 1.43E+02 | 1.49E+02 | 1.17E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | HHO | 3.62E+02 | 1.73E+03 | 9.50E+02 | 9.24E+02 | 2.96E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | GWO | 3.26E+01 | 6.77E+02 | 2.68E+02 | 3.12E+02 | 1.67E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| F6 | MFO | 5.34E+01 | 9.81E+02 | 3.96E+02 | 3.99E+02 | 2.20E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | WOA | 7.22E+01 | 1.15E+03 | 5.07E+02 | 5.38E+02 | 2.45E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | CMAES | 9.14E+02 | 1.64E+03 | 1.25E+03 | 1.24E+03 | 2.05E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | AGSK | 5.59E−01 | 1.53E+00 | 1.16E+00 | 1.15E+00 | 2.68E−01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | HSES | 1.93E+00 | 2.19E+02 | 2.39E+00 | 3.70E+01 | 6.11E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | MadDE | 1.08E+00 | 2.53E+00 | 1.97E+00 | 1.93E+00 | 3.92E−01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | IMODE | 1.63E+00 | 3.50E+00 | 2.32E+00 | 2.37E+00 | 3.83E−01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | ALSHADE | 1.15E−01 | 2.31E+00 | 5.73E−01 | **8.18E−01** | 5.63E−01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | EA4eig | 2.69E+02 | 9.75E+02 | 4.45E+02 | 4.67E+02 | 1.39E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | APGSKIMODE | 9.71E−02 | 1.63E+00 | 9.03E−01 | 8.84E−01 | 4.36E−01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | DA2MODE | 6.61E−01 | 3.58E+00 | 1.89E+00 | 1.95E+00 | 6.13E−01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | ABC | 3.80E+05 | 1.92E+06 | 8.02E+05 | 8.71E+05 | 4.35E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | GA | 7.13E+04 | 3.73E+06 | 1.11E+06 | 1.30E+06 | 1.00E+06 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | PSO | 9.56E+04 | 8.83E+06 | 7.02E+05 | 1.14E+06 | 1.64E+06 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | DE | 1.64E+01 | 3.76E+02 | 1.15E+02 | 1.32E+02 | 7.91E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | SA | 2.29E+03 | 3.39E+04 | 1.42E+04 | 1.52E+04 | 9.10E+03 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | TLBO | 8.92E+02 | 1.41E+04 | 3.50E+03 | 4.25E+03 | 2.68E+03 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | BAS | 5.06E+06 | 4.20E+08 | 8.16E+07 | 9.79E+07 | 9.32E+07 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | FA | 1.64E+03 | 1.31E+05 | 1.20E+04 | 2.31E+04 | 2.98E+04 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | HHO | 1.00E+05 | 2.13E+06 | 3.48E+05 | 6.05E+05 | 6.01E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | GWO | 5.38E+03 | 8.37E+05 | 9.11E+04 | 1.48E+05 | 1.99E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| F7 | MFO | 8.04E+03 | 4.90E+06 | 6.69E+04 | 4.15E+05 | 1.05E+06 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | WOA | 2.38E+04 | 9.95E+05 | 2.28E+05 | 3.34E+05 | 2.64E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | CMAES | 9.98E+05 | 2.13E+07 | 4.04E+06 | 5.71E+06 | 5.34E+06 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | AGSK | 1.72E+00 | 9.16E+01 | 3.25E+01 | 3.66E+01 | 2.69E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | HSES | 1.48E+00 | 8.93E+02 | 2.93E+02 | 3.33E+02 | 2.19E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | MadDE | 1.14E+00 | 1.36E+01 | 2.77E+00 | 4.51E+00 | 3.87E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | IMODE | 4.43E+00 | 2.22E+02 | 5.06E+01 | 7.96E+01 | 6.19E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | ALSHADE | 3.64E−01 | 9.87E+00 | 9.72E−01 | **2.06E+00** | 2.63E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | EA4eig | 2.73E+03 | 2.21E+05 | 8.83E+04 | 9.16E+04 | 6.29E+04 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | APGSKIMODE | 2.60E−01 | 9.23E+00 | 9.34E−01 | 2.62E+00 | 3.37E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | DA2MODE | 5.26E−01 | 1.85E+01 | 1.15E+00 | 2.24E+00 | 3.31E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | ABC | 1.42E+03 | 4.37E+03 | 2.89E+03 | 2.96E+03 | 8.62E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | GA | 1.01E+02 | 3.42E+03 | 1.05E+02 | 1.09E+03 | 1.15E+03 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | PSO | 3.30E+02 | 3.85E+03 | 1.39E+03 | 1.83E+03 | 1.26E+03 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | DE | 1.00E+02 | 3.42E+03 | 1.00E+02 | 2.11E+02 | 6.05E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | SA | 1.12E+02 | 7.64E+02 | 1.13E+02 | 1.61E+02 | 1.57E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | TLBO | 1.00E+02 | 1.95E+03 | 1.02E+02 | 1.65E+02 | 3.36E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | BAS | 4.80E+03 | 6.90E+03 | 6.07E+03 | 5.99E+03 | 5.22E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | FA | 1.00E+02 | 1.00E+02 | 1.00E+02 | 1.00E+02 | 3.45E−11 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | HHO | 1.20E+02 | 4.13E+03 | 2.37E+02 | 1.31E+03 | 1.48E+03 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | GWO | 1.09E+02 | 2.52E+03 | 1.83E+02 | 6.49E+02 | 7.94E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| F8 | MFO | 1.75E+02 | 3.88E+03 | 1.99E+03 | 1.89E+03 | 1.31E+03 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | WOA | 1.02E+02 | 4.01E+03 | 2.15E+03 | 1.77E+03 | 1.64E+03 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | CMAES | 1.00E+02 | 4.94E+03 | 4.66E+03 | 3.73E+03 | 1.86E+03 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | AGSK | 1.00E+02 | 1.00E+02 | 1.00E+02 | 1.00E+02 | 2.29E−13 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | HSES | 1.00E+02 | 1.00E+02 | 1.00E+02 | 1.00E+02 | 7.97E−10 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | MadDE | 1.00E+02 | 1.00E+02 | 1.00E+02 | **1.00E+02** | 0.00E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | IMODE | 1.00E+02 | 1.00E+02 | 1.00E+02 | 1.00E+02 | 1.20E−07 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | ALSHADE | 1.00E+02 | 1.00E+02 | 1.00E+02 | **1.00E+02** | 0.00E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | EA4eig | 1.14E+02 | 1.87E+02 | 1.42E+02 | 1.44E+02 | 1.96E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | APGSKIMODE | 1.00E+02 | 1.00E+02 | 1.00E+02 | **1.00E+02** | 8.30E−14 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | DA2MODE | 1.00E+02 | 1.00E+02 | 1.00E+02 | **1.00E+02** | 8.30E−14 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | ABC | 4.92E+02 | 5.28E+02 | 5.21E+02 | 5.19E+02 | 7.17E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | GA | 4.14E+02 | 5.85E+02 | 5.13E+02 | 5.13E+02 | 3.77E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | PSO | 4.70E+02 | 1.17E+03 | 9.12E+02 | 8.92E+02 | 1.29E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | DE | 4.59E+02 | 4.87E+02 | 4.77E+02 | 4.75E+02 | 8.01E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | SA | 4.06E+02 | 4.18E+02 | 4.11E+02 | 4.11E+02 | 2.84E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | TLBO | 4.14E+02 | 4.74E+02 | 4.43E+02 | 4.44E+02 | 1.81E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | BAS | 9.66E+02 | 1.76E+03 | 1.42E+03 | 1.40E+03 | 1.77E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | FA | 4.17E+02 | 4.78E+02 | 4.40E+02 | 4.42E+02 | 1.44E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | HHO | 2.43E+02 | 8.39E+02 | 7.04E+02 | 6.69E+02 | 1.32E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | GWO | 4.13E+02 | 5.22E+02 | 4.46E+02 | 4.53E+02 | 3.11E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| F9 | MFO | 4.44E+02 | 5.60E+02 | 4.90E+02 | 4.91E+02 | 2.25E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | WOA | 4.46E+02 | 7.56E+02 | 5.81E+02 | 5.82E+02 | 7.28E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | CMAES | 5.55E+02 | 6.51E+02 | 6.04E+02 | 6.06E+02 | 2.11E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | AGSK | 1.00E+02 | 4.20E+02 | 1.00E+02 | **1.85E+02** | 1.36E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | HSES | 3.87E+02 | 4.03E+02 | 3.94E+02 | 3.95E+02 | 3.03E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | MadDE | 1.00E+02 | 4.13E+02 | 4.06E+02 | 3.36E+02 | 1.32E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | IMODE | 3.26E+01 | 4.41E+02 | 4.20E+02 | 3.41E+02 | 1.46E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | ALSHADE | 3.97E+02 | 4.09E+02 | 4.02E+02 | 4.03E+02 | 2.33E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | EA4eig | 4.92E+02 | 5.56E+02 | 5.29E+02 | 5.27E+02 | 1.17E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | APGSKIMODE | 8.04E−07 | 4.18E+02 | 1.00E+02 | 2.21E+02 | 1.58E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | DA2MODE | 4.02E+02 | 4.07E+02 | 4.04E+02 | 4.04E+02 | 1.29E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |

(*continued on next page*)

**Table B.6** (*continued*).

| Fun | Alg. | Error | | | | | Function evaluations | | | | | SR (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No. | Name | Best | Worst | Median | Mean | SD | Best | Worst | Median | Mean | SD | |
| | ABC | 4.06E+02 | 4.07E+02 | 4.07E+02 | 4.07E+02 | 5.16E−02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | GA | 4.02E+02 | 5.24E+02 | 4.68E+02 | 4.65E+02 | 3.75E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | PSO | 6.05E+02 | 1.70E+03 | 8.49E+02 | 8.92E+02 | 2.36E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | DE | 4.14E+02 | 4.14E+02 | 4.14E+02 | 4.14E+02 | 2.04E−02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | SA | 4.14E+02 | 4.14E+02 | 4.14E+02 | 4.14E+02 | 4.46E−02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | TLBO | 4.02E+02 | 5.24E+02 | 4.86E+02 | 4.78E+02 | 3.31E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | BAS | 3.03E+03 | 2.19E+04 | 9.51E+03 | 1.06E+04 | 4.56E+03 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | FA | 4.03E+02 | 4.93E+02 | 4.14E+02 | 4.26E+02 | 2.48E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | HHO | 4.89E+02 | 7.09E+02 | 5.39E+02 | 5.44E+02 | 4.13E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | GWO | 4.19E+02 | 5.08E+02 | 4.73E+02 | 4.67E+02 | 2.80E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| F10 | MFO | 4.11E+02 | 1.87E+03 | 4.85E+02 | 5.70E+02 | 2.90E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | WOA | 4.16E+02 | 5.36E+02 | 4.92E+02 | 4.87E+02 | 2.93E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | CMAES | 4.54E+02 | 2.11E+03 | 1.14E+03 | 1.10E+03 | 3.84E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | AGSK | 4.14E+02 | 4.14E+02 | 4.14E+02 | 4.14E+02 | 8.33E−03 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | HSES | 4.14E+02 | 4.86E+02 | 4.14E+02 | 4.29E+02 | 2.85E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | MadDE | 4.14E+02 | 4.14E+02 | 4.14E+02 | 4.14E+02 | 2.98E−03 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | IMODE | 4.92E+02 | 4.94E+02 | 4.93E+02 | 4.93E+02 | 4.51E−01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | ALSHADE | 4.14E+02 | 4.14E+02 | 4.14E+02 | 4.14E+02 | 7.10E−03 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | EA4eig | 4.17E+02 | 5.75E+02 | 4.81E+02 | 4.79E+02 | 4.37E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | APGSKIMODE | 4.14E+02 | 4.14E+02 | 4.14E+02 | 4.14E+02 | 3.35E−04 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | DA2MODE | 4.06E+02 | 4.06E+02 | 4.06E+02 | **4.06E+02** | 5.82E−03 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | ABC | 3.76E+04 | 9.26E+04 | 6.24E+04 | 6.31E+04 | 1.39E+04 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | GA | 4.33E+03 | 4.72E+04 | 1.63E+04 | 1.81E+04 | 9.19E+03 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | PSO | 1.77E+04 | 5.99E+04 | 3.50E+04 | 3.61E+04 | 1.31E+04 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | DE | 0.00E+00 | 0.00E+00 | 0.00E+00 | **0.00E+00** | 0.00E+00 | 2.62E+05 | 3.15E+05 | 2.91E+05 | 2.92E+05 | 1.25E+04 | 100.00 |
| | SA | 2.76E+00 | 9.27E+00 | 6.18E+00 | 6.02E+00 | 1.67E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | TLBO | 0.00E+00 | 0.00E+00 | 0.00E+00 | **0.00E+00** | 0.00E+00 | 7.86E+04 | 1.15E+05 | 9.47E+04 | 9.52E+04 | 7.78E+03 | 100.00 |
| | BAS | 4.75E+04 | 1.31E+11 | 8.47E+05 | 5.96E+09 | 2.40E+10 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | FA | 0.00E+00 | 0.00E+00 | 0.00E+00 | **0.00E+00** | 0.00E+00 | 2.38E+05 | 2.47E+05 | 2.43E+05 | 2.43E+05 | 2.43E+03 | 100.00 |
| | HHO | 1.16E+04 | 7.59E+04 | 3.52E+04 | 3.63E+04 | 1.40E+04 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | GWO | 9.71E+02 | 1.65E+04 | 6.40E+03 | 7.77E+03 | 4.16E+03 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| F11 | MFO | 0.00E+00 | 8.07E+04 | 3.11E+04 | 3.35E+04 | 2.19E+04 | 1.54E+05 | 5.00E+05 | 5.00E+05 | 4.88E+05 | 6.31E+04 | 3.33 |
| | WOA | 1.31E+01 | 1.14E+03 | 1.43E+02 | 1.99E+02 | 2.39E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | CMAES | 4.07E+04 | 1.15E+05 | 7.08E+04 | 7.51E+04 | 2.06E+04 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | AGSK | 0.00E+00 | 0.00E+00 | 0.00E+00 | **0.00E+00** | 0.00E+00 | 4.00E+05 | 4.21E+05 | 4.15E+05 | 4.15E+05 | 4.06E+03 | 100.00 |
| | HSES | 0.00E+00 | 0.00E+00 | 0.00E+00 | **0.00E+00** | 0.00E+00 | 4.06E+04 | 4.30E+04 | 4.18E+04 | 4.18E+04 | 5.59E+02 | 100.00 |
| | MadDE | 0.00E+00 | 0.00E+00 | 0.00E+00 | **0.00E+00** | 0.00E+00 | 2.70E+05 | 2.81E+05 | 2.76E+05 | 2.76E+05 | 2.38E+03 | 100.00 |
| | IMODE | 0.00E+00 | 0.00E+00 | 0.00E+00 | **0.00E+00** | 0.00E+00 | 4.25E+05 | 4.40E+05 | 4.27E+05 | 4.28E+05 | 3.41E+03 | 100.00 |
| | ALSHADE | 0.00E+00 | 0.00E+00 | 0.00E+00 | **0.00E+00** | 0.00E+00 | 1.07E+05 | 1.21E+05 | 1.13E+05 | 1.14E+05 | 3.33E+03 | 100.00 |
| | EA4eig | 9.90E+02 | 4.81E+03 | 2.73E+03 | 2.83E+03 | 9.77E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | APGSKIMODE | 0.00E+00 | 0.00E+00 | 0.00E+00 | **0.00E+00** | 0.00E+00 | 1.95E+05 | 2.08E+05 | 1.98E+05 | 1.99E+05 | 3.34E+03 | 100.00 |
| | DA2MODE | 0.00E+00 | 0.00E+00 | 0.00E+00 | **0.00E+00** | 0.00E+00 | 7.68E+04 | 8.13E+04 | 7.87E+04 | 7.86E+04 | 9.07E+02 | 100.00 |
| | ABC | 1.18E+01 | 1.43E+01 | 1.23E+01 | 1.25E+01 | 5.35E−01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | GA | 9.31E+00 | 9.47E+01 | 4.93E+01 | 5.52E+01 | 1.81E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | PSO | 2.33E+02 | 8.64E+02 | 4.31E+02 | 4.50E+02 | 1.58E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | DE | 1.05E−02 | 4.91E+01 | 4.91E+01 | 4.70E+01 | 8.97E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | SA | 4.50E+01 | 4.51E+01 | 4.51E+01 | 4.51E+01 | 3.07E−02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | TLBO | 1.72E−02 | 6.83E+01 | 4.91E+01 | 4.12E+01 | 2.13E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | BAS | 3.46E+03 | 1.68E+04 | 8.64E+03 | 9.20E+03 | 3.26E+03 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | FA | 4.45E+00 | 7.55E+01 | 4.91E+01 | 4.89E+01 | 1.08E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | HHO | 1.02E+02 | 3.14E+02 | 1.99E+02 | 1.91E+02 | 4.91E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | GWO | 4.54E+01 | 2.82E+02 | 8.41E+01 | 1.01E+02 | 4.95E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| F12 | MFO | 3.98E+01 | 6.19E+02 | 1.05E+02 | 1.46E+02 | 1.27E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | WOA | 4.94E−01 | 1.70E+02 | 7.20E+01 | 7.29E+01 | 3.92E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | CMAES | 2.15E+02 | 1.51E+03 | 6.81E+02 | 7.55E+02 | 3.50E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | AGSK | 4.49E+01 | 4.91E+01 | 4.91E+01 | 4.82E+01 | 1.70E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | HSES | 4.49E+01 | 4.91E+01 | 4.49E+01 | 4.50E+01 | 7.65E−01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | MadDE | 4.91E+01 | 4.91E+01 | 4.91E+01 | 4.91E+01 | 3.54E−14 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | IMODE | 4.91E+01 | 4.91E+01 | 4.91E+01 | 4.91E+01 | 4.06E−12 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | ALSHADE | 4.49E+01 | 4.91E+01 | 4.91E+01 | 4.88E+01 | 1.06E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | EA4eig | 3.92E+01 | 1.55E+02 | 1.01E+02 | 1.00E+02 | 2.89E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | APGSKIMODE | 4.91E+01 | 4.91E+01 | 4.91E+01 | 4.91E+01 | 3.61E−14 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | DA2MODE | 0.00E+00 | 0.00E+00 | 0.00E+00 | **0.00E+00** | 0.00E+00 | 2.06E+05 | 2.32E+05 | 2.21E+05 | 2.21E+05 | 5.01E+03 | 100.00 |
| | ABC | 1.01E−05 | 6.33E−05 | 1.71E−05 | 2.56E−05 | 1.74E−05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | GA | 2.54E−03 | 4.23E−01 | 5.53E−02 | 6.95E−02 | 7.66E−02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | PSO | 4.00E+01 | 7.43E+01 | 5.44E+01 | 5.40E+01 | 8.13E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | DE | 0.00E+00 | 0.00E+00 | 0.00E+00 | **0.00E+00** | 0.00E+00 | 3.24E+04 | 3.71E+04 | 3.43E+04 | 3.45E+04 | 1.07E+03 | 100.00 |
| | SA | 4.55E−01 | 9.95E−01 | 7.30E−01 | 7.11E−01 | 1.44E−01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | TLBO | 6.74E−01 | 1.37E+01 | 4.80E+00 | 5.53E+00 | 3.24E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | BAS | 6.43E+01 | 1.38E+02 | 1.16E+02 | 1.13E+02 | 1.79E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | FA | 0.00E+00 | 0.00E+00 | 0.00E+00 | **0.00E+00** | 0.00E+00 | 4.14E+05 | 4.28E+05 | 4.24E+05 | 4.24E+05 | 2.76E+03 | 100.00 |
| | HHO | 3.94E+01 | 9.05E+01 | 7.04E+01 | 6.92E+01 | 1.13E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | GWO | 6.17E−02 | 1.74E+01 | 2.74E+00 | 4.02E+00 | 4.00E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| F13 | MFO | 9.83E+00 | 4.62E+01 | 2.06E+01 | 2.22E+01 | 8.67E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | WOA | 3.24E+01 | 7.59E+01 | 5.61E+01 | 5.69E+01 | 1.12E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | CMAES | 7.19E−07 | 7.03E+01 | 5.67E+01 | 5.32E+01 | 1.66E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | AGSK | 0.00E+00 | 2.57E−05 | 1.28E−06 | 2.51E−06 | 5.15E−06 | 4.27E+05 | 5.00E+05 | 5.00E+05 | 4.82E+05 | 3.11E+04 | 26.67 |
| | HSES | 0.00E+00 | 0.00E+00 | 0.00E+00 | **0.00E+00** | 0.00E+00 | 4.26E+04 | 7.71E+04 | 4.39E+04 | 5.05E+04 | 1.29E+04 | 100.00 |
| | MadDE | 0.00E+00 | 3.19E−07 | 0.00E+00 | 5.05E−08 | 1.10E−07 | 4.61E+05 | 5.00E+05 | 4.70E+05 | 4.78E+05 | 1.44E+04 | 76.67 |
| | IMODE | 3.41E−04 | 2.27E−03 | 1.05E−03 | 1.08E−03 | 4.87E−04 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | ALSHADE | 0.00E+00 | 0.00E+00 | 0.00E+00 | **0.00E+00** | 0.00E+00 | 1.70E+05 | 1.84E+05 | 1.76E+05 | 1.76E+05 | 3.42E+03 | 100.00 |
| | EA4eig | 4.62E+00 | 1.61E+01 | 1.09E+01 | 1.06E+01 | 2.68E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | APGSKIMODE | 0.00E+00 | 0.00E+00 | 0.00E+00 | **0.00E+00** | 0.00E+00 | 3.77E+05 | 3.87E+05 | 3.82E+05 | 3.82E+05 | 2.39E+03 | 100.00 |
| | DA2MODE | 0.00E+00 | 0.00E+00 | 0.00E+00 | **0.00E+00** | 0.00E+00 | 1.39E+05 | 1.46E+05 | 1.44E+05 | 1.43E+05 | 1.67E+03 | 100.00 |

(*continued on next page*)

**Table B.6** (*continued*).

| Fun | Alg. | Error | | | | | Function evaluations | | | | | SR (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No. | Name | Best | Worst | Median | Mean | SD | Best | Worst | Median | Mean | SD | |
| | ABC | 9.07E+01 | 1.27E+02 | 1.14E+02 | 1.13E+02 | 8.35E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | GA | 3.09E+01 | 1.04E+02 | 6.04E+01 | 6.24E+01 | 1.94E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | PSO | 4.12E+01 | 1.18E+02 | 8.35E+01 | 8.48E+01 | 1.95E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | DE | 6.12E+01 | 9.72E+01 | 8.41E+01 | 8.30E+01 | 7.65E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | SA | 9.83E+00 | 2.65E+01 | 1.95E+01 | 1.92E+01 | 4.08E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | TLBO | 1.89E+01 | 5.57E+01 | 3.48E+01 | 3.68E+01 | 1.02E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | BAS | 2.49E+02 | 3.73E+02 | 3.03E+02 | 3.07E+02 | 3.28E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | FA | 1.39E+01 | 7.52E+01 | 3.84E+01 | 3.92E+01 | 1.37E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | HHO | 5.52E+01 | 1.37E+02 | 1.03E+02 | 1.03E+02 | 1.65E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | GWO | 2.11E+01 | 8.17E+01 | 4.23E+01 | 4.53E+01 | 1.35E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| F14 | MFO | 3.68E+01 | 1.65E+02 | 8.61E+01 | 8.99E+01 | 2.66E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | WOA | 6.67E+01 | 1.78E+02 | 1.11E+02 | 1.24E+02 | 3.16E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | CMAES | 6.96E+00 | 1.91E+02 | 1.74E+01 | 4.77E+01 | 5.31E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | AGSK | 1.84E+01 | 3.76E+01 | 2.69E+01 | 2.64E+01 | 4.77E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | HSES | 9.95E−01 | 8.95E+00 | 3.98E+00 | 4.38E+00 | 2.03E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | MadDE | 1.79E+01 | 3.88E+01 | 2.89E+01 | 2.84E+01 | 4.24E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | IMODE | 2.09E+01 | 5.45E+01 | 3.73E+01 | 3.70E+01 | 7.25E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | ALSHADE | 0.00E+00 | 6.96E+00 | 2.49E+00 | **2.55E+00** | 1.91E+00 | 2.45E+05 | 5.00E+05 | 5.00E+05 | 4.72E+05 | 6.95E+04 | 20.00 |
| | EA4eig | 7.98E+01 | 1.10E+02 | 9.73E+01 | 9.69E+01 | 7.93E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | APGSKIMODE | 8.95E+00 | 2.39E+01 | 1.59E+01 | 1.64E+01 | 3.31E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | DA2MODE | 9.95E−01 | 4.98E+00 | 3.48E+00 | 3.28E+00 | 1.28E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | ABC | 5.62E−06 | 9.25E−03 | 5.91E−05 | 4.01E−04 | 1.68E−03 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | GA | 2.42E+02 | 4.20E+03 | 1.06E+03 | 1.19E+03 | 8.79E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | PSO | 6.21E+02 | 2.37E+03 | 1.38E+03 | 1.37E+03 | 4.09E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | DE | 0.00E+00 | 0.00E+00 | 0.00E+00 | **0.00E+00** | 0.00E+00 | 2.42E+04 | 3.23E+04 | 2.77E+04 | 2.74E+04 | 1.93E+03 | 100.00 |
| | SA | 4.56E−01 | 8.23E−01 | 6.81E−01 | 6.67E−01 | 8.50E−02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | TLBO | 1.91E+00 | 3.22E+02 | 3.20E+01 | 5.81E+01 | 6.51E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | BAS | 3.52E+03 | 9.95E+03 | 7.17E+03 | 7.09E+03 | 1.68E+03 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | FA | 0.00E+00 | 2.19E+01 | 0.00E+00 | 7.30E−01 | 4.00E+00 | 2.21E+05 | 5.00E+05 | 2.25E+05 | 2.33E+05 | 5.04E+04 | 96.67 |
| | HHO | 1.55E+03 | 3.31E+03 | 2.20E+03 | 2.34E+03 | 5.02E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | GWO | 9.74E+00 | 8.73E+02 | 1.38E+02 | 2.00E+02 | 1.81E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| F15 | MFO | 6.57E+02 | 4.65E+03 | 2.03E+03 | 2.09E+03 | 1.01E+03 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | WOA | 1.13E+03 | 4.97E+03 | 2.31E+03 | 2.35E+03 | 8.53E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | CMAES | 0.00E+00 | 0.00E+00 | 0.00E+00 | **0.00E+00** | 0.00E+00 | 1.53E+04 | 1.73E+04 | 1.63E+04 | 1.63E+04 | 4.65E+02 | 100.00 |
| | AGSK | 0.00E+00 | 8.95E−02 | 0.00E+00 | 5.97E−03 | 2.27E−02 | 3.52E+05 | 5.00E+05 | 3.60E+05 | 3.69E+05 | 3.61E+04 | 93.33 |
| | HSES | 0.00E+00 | 0.00E+00 | 0.00E+00 | **0.00E+00** | 0.00E+00 | 2.86E+04 | 3.01E+04 | 2.93E+04 | 2.92E+04 | 3.53E+02 | 100.00 |
| | MadDE | 0.00E+00 | 0.00E+00 | 0.00E+00 | **0.00E+00** | 0.00E+00 | 3.58E+05 | 3.69E+05 | 3.64E+05 | 3.64E+05 | 2.56E+03 | 100.00 |
| | IMODE | 0.00E+00 | 4.01E−03 | 1.39E−04 | 5.38E−04 | 1.03E−03 | 4.97E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.48E+02 | 10.00 |
| | ALSHADE | 0.00E+00 | 0.00E+00 | 0.00E+00 | **0.00E+00** | 0.00E+00 | 8.55E+04 | 9.29E+04 | 8.97E+04 | 8.96E+04 | 1.84E+03 | 100.00 |
| | EA4eig | 1.84E+01 | 1.09E+02 | 5.71E+01 | 5.60E+01 | 2.42E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | APGSKIMODE | 0.00E+00 | 0.00E+00 | 0.00E+00 | **0.00E+00** | 0.00E+00 | 2.62E+05 | 2.71E+05 | 2.65E+05 | 2.66E+05 | 2.29E+03 | 100.00 |
| | DA2MODE | 0.00E+00 | 0.00E+00 | 0.00E+00 | **0.00E+00** | 0.00E+00 | 6.96E+04 | 7.34E+04 | 7.11E+04 | 7.11E+04 | 8.57E+02 | 100.00 |
| | ABC | 1.52E+07 | 1.77E+08 | 5.98E+07 | 6.20E+07 | 3.58E+07 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | GA | 3.55E+02 | 3.11E+04 | 8.62E+03 | 9.81E+03 | 7.96E+03 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | PSO | 1.11E+02 | 1.82E+08 | 1.93E+04 | 7.52E+06 | 3.31E+07 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | DE | 2.68E+03 | 1.43E+05 | 1.54E+04 | 2.72E+04 | 3.32E+04 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | SA | 1.18E+04 | 5.81E+04 | 3.03E+04 | 3.13E+04 | 1.20E+04 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | TLBO | 8.45E+01 | 1.14E+04 | 1.71E+03 | 2.89E+03 | 3.32E+03 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | BAS | 3.67E+09 | 1.38E+10 | 8.71E+09 | 8.53E+09 | 2.99E+09 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | FA | 7.94E+01 | 1.70E+04 | 2.54E+03 | 4.58E+03 | 5.18E+03 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | HHO | 1.75E+05 | 2.17E+06 | 5.68E+05 | 8.14E+05 | 5.47E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | GWO | 1.92E+02 | 5.52E+06 | 3.74E+03 | 5.07E+05 | 1.48E+06 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| F16 | MFO | 2.97E+02 | 4.32E+07 | 1.88E+04 | 7.40E+06 | 1.33E+07 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | WOA | 2.42E+02 | 2.37E+04 | 5.71E+03 | 6.64E+03 | 6.02E+03 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | CMAES | 5.24E+06 | 1.29E+09 | 2.59E+08 | 3.83E+08 | 3.56E+08 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | AGSK | 5.31E−01 | 3.70E+01 | 1.30E+01 | 1.57E+01 | 9.35E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | HSES | 1.19E+00 | 1.55E+01 | 4.80E+00 | 5.23E+00 | 3.29E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | MadDE | 1.92E−01 | 1.49E+00 | 4.29E−01 | **4.31E−01** | 2.19E−01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | IMODE | 8.34E+00 | 4.61E+01 | 2.92E+01 | 2.85E+01 | 7.37E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | ALSHADE | 2.06E−01 | 1.48E+00 | 4.44E−01 | 4.78E−01 | 2.66E−01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | EA4eig | 7.73E+04 | 3.99E+07 | 1.50E+07 | 1.57E+07 | 1.25E+07 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | APGSKIMODE | 1.74E−01 | 1.48E+00 | 4.55E−01 | 5.50E−01 | 3.63E−01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | DA2MODE | 2.81E−01 | 2.28E+00 | 4.77E−01 | 5.62E−01 | 4.14E−01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | ABC | 8.47E+01 | 1.42E+02 | 1.17E+02 | 1.15E+02 | 1.23E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | GA | 2.07E+01 | 1.93E+02 | 6.78E+01 | 7.75E+01 | 4.18E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | PSO | 6.83E+01 | 3.02E+02 | 1.55E+02 | 1.59E+02 | 6.00E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | DE | 1.05E+01 | 2.90E+01 | 2.13E+01 | 2.08E+01 | 4.37E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | SA | 2.38E+01 | 1.72E+02 | 2.94E+01 | 4.76E+01 | 4.09E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | TLBO | 2.62E+01 | 8.69E+01 | 4.47E+01 | 4.73E+01 | 1.47E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | BAS | 2.85E+02 | 7.05E+02 | 4.87E+02 | 4.93E+02 | 1.16E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | FA | 2.30E+00 | 1.17E+02 | 5.29E+01 | 5.00E+01 | 2.34E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | HHO | 9.63E+01 | 2.77E+02 | 1.72E+02 | 1.77E+02 | 4.78E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | GWO | 2.51E+01 | 1.42E+02 | 5.26E+01 | 6.53E+01 | 3.05E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| F17 | MFO | 4.63E+01 | 2.11E+02 | 1.08E+02 | 1.14E+02 | 4.89E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | WOA | 6.05E+01 | 2.60E+02 | 1.56E+02 | 1.62E+02 | 4.90E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | CMAES | 7.26E+01 | 3.46E+02 | 2.20E+02 | 2.24E+02 | 6.22E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | AGSK | 1.90E+00 | 2.36E+01 | 2.17E+01 | 2.00E+01 | 4.67E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | HSES | 5.29E+00 | 4.52E+01 | 2.71E+01 | 2.52E+01 | 1.07E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | MadDE | 3.30E+00 | 2.75E+01 | 2.22E+01 | 2.06E+01 | 6.09E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | IMODE | 2.42E+01 | 4.15E+01 | 3.26E+01 | 3.23E+01 | 4.98E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | ALSHADE | 3.12E−01 | 2.26E+01 | 3.13E+00 | **9.17E+00** | 9.14E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | EA4eig | 5.51E+01 | 9.44E+01 | 7.72E+01 | 7.61E+01 | 9.21E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | APGSKIMODE | 1.99E+00 | 2.26E+01 | 2.11E+01 | 1.65E+01 | 8.28E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | DA2MODE | 2.01E+00 | 2.09E+01 | 1.70E+01 | 1.27E+01 | 8.06E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | ABC | 5.97E+01 | 1.73E+02 | 1.05E+02 | 1.11E+02 | 2.77E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | GA | 2.06E+01 | 1.43E+02 | 2.21E+01 | 3.16E+01 | 3.05E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | PSO | 2.62E+01 | 7.04E+02 | 7.72E+01 | 1.68E+02 | 1.60E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | DE | 1.83E+01 | 2.89E+01 | 2.73E+01 | 2.69E+01 | 1.84E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | SA | 2.31E+01 | 1.45E+02 | 2.45E+01 | 2.87E+01 | 2.19E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | TLBO | 2.12E+01 | 1.41E+02 | 2.41E+01 | 2.90E+01 | 2.15E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | BAS | 3.96E+02 | 1.57E+05 | 5.79E+03 | 1.86E+04 | 3.28E+04 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | FA | 2.02E+01 | 3.82E+01 | 2.11E+01 | 2.17E+01 | 3.16E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | HHO | 3.10E+01 | 2.69E+02 | 4.64E+01 | 8.00E+01 | 6.24E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | GWO | 2.25E+01 | 1.45E+02 | 2.54E+01 | 3.85E+01 | 3.62E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| F18 | MFO | 2.16E+01 | 2.44E+02 | 4.50E+01 | 6.96E+01 | 5.75E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | WOA | 3.08E+01 | 9.79E+01 | 4.52E+01 | 4.74E+01 | 1.33E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | CMAES | 4.75E+01 | 5.89E+02 | 1.92E+02 | 2.05E+02 | 1.15E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | AGSK | 2.11E+01 | 2.34E+01 | 2.28E+01 | 2.27E+01 | 5.51E−01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | HSES | 2.04E+01 | 2.20E+01 | 2.09E+01 | 2.10E+01 | 4.71E−01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | MadDE | 1.15E+01 | 2.17E+01 | 2.11E+01 | 2.05E+01 | 2.06E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | IMODE | 1.69E+01 | 2.31E+01 | 2.14E+01 | 2.14E+01 | 1.08E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | ALSHADE | 9.84E+00 | 2.07E+01 | 2.02E+01 | **1.88E+01** | 2.83E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | EA4eig | 3.16E+01 | 5.78E+01 | 4.01E+01 | 4.02E+01 | 4.41E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | APGSKIMODE | 1.26E+01 | 2.15E+01 | 2.05E+01 | 1.98E+01 | 2.16E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | DA2MODE | 1.42E+01 | 2.09E+01 | 2.06E+01 | 1.98E+01 | 1.86E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |

(*continued on next page*)

**Table B.6** (*continued*).

| Fun | Alg. | Error | | | | | Function evaluations | | | | | SR (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No. | Name | Best | Worst | Median | Mean | SD | Best | Worst | Median | Mean | SD | |
| | ABC | 1.85E+02 | 2.18E+02 | 2.00E+02 | 2.00E+02 | 7.99E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | GA | 1.81E+02 | 2.03E+02 | 1.85E+02 | 1.86E+02 | 5.93E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | PSO | 2.71E+02 | 6.25E+02 | 3.81E+02 | 3.98E+02 | 8.62E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | DE | 1.81E+02 | 1.81E+02 | 1.81E+02 | 1.81E+02 | 8.67E−14 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | SA | 1.81E+02 | 1.81E+02 | 1.81E+02 | 1.81E+02 | 1.39E−02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | TLBO | 1.81E+02 | 1.81E+02 | 1.81E+02 | 1.81E+02 | 2.57E−12 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | BAS | 8.14E+02 | 3.13E+03 | 1.88E+03 | 2.02E+03 | 6.26E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | FA | 1.81E+02 | 1.81E+02 | 1.81E+02 | 1.81E+02 | 2.28E−11 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | HHO | 2.16E+02 | 3.82E+02 | 2.79E+02 | 2.82E+02 | 4.82E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | GWO | 1.81E+02 | 2.78E+02 | 1.98E+02 | 2.06E+02 | 2.70E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| F19 | MFO | 1.81E+02 | 3.41E+02 | 1.88E+02 | 2.05E+02 | 3.77E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | WOA | 1.81E+02 | 1.94E+02 | 1.83E+02 | 1.83E+02 | 2.53E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | CMAES | 2.41E+02 | 7.27E+02 | 4.48E+02 | 4.30E+02 | 1.25E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | AGSK | 1.81E+02 | 1.81E+02 | 1.81E+02 | 1.81E+02 | 2.38E−13 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | HSES | 1.81E+02 | 1.81E+02 | 1.81E+02 | 1.81E+02 | 8.23E−04 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | MadDE | 1.81E+02 | 1.81E+02 | 1.81E+02 | 1.81E+02 | 8.67E−14 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | IMODE | 1.81E+02 | 1.81E+02 | 1.81E+02 | 1.81E+02 | 6.24E−09 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | ALSHADE | 1.81E+02 | 1.81E+02 | 1.81E+02 | 1.81E+02 | 8.67E−14 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | EA4eig | 1.82E+02 | 2.23E+02 | 2.01E+02 | 2.01E+02 | 1.07E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | APGSKIMODE | 1.81E+02 | 1.81E+02 | 1.81E+02 | 1.81E+02 | 8.67E−14 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | DA2MODE | 1.65E+02 | 1.65E+02 | 1.65E+02 | **1.65E+02** | 0.00E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | ABC | 1.87E+02 | 4.14E+03 | 9.34E+02 | 1.52E+03 | 1.39E+03 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | GA | 1.08E−01 | 2.77E+02 | 5.06E+01 | **6.77E+01** | 8.43E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | PSO | 1.16E+02 | 3.18E+03 | 2.20E+03 | 2.01E+03 | 7.97E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | DE | 4.27E+01 | 1.98E+02 | 1.00E+02 | 1.04E+02 | 3.58E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | SA | 8.55E+01 | 8.55E+02 | 1.96E+02 | 2.43E+02 | 1.84E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | TLBO | 1.00E+02 | 1.18E+03 | 1.00E+02 | 2.37E+02 | 3.04E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | BAS | 2.39E+03 | 6.28E+03 | 5.52E+03 | 5.36E+03 | 8.01E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | FA | 1.00E+02 | 1.75E+03 | 1.00E+02 | 3.09E+02 | 4.72E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | HHO | 1.02E+02 | 3.99E+03 | 2.55E+03 | 2.48E+03 | 1.03E+03 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | GWO | 1.00E+02 | 1.78E+03 | 9.29E+02 | 8.65E+02 | 5.65E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| F20 | MFO | 1.01E+02 | 3.37E+03 | 1.75E+03 | 1.57E+03 | 1.05E+03 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | WOA | 1.01E+02 | 3.98E+03 | 1.87E+03 | 1.53E+03 | 1.34E+03 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | CMAES | 1.78E+02 | 4.63E+03 | 4.34E+03 | 3.75E+03 | 1.40E+03 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | AGSK | 1.00E+02 | 1.00E+02 | 1.00E+02 | 1.00E+02 | 3.48E−02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | HSES | 5.28E+00 | 4.18E+02 | 1.01E+02 | 1.44E+02 | 8.08E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | MadDE | 1.00E+02 | 1.00E+02 | 1.00E+02 | 1.00E+02 | 4.27E−02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | IMODE | 1.00E+02 | 1.01E+02 | 1.00E+02 | 1.00E+02 | 6.53E−02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | ALSHADE | 1.00E+02 | 1.00E+02 | 1.00E+02 | 1.00E+02 | 2.54E−02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | EA4eig | 1.01E+02 | 1.32E+02 | 1.01E+02 | 1.03E+02 | 7.00E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | APGSKIMODE | 1.00E+02 | 1.00E+02 | 1.00E+02 | 1.00E+02 | 4.78E−02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | DA2MODE | 1.00E+02 | 1.00E+02 | 1.00E+02 | 1.00E+02 | 2.61E−02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | ABC | 3.00E+02 | 3.00E+02 | 3.00E+02 | 3.00E+02 | 9.59E−04 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | GA | 4.31E+00 | 4.02E+02 | 3.05E+02 | 3.21E+02 | 7.36E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | PSO | 1.24E+03 | 4.65E+03 | 3.07E+03 | 2.90E+03 | 9.41E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | DE | 3.00E+02 | 3.00E+02 | 3.00E+02 | **3.00E+02** | 2.72E−13 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | SA | 3.29E+01 | 4.09E+02 | 4.08E+02 | 3.55E+02 | 1.11E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | TLBO | 0.00E+00 | 4.00E+02 | 3.00E+02 | 3.13E+02 | 9.73E+01 | 5.56E+04 | 5.00E+05 | 5.00E+05 | 4.71E+05 | 1.12E+05 | 6.67 |
| | BAS | 8.05E+03 | 1.78E+04 | 1.38E+04 | 1.35E+04 | 2.43E+03 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | FA | 3.00E+02 | 4.00E+02 | 3.00E+02 | 3.40E+02 | 4.98E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | HHO | 4.33E+02 | 3.66E+03 | 8.20E+02 | 9.32E+02 | 5.92E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | GWO | 3.38E+02 | 1.85E+03 | 7.81E+02 | 8.67E+02 | 3.18E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| F21 | MFO | 3.00E+02 | 3.27E+03 | 1.50E+03 | 1.69E+03 | 8.44E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | WOA | 1.36E+00 | 5.97E+03 | 3.05E+02 | 6.23E+02 | 1.16E+03 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | CMAES | 1.53E+03 | 5.95E+03 | 4.61E+03 | 4.47E+03 | 9.80E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | AGSK | 3.00E+02 | 4.00E+02 | 4.00E+02 | 3.73E+02 | 4.50E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | HSES | 3.00E+02 | 3.00E+02 | 3.00E+02 | 3.00E+02 | 2.07E−10 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | MadDE | 3.00E+02 | 3.00E+02 | 3.00E+02 | **3.00E+02** | 2.73E−13 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | IMODE | 3.00E+02 | 3.00E+02 | 3.00E+02 | 3.00E+02 | 2.31E−07 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | ALSHADE | 3.00E+02 | 4.00E+02 | 3.00E+02 | 3.17E+02 | 3.79E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | EA4eig | 3.36E+02 | 9.05E+02 | 6.76E+02 | 6.65E+02 | 1.56E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | APGSKIMODE | 3.00E+02 | 3.00E+02 | 3.00E+02 | **3.00E+02** | 2.02E−13 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | DA2MODE | 3.00E+02 | 4.00E+02 | 3.00E+02 | 3.17E+02 | 3.79E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | ABC | 2.00E+02 | 2.00E+02 | 2.00E+02 | 2.00E+02 | 5.22E−05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | GA | 2.53E+02 | 3.17E+02 | 2.81E+02 | 2.83E+02 | 1.81E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | PSO | 6.68E+02 | 1.45E+03 | 8.92E+02 | 9.71E+02 | 2.28E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | DE | 2.36E+02 | 2.45E+02 | 2.40E+02 | 2.40E+02 | 3.26E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | SA | 2.32E+02 | 2.45E+02 | 2.35E+02 | 2.37E+02 | 3.74E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | TLBO | 2.45E+02 | 3.22E+02 | 2.73E+02 | 2.75E+02 | 2.24E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | BAS | 9.12E+02 | 2.79E+03 | 1.74E+03 | 1.77E+03 | 3.83E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | FA | 2.36E+02 | 2.68E+02 | 2.48E+02 | 2.49E+02 | 8.74E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | HHO | 3.10E+02 | 9.40E+02 | 4.70E+02 | 5.38E+02 | 1.43E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | GWO | 2.42E+02 | 3.17E+02 | 2.66E+02 | 2.68E+02 | 1.88E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| F22 | MFO | 2.44E+02 | 3.29E+02 | 2.52E+02 | 2.63E+02 | 2.29E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | WOA | 2.56E+02 | 5.06E+02 | 3.04E+02 | 3.17E+02 | 5.61E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | CMAES | 2.63E+02 | 3.72E+02 | 3.56E+02 | 3.50E+02 | 2.74E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | AGSK | 2.32E+02 | 2.39E+02 | 2.34E+02 | 2.35E+02 | 2.50E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | HSES | 2.45E+02 | 2.68E+02 | 2.51E+02 | 2.52E+02 | 5.21E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | MadDE | 2.31E+02 | 2.35E+02 | 2.33E+02 | 2.33E+02 | 1.10E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | IMODE | 2.36E+02 | 2.47E+02 | 2.42E+02 | 2.42E+02 | 2.78E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | ALSHADE | 2.32E+02 | 2.40E+02 | 2.34E+02 | 2.34E+02 | 1.94E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | EA4eig | 2.00E+02 | 4.02E+02 | 3.12E+02 | 2.98E+02 | 5.65E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | APGSKIMODE | 2.29E+02 | 2.32E+02 | 2.32E+02 | 2.32E+02 | 6.81E−01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | DA2MODE | 2.00E+02 | 2.00E+02 | 2.00E+02 | **2.00E+02** | 2.91E−04 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |

**Table B.7**
The results metrics for the error and function evaluation metrics for 14 advanced DE variants, CEC2020-2022 (F1–F5), (10 Dim).

| Fun | Alg. | Error | | | | | Function evaluations | | | | | SR (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No. | Name | Best | Worst | Median | Mean | SD | Best | Worst | Median | Mean | SD | |
| F1 | MDE | 0.00E+00 | 0.00E+00 | 0.00E+00 | **0.00E+00** | 0.00E+00 | 1.02E+05 | 1.39E+05 | 1.36E+05 | 1.28E+05 | 1.62E+04 | 100.00 |
| | WDE | 8.00E−04 | 2.93E−03 | 1.52E−03 | 1.59E−03 | 8.74E−04 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | EODE | 0.00E+00 | 0.00E+00 | 0.00E+00 | **0.00E+00** | 0.00E+00 | 1.01E+05 | 1.13E+05 | 1.09E+05 | 1.09E+05 | 3.52E+03 | 100.00 |
| | MTDE | 0.00E+00 | 0.00E+00 | 0.00E+00 | **0.00E+00** | 0.00E+00 | 6.00E+04 | 6.50E+04 | 6.16E+04 | 6.21E+04 | 1.72E+03 | 100.00 |
| | mDEW | 0.00E+00 | 0.00E+00 | 0.00E+00 | **0.00E+00** | 0.00E+00 | 7.72E+04 | 7.91E+04 | 7.76E+04 | 7.79E+04 | 7.58E+02 | 100.00 |
| | BSD | 8.08E−05 | 2.70E+01 | 2.46E−02 | 6.66E+00 | 1.15E+01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | QRDE | 1.58E+03 | 5.53E+03 | 1.93E+03 | 2.83E+03 | 1.47E+03 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | BDE | 0.00E+00 | 0.00E+00 | 0.00E+00 | **0.00E+00** | 0.00E+00 | 8.38E+04 | 9.07E+04 | 8.56E+04 | 8.72E+04 | 2.58E+03 | 100.00 |
| | dFDBLSHADE | 0.00E+00 | 1.04E−07 | 0.00E+00 | 2.78E−08 | 4.70E−08 | 8.36E+04 | 2.00E+05 | 1.63E+05 | 1.42E+05 | 4.97E+04 | 73.33 |
| | BeSD | 0.00E+00 | 0.00E+00 | 0.00E+00 | **0.00E+00** | 0.00E+00 | 1.42E+05 | 1.56E+05 | 1.52E+05 | 1.51E+05 | 4.72E+03 | 100.00 |
| | JADEGMO | 0.00E+00 | 7.12E−06 | 1.77E−07 | 5.86E−07 | 1.78E−06 | 1.67E+05 | 2.00E+05 | 2.00E+05 | 1.95E+05 | 1.25E+04 | 16.67 |
| | JADE | 0.00E+00 | 0.00E+00 | 0.00E+00 | **0.00E+00** | 0.00E+00 | 1.01E+04 | 2.40E+04 | 1.18E+04 | 1.51E+04 | 5.58E+03 | 100.00 |
| | meanDE | 0.00E+00 | 0.00E+00 | 0.00E+00 | **0.00E+00** | 0.00E+00 | 1.24E+05 | 1.27E+05 | 1.26E+05 | 1.26E+05 | 8.07E+02 | 100.00 |
| | DA2MODE | 0.00E+00 | 0.00E+00 | 0.00E+00 | **0.00E+00** | 0.00E+00 | 4.45E+04 | 4.62E+04 | 4.56E+04 | 4.56E+04 | 4.12E+02 | 100.00 |
| F2 | MDE | 2.70E+01 | 2.66E+02 | 4.43E+01 | 1.03E+02 | 8.76E+01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | WDE | 1.56E+01 | 1.23E+02 | 2.27E+01 | 3.24E+01 | 2.45E+01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | EODE | 1.04E+01 | 8.63E+02 | 2.61E+02 | 3.06E+02 | 2.79E+02 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | MTDE | 2.19E+01 | 1.97E+02 | 1.32E+02 | 1.28E+02 | 6.54E+01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | mDEW | 1.13E+01 | 2.40E+02 | 1.58E+01 | 6.99E+01 | 9.33E+01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | BSD | 1.35E+01 | 2.24E+02 | 1.34E+02 | 1.24E+02 | 7.07E+01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | QRDE | 6.51E+01 | 4.96E+02 | 1.32E+02 | 1.69E+02 | 1.07E+02 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | BDE | 1.03E+01 | 1.52E+02 | 3.68E+01 | 6.19E+01 | 5.74E+01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | dFDBLSHADE | 4.88E−01 | 1.54E+01 | 7.21E+00 | 7.56E+00 | 5.36E+00 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | BeSD | 4.66E+01 | 1.57E+02 | 9.89E+01 | 1.03E+02 | 4.31E+01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | JADEGMO | 1.76E+02 | 9.63E+02 | 6.88E+02 | 6.45E+02 | 2.58E+02 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | JADE | 1.80E+01 | 7.59E+02 | 2.85E+02 | 2.88E+02 | 1.94E+02 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | meanDE | 3.75E−01 | 1.27E+02 | 6.95E+00 | 3.02E+01 | 4.95E+01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | DA2MODE | 3.43E−01 | 1.54E+01 | 3.86E+00 | **4.79E+00** | 3.75E+00 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| F3 | MDE | 1.34E+01 | 2.24E+01 | 1.73E+01 | 1.83E+01 | 3.85E+00 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | WDE | 1.70E+01 | 2.56E+01 | 2.36E+01 | 2.17E+01 | 3.45E+00 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | EODE | 1.49E+01 | 1.97E+01 | 1.69E+01 | 1.69E+01 | 2.04E+00 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | MTDE | 6.59E+00 | 2.43E+01 | 9.56E+00 | 1.22E+01 | 6.96E+00 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | mDEW | 1.27E+01 | 2.07E+01 | 1.61E+01 | 1.65E+01 | 2.84E+00 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | BSD | 1.41E+01 | 1.96E+01 | 1.78E+01 | 1.70E+01 | 2.26E+00 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | QRDE | 1.31E+01 | 1.90E+01 | 1.76E+01 | 1.66E+01 | 2.13E+00 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | BDE | 1.37E+01 | 1.68E+01 | 1.63E+01 | 1.59E+01 | 9.06E−01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | dFDBLSHADE | 2.61E+00 | 5.81E+00 | 3.61E+00 | **3.93E+00** | 1.23E+00 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | BeSD | 1.26E+01 | 1.48E+01 | 1.40E+01 | 1.38E+01 | 8.97E−01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | JADEGMO | 1.39E+01 | 1.68E+01 | 1.60E+01 | 1.57E+01 | 1.16E+00 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | JADE | 4.86E+00 | 1.97E+01 | 1.39E+01 | 1.31E+01 | 5.52E+00 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | meanDE | 1.21E+01 | 1.61E+01 | 1.51E+01 | 1.47E+01 | 1.41E+00 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | DA2MODE | 1.04E+01 | 1.24E+01 | 1.13E+01 | 1.14E+01 | 5.30E−01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| F4 | MDE | 5.12E−01 | 9.70E−01 | 6.14E−01 | 6.25E−01 | 1.28E−01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | WDE | 4.91E−01 | 1.18E+00 | 7.47E−01 | 7.33E−01 | 1.76E−01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | EODE | 7.83E−01 | 1.04E+00 | 1.01E+00 | 9.23E−01 | 1.14E−01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | MTDE | 4.29E−01 | 8.36E−01 | 5.66E−01 | 6.17E−01 | 1.61E−01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | mDEW | 3.45E−01 | 6.25E−01 | 4.34E−01 | 4.61E−01 | 1.08E−01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | BSD | 3.88E−01 | 1.81E+00 | 1.32E+00 | 1.23E+00 | 5.80E−01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | QRDE | 5.50E−01 | 1.14E+00 | 7.90E−01 | 7.68E−01 | 1.38E−01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | BDE | 4.37E−01 | 8.61E−01 | 6.88E−01 | 6.36E−01 | 1.31E−01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | dFDBLSHADE | 1.59E−01 | 4.50E−01 | 3.40E−01 | 3.12E−01 | 9.92E−02 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | BeSD | 5.32E−02 | 3.69E−01 | 2.48E−01 | **2.38E−01** | 1.22E−01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | JADEGMO | 7.21E−01 | 1.15E+00 | 1.02E+00 | 9.88E−01 | 1.68E−01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | JADE | 4.48E−01 | 9.36E−01 | 6.93E−01 | 6.47E−01 | 1.54E−01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | meanDE | 3.60E−01 | 7.09E−01 | 5.86E−01 | 5.67E−01 | 1.21E−01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | DA2MODE | 2.49E−01 | 4.70E−01 | 3.23E−01 | 3.36E−01 | 6.72E−02 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |

(*continued on next page*)

**Table B.7** (*continued*).

| Fun | Alg. | Error | | | | | Function evaluations | | | | | SR (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No. | Name | Best | Worst | Median | Mean | SD | Best | Worst | Median | Mean | SD | |
| F5 | MDE | 4.08E+01 | 4.92E+03 | 5.29E+02 | 1.11E+03 | 1.57E+03 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | WDE | 1.44E+01 | 3.52E+01 | 2.28E+01 | 2.38E+01 | 7.96E+00 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | EODE | 5.64E+00 | 1.25E+02 | 1.39E+01 | 4.87E+01 | 4.94E+01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | MTDE | 2.08E−01 | 4.60E+00 | 2.41E+00 | 2.30E+00 | 1.59E+00 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | mDEW | 1.55E+00 | 1.53E+01 | 3.70E+00 | 6.03E+00 | 5.71E+00 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | BSD | 7.62E+01 | 8.38E+02 | 4.74E+02 | 4.19E+02 | 2.94E+02 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | QRDE | 2.61E+04 | 5.87E+05 | 3.21E+04 | 1.63E+05 | 2.24E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | BDE | 2.08E−01 | 5.12E+01 | 2.61E+00 | 1.65E+01 | 2.16E+01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | dFDBLSHADE | 2.03E+00 | 2.46E+02 | 2.18E+02 | 1.96E+02 | 5.12E+01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | BeSD | 1.41E+01 | 2.64E+01 | 1.82E+01 | 2.00E+01 | 5.82E+00 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | JADEGMO | 1.74E+01 | 3.96E+02 | 1.16E+02 | 1.63E+02 | 1.11E+02 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | JADE | 5.99E+01 | 3.32E+02 | 1.66E+02 | 1.74E+02 | 8.42E+01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | meanDE | 2.20E+00 | 1.74E+02 | 4.90E+01 | 7.20E+01 | 6.52E+01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | DA2MODE | 0.00E+00 | 2.41E+00 | 5.20E−01 | **8.83E−01** | 7.22E−01 | 1.46E+05 | 2.00E+05 | 2.00E+05 | 1.97E+05 | 1.24E+04 | 6.67 |
| F6 | MDE | 1.61E+00 | 1.35E+02 | 1.30E+01 | 5.59E+01 | 6.15E+01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | WDE | 5.91E−01 | 1.50E+00 | 1.17E+00 | 1.19E+00 | 2.33E−01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | EODE | 6.16E−01 | 1.26E+01 | 1.43E+00 | 6.11E+00 | 5.55E+00 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | MTDE | 5.22E−02 | 1.14E+00 | 6.58E−01 | 5.44E−01 | 4.29E−01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | mDEW | 4.85E−01 | 6.67E−01 | 5.44E−01 | 5.61E−01 | 6.37E−02 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | BSD | 5.86E−01 | 7.70E−01 | 7.45E−01 | 7.01E−01 | 7.43E−02 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | QRDE | 7.70E−01 | 2.60E+02 | 6.02E+01 | 6.91E+01 | 7.64E+01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | BDE | 7.45E−02 | 1.41E+00 | 2.58E−01 | 5.52E−01 | 5.36E−01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | dFDBLSHADE | 1.24E−01 | 1.19E+00 | 2.47E−01 | 4.74E−01 | 4.42E−01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | BeSD | 5.28E−01 | 1.46E+00 | 6.80E−01 | 9.03E−01 | 3.19E−01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | JADEGMO | 1.50E+00 | 3.73E+02 | 6.35E+00 | 1.17E+02 | 1.51E+02 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | JADE | 7.50E−01 | 1.09E+02 | 1.65E+00 | 1.63E+01 | 3.71E+01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | meanDE | 9.09E−01 | 2.80E+00 | 1.79E+00 | 1.74E+00 | 7.54E−01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | DA2MODE | 2.53E−02 | 1.21E+00 | 3.24E−01 | **3.96E−01** | 3.19E−01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| F7 | MDE | 1.68E+01 | 1.37E+02 | 1.18E+02 | 8.05E+01 | 5.23E+01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | WDE | 7.93E−01 | 2.08E+00 | 1.27E+00 | 1.47E+00 | 5.17E−01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | EODE | 3.25E−01 | 1.91E+02 | 6.30E−01 | 3.85E+01 | 7.73E+01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | MTDE | 3.06E−03 | 9.95E−01 | 6.32E−01 | 5.36E−01 | 2.77E−01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | mDEW | 3.04E−02 | 6.44E−01 | 7.06E−02 | 2.15E−01 | 2.35E−01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | BSD | 1.50E+00 | 5.99E+01 | 2.04E+01 | 2.48E+01 | 2.07E+01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | QRDE | 1.20E+03 | 7.44E+04 | 1.63E+03 | 1.78E+04 | 2.89E+04 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | BDE | 4.99E−04 | 6.28E−01 | 3.12E−01 | **2.04E−01** | 2.05E−01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | dFDBLSHADE | 1.58E−03 | 1.37E+02 | 8.15E−01 | 3.23E+01 | 5.38E+01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | BeSD | 3.34E−01 | 1.04E+00 | 6.72E−01 | 6.25E−01 | 2.87E−01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | JADEGMO | 8.22E+00 | 2.04E+03 | 1.91E+02 | 6.48E+02 | 7.53E+02 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | JADE | 3.20E−01 | 1.71E+01 | 9.29E−01 | 5.48E+00 | 7.21E+00 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | meanDE | 6.20E−04 | 5.91E+01 | 1.18E+00 | 1.32E+01 | 2.18E+01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | DA2MODE | 3.38E−05 | 8.12E−01 | 1.09E−01 | 2.40E−01 | 2.62E−01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| F8 | MDE | 1.00E+02 | 1.02E+02 | 1.01E+02 | 1.01E+02 | 7.22E−01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | WDE | 2.32E+01 | 1.01E+02 | 7.42E+01 | 6.70E+01 | 3.51E+01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | EODE | 1.00E+02 | 1.01E+02 | 1.00E+02 | 1.00E+02 | 3.67E−01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | MTDE | 0.00E+00 | 1.01E+02 | 1.00E+02 | 8.03E+01 | 4.08E+01 | 6.51E+04 | 2.00E+05 | 2.00E+05 | 1.73E+05 | 5.49E+04 | 20.00 |
| | mDEW | 0.00E+00 | 1.00E+02 | 1.87E+01 | **3.51E+01** | 4.05E+01 | 1.45E+05 | 2.00E+05 | 2.00E+05 | 1.89E+05 | 2.23E+04 | 20.00 |
| | BSD | 1.40E+00 | 1.01E+02 | 4.57E+00 | 4.57E+01 | 4.91E+01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | QRDE | 1.00E+02 | 1.01E+02 | 1.01E+02 | 1.01E+02 | 2.93E−01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | BDE | 0.00E+00 | 1.01E+02 | 1.00E+02 | 7.36E+01 | 4.52E+01 | 7.06E+04 | 2.00E+05 | 2.00E+05 | 1.65E+05 | 5.82E+04 | 26.67 |
| | dFDBLSHADE | 0.00E+00 | 1.01E+02 | 1.01E+02 | 6.07E+01 | 4.49E+01 | 3.93E+04 | 2.00E+05 | 2.00E+05 | 1.68E+05 | 6.54E+04 | 20.00 |
| | BeSD | 2.91E+01 | 1.00E+02 | 1.00E+02 | 8.12E+01 | 3.20E+01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | JADEGMO | 1.00E+02 | 1.02E+02 | 1.01E+02 | 1.01E+02 | 5.02E−01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | JADE | 2.54E+01 | 1.01E+02 | 1.00E+02 | 8.77E+01 | 2.83E+01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | meanDE | 1.00E+02 | 1.00E+02 | 1.00E+02 | 1.00E+02 | 6.63E−02 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | DA2MODE | 1.00E+02 | 1.00E+02 | 1.00E+02 | 1.00E+02 | 0.00E+00 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| F9 | MDE | 1.00E+02 | 3.44E+02 | 3.41E+02 | 3.25E+02 | 6.12E+01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | WDE | 1.00E+02 | 1.01E+02 | 1.00E+02 | 1.00E+02 | 1.31E−01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | EODE | 3.38E+02 | 3.48E+02 | 3.43E+02 | 3.42E+02 | 2.80E+00 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | MTDE | 3.37E+02 | 3.43E+02 | 3.40E+02 | 3.40E+02 | 2.11E+00 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | mDEW | 1.00E+02 | 1.00E+02 | 1.00E+02 | **1.00E+02** | 2.31E−13 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | BSD | 1.00E+02 | 1.00E+02 | 1.00E+02 | 1.00E+02 | 7.79E−04 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | QRDE | 3.36E+02 | 3.53E+02 | 3.51E+02 | 3.48E+02 | 6.34E+00 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | BDE | 1.00E+02 | 3.36E+02 | 2.17E+02 | 2.18E+02 | 1.20E+02 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | dFDBLSHADE | 1.00E+02 | 2.01E+02 | 1.00E+02 | 1.27E+02 | 4.55E+01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | BeSD | 1.00E+02 | 1.00E+02 | 1.00E+02 | 1.00E+02 | 6.62E−03 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | JADEGMO | 3.39E+02 | 3.82E+02 | 3.45E+02 | 3.45E+02 | 7.56E+00 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | JADE | 3.34E+02 | 3.84E+02 | 3.37E+02 | 3.51E+02 | 2.24E+01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | meanDE | 3.21E+02 | 3.31E+02 | 3.30E+02 | 3.28E+02 | 3.95E+00 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | DA2MODE | 1.00E+02 | 3.30E+02 | 3.00E+02 | 2.39E+02 | 1.08E+02 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |

(*continued on next page*)

**Table B.7** (*continued*).

| Fun | Alg. | Error | | | | | Function evaluations | | | | | SR (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No. | Name | Best | Worst | Median | Mean | SD | Best | Worst | Median | Mean | SD | |
| F10 | MDE | 3.98E+02 | 4.49E+02 | 4.22E+02 | 4.23E+02 | 2.41E+01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | WDE | 1.01E+02 | 3.98E+02 | 2.02E+02 | **2.07E+02** | 1.24E+02 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | EODE | 3.98E+02 | 4.46E+02 | 4.22E+02 | 4.22E+02 | 2.36E+01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | MTDE | 3.98E+02 | 3.98E+02 | 3.98E+02 | 3.98E+02 | 1.70E−01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | mDEW | 2.00E+02 | 3.98E+02 | 3.98E+02 | 3.59E+02 | 6.11E+01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | BSD | 4.00E+02 | 4.44E+02 | 4.44E+02 | 4.32E+02 | 1.98E+01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | QRDE | 3.98E+02 | 4.44E+02 | 4.44E+02 | 4.23E+02 | 2.34E+01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | BDE | 3.98E+02 | 3.98E+02 | 3.98E+02 | 3.98E+02 | 1.81E−01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | dFDBLSHADE | 3.98E+02 | 4.01E+02 | 4.00E+02 | 4.00E+02 | 8.87E−01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | BeSD | 3.98E+02 | 4.00E+02 | 4.00E+02 | 3.99E+02 | 9.35E−01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | JADEGMO | 3.98E+02 | 4.46E+02 | 3.98E+02 | 4.12E+02 | 2.13E+01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | JADE | 3.98E+02 | 4.46E+02 | 3.98E+02 | 4.19E+02 | 2.41E+01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | meanDE | 3.98E+02 | 4.46E+02 | 4.01E+02 | 4.20E+02 | 2.33E+01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | DA2MODE | 3.98E+02 | 4.43E+02 | 3.98E+02 | 4.08E+02 | 1.96E+01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| F11 | MDE | 0.00E+00 | 0.00E+00 | 0.00E+00 | **0.00E+00** | 0.00E+00 | 7.70E+04 | 8.87E+04 | 7.96E+04 | 8.15E+04 | 3.61E+03 | 100.00 |
| | WDE | 3.57E−03 | 1.31E−02 | 6.76E−03 | 7.21E−03 | 3.59E−03 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | EODE | 0.00E+00 | 0.00E+00 | 0.00E+00 | **0.00E+00** | 0.00E+00 | 3.52E+04 | 3.87E+04 | 3.77E+04 | 3.73E+04 | 1.23E+03 | 100.00 |
| | MTDE | 0.00E+00 | 0.00E+00 | 0.00E+00 | **0.00E+00** | 0.00E+00 | 5.54E+04 | 5.80E+04 | 5.60E+04 | 5.66E+04 | 1.03E+03 | 100.00 |
| | mDEW | 0.00E+00 | 0.00E+00 | 0.00E+00 | **0.00E+00** | 0.00E+00 | 8.62E+04 | 8.92E+04 | 8.75E+04 | 8.76E+04 | 1.03E+03 | 100.00 |
| | BSD | 0.00E+00 | 0.00E+00 | 0.00E+00 | **0.00E+00** | 0.00E+00 | 1.30E+05 | 1.39E+05 | 1.31E+05 | 1.32E+05 | 2.67E+03 | 100.00 |
| | QRDE | 0.00E+00 | 0.00E+00 | 0.00E+00 | **0.00E+00** | 0.00E+00 | 6.67E+04 | 7.40E+04 | 7.27E+04 | 7.15E+04 | 2.73E+03 | 100.00 |
| | BDE | 0.00E+00 | 0.00E+00 | 0.00E+00 | **0.00E+00** | 0.00E+00 | 7.46E+04 | 9.67E+04 | 9.33E+04 | 8.85E+04 | 8.19E+03 | 100.00 |
| | dFDBLSHADE | 0.00E+00 | 0.00E+00 | 0.00E+00 | **0.00E+00** | 0.00E+00 | 6.29E+04 | 7.94E+04 | 7.00E+04 | 6.93E+04 | 6.83E+03 | 100.00 |
| | BeSD | 0.00E+00 | 0.00E+00 | 0.00E+00 | **0.00E+00** | 0.00E+00 | 1.11E+05 | 1.24E+05 | 1.20E+05 | 1.18E+05 | 4.84E+03 | 100.00 |
| | JADEGMO | 0.00E+00 | 0.00E+00 | 0.00E+00 | **0.00E+00** | 0.00E+00 | 5.85E+04 | 7.64E+04 | 6.97E+04 | 6.88E+04 | 6.07E+03 | 100.00 |
| | JADE | 0.00E+00 | 4.15E+03 | 0.00E+00 | 9.69E+02 | 1.79E+03 | 9.27E+03 | 2.00E+05 | 1.71E+04 | 5.80E+04 | 7.98E+04 | 76.67 |
| | meanDE | 0.00E+00 | 0.00E+00 | 0.00E+00 | **0.00E+00** | 0.00E+00 | 1.45E+04 | 1.84E+04 | 1.67E+04 | 1.63E+04 | 1.36E+03 | 100.00 |
| | DA2MODE | 0.00E+00 | 0.00E+00 | 0.00E+00 | **0.00E+00** | 0.00E+00 | 3.39E+04 | 3.56E+04 | 3.46E+04 | 3.47E+04 | 4.29E+02 | 100.00 |
| F12 | MDE | 8.92E+00 | 8.92E+00 | 8.92E+00 | 8.92E+00 | 0.00E+00 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | WDE | 6.59E−04 | 1.66E−03 | 9.44E−04 | 1.19E−03 | 4.33E−04 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | EODE | 0.00E+00 | 8.92E+00 | 8.92E+00 | 5.55E+00 | 3.91E+00 | 9.78E+04 | 2.00E+05 | 2.00E+05 | 1.73E+05 | 4.60E+04 | 26.67 |
| | MTDE | 3.99E+00 | 3.99E+00 | 3.99E+00 | 3.99E+00 | 0.00E+00 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | mDEW | 0.00E+00 | 2.87E−07 | 5.60E−08 | 1.07E−07 | 1.22E−07 | 1.47E+05 | 2.00E+05 | 2.00E+05 | 1.87E+05 | 2.15E+04 | 26.67 |
| | BSD | 3.72E−06 | 1.38E−02 | 3.70E−03 | 5.44E−03 | 5.97E−03 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | QRDE | 7.55E+00 | 8.92E+00 | 8.92E+00 | 8.64E+00 | 5.54E−01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | BDE | 0.00E+00 | 3.99E+00 | 0.00E+00 | 7.97E−01 | 1.62E+00 | 7.41E+04 | 2.00E+05 | 9.82E+04 | 1.19E+05 | 4.26E+04 | 80.00 |
| | dFDBLSHADE | 4.01E+00 | 8.92E+00 | 4.10E+00 | 6.32E+00 | 2.47E+00 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | BeSD | 0.00E+00 | 0.00E+00 | 0.00E+00 | **0.00E+00** | 0.00E+00 | 1.10E+05 | 1.45E+05 | 1.26E+05 | 1.24E+05 | 1.44E+04 | 100.00 |
| | JADEGMO | 3.99E+00 | 9.26E+02 | 8.92E+00 | 1.66E+02 | 3.47E+02 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | JADE | 0.00E+00 | 8.92E+00 | 8.92E+00 | 4.76E+00 | 4.52E+00 | 1.06E+04 | 2.00E+05 | 2.00E+05 | 1.12E+05 | 9.59E+04 | 46.67 |
| | meanDE | 0.00E+00 | 4.64E−02 | 1.16E−06 | 1.08E−02 | 2.00E−02 | 1.50E+05 | 2.00E+05 | 1.93E+05 | 1.83E+05 | 2.12E+04 | 50.00 |
| | DA2MODE | 0.00E+00 | 0.00E+00 | 0.00E+00 | **0.00E+00** | 0.00E+00 | 5.03E+04 | 6.28E+04 | 5.96E+04 | 5.90E+04 | 2.87E+03 | 100.00 |
| F13 | MDE | 0.00E+00 | 0.00E+00 | 0.00E+00 | **0.00E+00** | 0.00E+00 | 2.58E+04 | 2.87E+04 | 2.72E+04 | 2.73E+04 | 1.00E+03 | 100.00 |
| | WDE | 4.66E−03 | 1.94E−02 | 1.26E−02 | 1.12E−02 | 5.83E−03 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | EODE | 0.00E+00 | 0.00E+00 | 0.00E+00 | **0.00E+00** | 0.00E+00 | 2.25E+04 | 2.44E+04 | 2.30E+04 | 2.33E+04 | 7.56E+02 | 100.00 |
| | MTDE | 0.00E+00 | 1.13E−05 | 0.00E+00 | 1.13E−06 | 3.46E−06 | 6.89E+04 | 2.00E+05 | 7.01E+04 | 8.28E+04 | 3.97E+04 | 90.00 |
| | mDEW | 0.00E+00 | 0.00E+00 | 0.00E+00 | **0.00E+00** | 0.00E+00 | 7.36E+04 | 8.02E+04 | 7.71E+04 | 7.68E+04 | 2.48E+03 | 100.00 |
| | BSD | 0.00E+00 | 0.00E+00 | 0.00E+00 | **0.00E+00** | 0.00E+00 | 4.93E+04 | 5.19E+04 | 5.12E+04 | 5.08E+04 | 9.89E+02 | 100.00 |
| | QRDE | 0.00E+00 | 0.00E+00 | 0.00E+00 | **0.00E+00** | 0.00E+00 | 1.70E+04 | 1.88E+04 | 1.81E+04 | 1.79E+04 | 6.10E+02 | 100.00 |
| | BDE | 0.00E+00 | 0.00E+00 | 0.00E+00 | **0.00E+00** | 0.00E+00 | 6.53E+04 | 6.85E+04 | 6.68E+04 | 6.68E+04 | 1.09E+03 | 100.00 |
| | dFDBLSHADE | 1.13E−05 | 3.73E−04 | 2.43E−04 | 1.81E−04 | 1.47E−04 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | BeSD | 0.00E+00 | 0.00E+00 | 0.00E+00 | **0.00E+00** | 0.00E+00 | 1.68E+05 | 1.77E+05 | 1.70E+05 | 1.72E+05 | 3.82E+03 | 100.00 |
| | JADEGMO | 1.82E−05 | 5.46E−03 | 3.57E−05 | 4.15E−04 | 1.37E−03 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | JADE | 0.00E+00 | 5.56E−01 | 1.33E−04 | 1.48E−01 | 2.50E−01 | 1.39E+04 | 2.00E+05 | 2.00E+05 | 1.63E+05 | 7.57E+04 | 20.00 |
| | meanDE | 0.00E+00 | 3.55E−07 | 0.00E+00 | 4.74E−08 | 1.23E−07 | 1.26E+04 | 2.00E+05 | 1.34E+04 | 3.79E+04 | 6.47E+04 | 86.67 |
| | DA2MODE | 0.00E+00 | 0.00E+00 | 0.00E+00 | **0.00E+00** | 0.00E+00 | 7.32E+04 | 7.74E+04 | 7.50E+04 | 7.52E+04 | 1.00E+03 | 100.00 |

(*continued on next page*)

**Table B.7** (*continued*).

| Fun | Alg. | Error | | | | | Function evaluations | | | | | SR (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No. | Name | Best | Worst | Median | Mean | SD | Best | Worst | Median | Mean | SD | |
| F14 | MDE | 4.97E+00 | 1.59E+01 | 8.95E+00 | 1.09E+01 | 4.59E+00 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | WDE | 9.96E+00 | 1.69E+01 | 1.40E+01 | 1.40E+01 | 2.49E+00 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | EODE | 5.97E+00 | 1.09E+01 | 6.96E+00 | 7.50E+00 | 1.81E+00 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | MTDE | 2.98E+00 | 1.79E+01 | 1.04E+01 | 1.01E+01 | 5.26E+00 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | mDEW | 5.97E+00 | 1.29E+01 | 1.09E+01 | 1.11E+01 | 2.33E+00 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | BSD | 5.97E+00 | 1.19E+01 | 8.95E+00 | 9.09E+00 | 1.93E+00 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | QRDE | 1.19E+01 | 1.90E+01 | 1.51E+01 | 1.48E+01 | 3.01E+00 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | BDE | 4.97E+00 | 1.49E+01 | 7.96E+00 | 1.06E+01 | 4.24E+00 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | dFDBLSHADE | 9.95E−01 | 2.98E+00 | 1.99E+00 | 2.16E+00 | 8.70E−01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | BeSD | 2.40E+00 | 5.22E+00 | 4.18E+00 | 4.04E+00 | 1.01E+00 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | JADEGMO | 3.98E+00 | 1.19E+01 | 6.96E+00 | 6.77E+00 | 2.66E+00 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | JADE | 4.28E+00 | 1.19E+01 | 5.99E+00 | 6.77E+00 | 3.22E+00 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | meanDE | 9.95E−01 | 6.96E+00 | 4.97E+00 | 4.21E+00 | 1.84E+00 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | DA2MODE | 0.00E+00 | 1.99E+00 | 9.95E−01 | **6.63E−01** | 6.58E−01 | 1.43E+05 | 2.00E+05 | 2.00E+05 | 1.79E+05 | 2.60E+04 | 40.00 |
| F15 | MDE | 0.00E+00 | 0.00E+00 | 0.00E+00 | **0.00E+00** | 0.00E+00 | 4.80E+04 | 5.56E+04 | 5.52E+04 | 5.36E+04 | 2.88E+03 | 100.00 |
| | WDE | 1.38E+01 | 5.76E+01 | 2.77E+01 | 3.22E+01 | 1.67E+01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | EODE | 0.00E+00 | 0.00E+00 | 0.00E+00 | **0.00E+00** | 0.00E+00 | 1.12E+04 | 1.38E+04 | 1.12E+04 | 1.20E+04 | 1.02E+03 | 100.00 |
| | MTDE | 0.00E+00 | 0.00E+00 | 0.00E+00 | **0.00E+00** | 0.00E+00 | 5.38E+04 | 5.87E+04 | 5.66E+04 | 5.60E+04 | 1.93E+03 | 100.00 |
| | mDEW | 0.00E+00 | 0.00E+00 | 0.00E+00 | **0.00E+00** | 0.00E+00 | 7.27E+04 | 7.54E+04 | 7.29E+04 | 7.34E+04 | 1.01E+03 | 100.00 |
| | BSD | 0.00E+00 | 0.00E+00 | 0.00E+00 | **0.00E+00** | 0.00E+00 | 1.16E+05 | 1.68E+05 | 1.43E+05 | 1.44E+05 | 1.79E+04 | 100.00 |
| | QRDE | 0.00E+00 | 0.00E+00 | 0.00E+00 | **0.00E+00** | 0.00E+00 | 1.55E+04 | 1.79E+04 | 1.63E+04 | 1.65E+04 | 9.35E+02 | 100.00 |
| | BDE | 0.00E+00 | 0.00E+00 | 0.00E+00 | **0.00E+00** | 0.00E+00 | 4.66E+04 | 5.85E+04 | 5.08E+04 | 5.16E+04 | 3.62E+03 | 100.00 |
| | dFDBLSHADE | 0.00E+00 | 8.95E−02 | 0.00E+00 | 2.39E−02 | 4.03E−02 | 2.97E+04 | 2.00E+05 | 4.10E+04 | 7.84E+04 | 7.47E+04 | 73.33 |
| | BeSD | 0.00E+00 | 0.00E+00 | 0.00E+00 | **0.00E+00** | 0.00E+00 | 9.34E+04 | 1.06E+05 | 9.98E+04 | 9.98E+04 | 4.62E+03 | 100.00 |
| | JADEGMO | 0.00E+00 | 0.00E+00 | 0.00E+00 | **0.00E+00** | 0.00E+00 | 5.83E+04 | 8.06E+04 | 6.23E+04 | 6.70E+04 | 8.67E+03 | 100.00 |
| | JADE | 0.00E+00 | 4.07E+02 | 0.00E+00 | 1.36E+01 | 7.43E+01 | 7.20E+03 | 2.00E+05 | 8.06E+03 | 1.53E+04 | 3.50E+04 | 96.67 |
| | meanDE | 0.00E+00 | 0.00E+00 | 0.00E+00 | **0.00E+00** | 0.00E+00 | 5.91E+03 | 6.36E+03 | 6.00E+03 | 6.12E+03 | 1.90E+02 | 100.00 |
| | DA2MODE | 0.00E+00 | 0.00E+00 | 0.00E+00 | **0.00E+00** | 0.00E+00 | 3.21E+04 | 3.44E+04 | 3.32E+04 | 3.33E+04 | 6.02E+02 | 100.00 |
| F16 | MDE | 3.31E−01 | 1.33E+01 | 1.24E+01 | 7.61E+00 | 5.69E+00 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | WDE | 3.74E−01 | 1.78E+00 | 5.37E−01 | 6.57E−01 | 3.77E−01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | EODE | 5.97E−01 | 7.54E+00 | 1.62E+00 | 3.80E+00 | 3.00E+00 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | MTDE | 4.86E−02 | 1.22E+00 | 3.24E−01 | 4.61E−01 | 4.46E−01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | mDEW | 5.78E−02 | 3.78E−01 | 2.34E−01 | **2.08E−01** | 9.32E−02 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | BSD | 1.77E+00 | 1.39E+01 | 1.31E+01 | 9.01E+00 | 5.03E+00 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | QRDE | 4.04E+02 | 7.64E+03 | 5.43E+03 | 4.83E+03 | 2.84E+03 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | BDE | 3.47E−01 | 1.29E+00 | 1.16E+00 | 1.08E+00 | 2.98E−01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | dFDBLSHADE | 1.81E−01 | 2.20E+01 | 8.08E+00 | 1.05E+01 | 8.13E+00 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | BeSD | 9.38E−02 | 6.66E−01 | 1.14E−01 | 2.36E−01 | 2.21E−01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | JADEGMO | 1.75E+00 | 5.43E+01 | 2.14E+01 | 1.92E+01 | 1.63E+01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | JADE | 4.24E−01 | 9.03E+00 | 1.09E+00 | 2.97E+00 | 2.75E+00 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | meanDE | 1.40E−01 | 2.51E+01 | 2.60E+00 | 7.09E+00 | 1.02E+01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | DA2MODE | 5.27E−02 | 4.98E−01 | 4.67E−01 | 4.22E−01 | 1.11E−01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| F17 | MDE | 0.00E+00 | 2.10E+01 | 2.65E−08 | 9.53E+00 | 1.04E+01 | 8.97E+04 | 2.00E+05 | 2.00E+05 | 1.82E+05 | 4.18E+04 | 16.67 |
| | WDE | 1.21E−01 | 7.06E−01 | 2.24E−01 | 4.05E−01 | 2.56E−01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | EODE | 2.06E+01 | 2.24E+01 | 2.07E+01 | 2.13E+01 | 7.23E−01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | MTDE | 0.00E+00 | 9.95E−01 | 9.95E−01 | 5.31E−01 | 5.05E−01 | 8.30E+04 | 2.00E+05 | 2.00E+05 | 1.46E+05 | 5.91E+04 | 46.67 |
| | mDEW | 0.00E+00 | 1.84E−04 | 6.05E−05 | 6.55E−05 | 7.69E−05 | 1.51E+05 | 2.00E+05 | 2.00E+05 | 1.90E+05 | 1.98E+04 | 20.00 |
| | BSD | 3.36E−04 | 1.14E−03 | 4.24E−04 | 6.02E−04 | 3.32E−04 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | QRDE | 4.97E+00 | 2.09E+01 | 2.02E+01 | 1.65E+01 | 7.05E+00 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | BDE | 0.00E+00 | 0.00E+00 | 0.00E+00 | **0.00E+00** | 0.00E+00 | 8.62E+04 | 1.18E+05 | 9.83E+04 | 1.03E+05 | 1.41E+04 | 100.00 |
| | dFDBLSHADE | 0.00E+00 | 9.54E−08 | 0.00E+00 | 4.04E−09 | 1.79E−08 | 1.66E+05 | 2.00E+05 | 1.75E+05 | 1.73E+05 | 8.33E+03 | 93.33 |
| | BeSD | 1.23E+00 | 2.87E+00 | 1.45E+00 | 1.60E+00 | 4.65E−01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | JADEGMO | 2.04E+01 | 2.21E+01 | 2.09E+01 | 2.12E+01 | 5.70E−01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | JADE | 1.41E+00 | 2.50E+01 | 5.85E+00 | 9.49E+00 | 8.88E+00 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | meanDE | 5.44E−04 | 2.06E+01 | 5.60E+00 | 9.39E+00 | 8.77E+00 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | DA2MODE | 0.00E+00 | 9.95E−01 | 0.00E+00 | 1.12E−01 | 2.95E−01 | 1.52E+05 | 2.00E+05 | 1.81E+05 | 1.84E+05 | 1.30E+04 | 70.00 |
| F18 | MDE | 1.76E−01 | 2.08E+01 | 2.00E+01 | 1.24E+01 | 9.92E+00 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | WDE | 2.37E−01 | 4.86E+00 | 7.38E−01 | 1.60E+00 | 1.86E+00 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | EODE | 3.28E−01 | 4.28E+00 | 2.13E+00 | 2.20E+00 | 1.44E+00 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | MTDE | 6.08E−04 | 6.48E−01 | 6.46E−02 | **2.21E−01** | 2.43E−01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | mDEW | 4.78E−02 | 8.35E−01 | 1.06E−01 | 2.93E−01 | 3.35E−01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | BSD | 7.26E−01 | 2.02E+01 | 1.18E+01 | 1.26E+01 | 7.98E+00 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | QRDE | 1.40E+00 | 2.42E+01 | 1.62E+01 | 1.43E+01 | 8.70E+00 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | BDE | 5.14E−03 | 2.00E+01 | 6.25E−01 | 2.31E+00 | 6.02E+00 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | dFDBLSHADE | 7.07E−03 | 5.74E+00 | 1.94E−01 | 1.78E+00 | 2.29E+00 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | BeSD | 2.22E+00 | 7.83E+00 | 6.86E+00 | 5.24E+00 | 2.42E+00 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | JADEGMO | 6.48E−01 | 2.19E+01 | 1.06E+01 | 1.05E+01 | 8.06E+00 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | JADE | 8.63E−01 | 3.30E+01 | 2.06E+01 | 1.55E+01 | 1.32E+01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | meanDE | 4.84E−02 | 2.07E+01 | 2.02E+01 | 1.17E+01 | 9.98E+00 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | DA2MODE | 2.84E−02 | 5.92E−01 | 2.24E−01 | 2.31E−01 | 1.30E−01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |

(*continued on next page*)

**Table B.7** (*continued*).

| Fun | Alg. | Error | | | | | Function evaluations | | | | | SR (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No. | Name | Best | Worst | Median | Mean | SD | Best | Worst | Median | Mean | SD | |
| F19 | MDE | 2.29E+02 | 2.29E+02 | 2.29E+02 | 2.29E+02 | 0.00E+00 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | WDE | 1.00E+02 | 2.29E+02 | 2.00E+02 | 1.87E+02 | 5.47E+01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | EODE | 2.29E+02 | 2.29E+02 | 2.29E+02 | 2.29E+02 | 0.00E+00 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | MTDE | 2.29E+02 | 2.29E+02 | 2.29E+02 | 2.29E+02 | 0.00E+00 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | mDEW | 2.00E+02 | 2.29E+02 | 2.29E+02 | 2.21E+02 | 1.31E+01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | BSD | 2.29E+02 | 2.29E+02 | 2.29E+02 | 2.29E+02 | 0.00E+00 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | QRDE | 2.29E+02 | 2.29E+02 | 2.29E+02 | 2.29E+02 | 0.00E+00 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | BDE | 2.29E+02 | 2.29E+02 | 2.29E+02 | 2.29E+02 | 0.00E+00 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | dFDBLSHADE | 2.29E+02 | 2.29E+02 | 2.29E+02 | 2.29E+02 | 0.00E+00 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | BeSD | 2.29E+02 | 2.29E+02 | 2.29E+02 | 2.29E+02 | 1.11E−11 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | JADEGMO | 2.29E+02 | 2.33E+02 | 2.29E+02 | 2.30E+02 | 1.26E+00 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | JADE | 2.29E+02 | 2.29E+02 | 2.29E+02 | 2.29E+02 | 0.00E+00 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | meanDE | 2.29E+02 | 2.29E+02 | 2.29E+02 | 2.29E+02 | 0.00E+00 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | DA2MODE | 1.86E+02 | 1.86E+02 | 1.86E+02 | **1.86E+02** | 0.00E+00 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| F20 | MDE | 1.00E+02 | 1.00E+02 | 1.00E+02 | 1.00E+02 | 4.10E−02 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | WDE | 2.00E−01 | 3.74E+00 | 2.57E−01 | 1.73E+00 | 1.75E+00 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | EODE | 1.00E+02 | 2.10E+02 | 1.00E+02 | 1.34E+02 | 4.89E+01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | MTDE | 1.00E+02 | 1.00E+02 | 1.00E+02 | 1.00E+02 | 2.34E−02 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | mDEW | 2.53E−01 | 2.90E−01 | 2.84E−01 | **2.72E−01** | 1.68E−02 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | BSD | 1.92E−01 | 7.00E+00 | 5.41E−01 | 2.24E+00 | 2.99E+00 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | QRDE | 1.00E+02 | 1.00E+02 | 1.00E+02 | 1.00E+02 | 3.55E−02 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | BDE | 1.00E+02 | 1.00E+02 | 1.00E+02 | 1.00E+02 | 3.14E−02 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | dFDBLSHADE | 1.00E+02 | 1.00E+02 | 1.00E+02 | 1.00E+02 | 2.29E−02 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | BeSD | 1.00E+02 | 1.00E+02 | 1.00E+02 | 1.00E+02 | 4.04E−02 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | JADEGMO | 1.00E+02 | 2.12E+02 | 1.24E+02 | 1.53E+02 | 5.51E+01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | JADE | 1.00E+02 | 1.00E+02 | 1.00E+02 | 1.00E+02 | 2.41E−02 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | meanDE | 1.00E+02 | 2.07E+02 | 2.05E+02 | 1.78E+02 | 4.76E+01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | DA2MODE | 1.00E+02 | 1.00E+02 | 1.00E+02 | 1.00E+02 | 3.28E−02 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| F21 | MDE | 0.00E+00 | 1.50E+02 | 0.00E+00 | 3.01E+01 | 6.12E+01 | 3.99E+04 | 2.00E+05 | 4.35E+04 | 7.45E+04 | 6.39E+04 | 80.00 |
| | WDE | 2.78E−04 | 7.23E−04 | 5.08E−04 | 5.11E−04 | 1.61E−04 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | EODE | 0.00E+00 | 0.00E+00 | 0.00E+00 | **0.00E+00** | 0.00E+00 | 1.82E+04 | 1.93E+04 | 1.88E+04 | 1.87E+04 | 4.60E+02 | 100.00 |
| | MTDE | 0.00E+00 | 0.00E+00 | 0.00E+00 | **0.00E+00** | 0.00E+00 | 6.35E+04 | 6.57E+04 | 6.42E+04 | 6.46E+04 | 8.57E+02 | 100.00 |
| | mDEW | 0.00E+00 | 0.00E+00 | 0.00E+00 | **0.00E+00** | 0.00E+00 | 7.48E+04 | 8.70E+04 | 8.10E+04 | 8.07E+04 | 4.42E+03 | 100.00 |
| | BSD | 0.00E+00 | 0.00E+00 | 0.00E+00 | **0.00E+00** | 0.00E+00 | 3.77E+04 | 1.11E+05 | 5.79E+04 | 6.66E+04 | 2.83E+04 | 100.00 |
| | QRDE | 0.00E+00 | 1.50E+02 | 0.00E+00 | 3.01E+01 | 6.12E+01 | 1.94E+04 | 2.00E+05 | 2.02E+04 | 5.59E+04 | 7.33E+04 | 80.00 |
| | BDE | 0.00E+00 | 0.00E+00 | 0.00E+00 | **0.00E+00** | 0.00E+00 | 5.91E+04 | 6.43E+04 | 5.97E+04 | 6.12E+04 | 2.11E+03 | 100.00 |
| | dFDBLSHADE | 0.00E+00 | 0.00E+00 | 0.00E+00 | **0.00E+00** | 0.00E+00 | 4.37E+04 | 4.43E+04 | 4.41E+04 | 4.41E+04 | 2.01E+02 | 100.00 |
| | BeSD | 0.00E+00 | 0.00E+00 | 0.00E+00 | **0.00E+00** | 0.00E+00 | 1.32E+05 | 1.43E+05 | 1.39E+05 | 1.37E+05 | 4.54E+03 | 100.00 |
| | JADEGMO | 0.00E+00 | 1.82E+02 | 3.80E−08 | 1.16E+01 | 4.43E+01 | 1.90E+05 | 2.00E+05 | 2.00E+05 | 1.97E+05 | 4.44E+03 | 30.00 |
| | JADE | 0.00E+00 | 3.00E+02 | 0.00E+00 | 1.00E+01 | 5.48E+01 | 9.93E+03 | 2.00E+05 | 1.02E+04 | 1.67E+04 | 3.46E+04 | 96.67 |
| | meanDE | 0.00E+00 | 0.00E+00 | 0.00E+00 | **0.00E+00** | 0.00E+00 | 8.46E+03 | 1.25E+05 | 9.38E+03 | 4.00E+04 | 5.22E+04 | 100.00 |
| | DA2MODE | 0.00E+00 | 0.00E+00 | 0.00E+00 | **0.00E+00** | 0.00E+00 | 5.26E+04 | 5.52E+04 | 5.36E+04 | 5.37E+04 | 6.09E+02 | 100.00 |
| F22 | MDE | 1.62E+02 | 1.64E+02 | 1.63E+02 | 1.63E+02 | 7.32E−01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | WDE | 1.63E+02 | 1.64E+02 | 1.64E+02 | 1.64E+02 | 4.52E−01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | EODE | 1.64E+02 | 1.65E+02 | 1.65E+02 | 1.65E+02 | 5.19E−01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | MTDE | 1.59E+02 | 1.65E+02 | 1.65E+02 | 1.63E+02 | 2.10E+00 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | mDEW | 1.61E+02 | 1.65E+02 | 1.64E+02 | 1.64E+02 | 1.30E+00 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | BSD | 1.63E+02 | 1.66E+02 | 1.66E+02 | 1.65E+02 | 8.57E−01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | QRDE | 1.59E+02 | 1.65E+02 | 1.63E+02 | 1.63E+02 | 2.11E+00 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | BDE | 1.63E+02 | 1.65E+02 | 1.65E+02 | 1.64E+02 | 1.00E+00 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | dFDBLSHADE | 1.63E+02 | 1.65E+02 | 1.64E+02 | 1.64E+02 | 6.33E−01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | BeSD | 1.63E+02 | 1.65E+02 | 1.65E+02 | 1.65E+02 | 6.79E−01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | JADEGMO | 1.61E+02 | 1.77E+02 | 1.61E+02 | 1.63E+02 | 4.26E+00 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | JADE | 1.59E+02 | 1.63E+02 | 1.61E+02 | 1.61E+02 | 1.15E+00 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | meanDE | 1.65E+02 | 1.67E+02 | 1.65E+02 | 1.65E+02 | 4.94E−01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |
| | DA2MODE | 1.45E+02 | 1.46E+02 | 1.46E+02 | **1.46E+02** | 1.40E−01 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 2.00E+05 | 0.00E+00 | 0.00 |

**Table B.8**
The results metrics for the error and function evaluation metrics for 14 advanced DE variants, CEC2020-2022 (F1-F5), (20 Dim).

| Fun | Alg. | Error | | | | | Function evaluations | | | | | SR (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No. | Name | Best | Worst | Median | Mean | SD | Best | Worst | Median | Mean | SD | |
| F1 | MDE | 0.00E+00 | 0.00E+00 | 0.00E+00 | **0.00E+00** | 0.00E+00 | 1.08E+05 | 2.11E+05 | 1.65E+05 | 1.58E+05 | 4.16E+04 | 100.00 |
| | WDE | 3.33E−05 | 1.13E−04 | 4.95E−05 | 6.26E−05 | 3.18E−05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | EODE | 0.00E+00 | 0.00E+00 | 0.00E+00 | **0.00E+00** | 0.00E+00 | 1.72E+05 | 2.21E+05 | 1.94E+05 | 1.94E+05 | 1.69E+04 | 100.00 |
| | MTDE | 0.00E+00 | 0.00E+00 | 0.00E+00 | **0.00E+00** | 0.00E+00 | 1.31E+05 | 1.40E+05 | 1.39E+05 | 1.36E+05 | 3.67E+03 | 100.00 |
| | mDEW | 0.00E+00 | 0.00E+00 | 0.00E+00 | **0.00E+00** | 0.00E+00 | 1.75E+05 | 1.98E+05 | 1.77E+05 | 1.80E+05 | 7.64E+03 | 100.00 |
| | BSD | 7.39E−08 | 2.20E−04 | 2.72E−06 | 6.50E−05 | 9.56E−05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | QRDE | 1.45E+02 | 1.13E+04 | 3.97E+02 | 3.30E+03 | 4.91E+03 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | BDE | 0.00E+00 | 0.00E+00 | 0.00E+00 | **0.00E+00** | 0.00E+00 | 1.54E+05 | 1.96E+05 | 1.66E+05 | 1.67E+05 | 1.20E+04 | 100.00 |
| | dFDBLSHADE | 0.00E+00 | 2.69E−06 | 1.21E−06 | 1.07E−06 | 1.11E−06 | 3.46E+05 | 5.00E+05 | 5.00E+05 | 4.59E+05 | 6.91E+04 | 26.67 |
| | BeSD | 0.00E+00 | 0.00E+00 | 0.00E+00 | **0.00E+00** | 0.00E+00 | 2.77E+05 | 3.05E+05 | 2.97E+05 | 2.96E+05 | 1.01E+04 | 100.00 |
| | JADEGMO | 1.80E−02 | 3.40E+01 | 1.07E+00 | 1.32E+01 | 1.52E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | JADE | 0.00E+00 | 8.93E+08 | 0.00E+00 | 1.79E+08 | 3.63E+08 | 2.58E+04 | 5.00E+05 | 3.65E+04 | 1.26E+05 | 1.90E+05 | 80.00 |
| | meanDE | 0.00E+00 | 1.64E+03 | 6.84E+02 | 7.22E+02 | 5.66E+02 | 3.11E+05 | 5.00E+05 | 5.00E+05 | 4.50E+05 | 8.49E+04 | 26.67 |
| | DA2MODE | 0.00E+00 | 0.00E+00 | 0.00E+00 | **0.00E+00** | 0.00E+00 | 9.34E+04 | 1.04E+05 | 9.77E+04 | 9.79E+04 | 2.63E+03 | 100.00 |
| F2 | MDE | 1.70E+01 | 5.11E+02 | 2.50E+02 | 2.94E+02 | 1.78E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | WDE | 1.37E+02 | 2.57E+02 | 1.39E+02 | 1.62E+02 | 4.79E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | EODE | 5.04E+02 | 1.48E+03 | 5.39E+02 | 9.23E+02 | 4.41E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | MTDE | 2.70E+02 | 4.77E+02 | 3.33E+02 | 3.55E+02 | 8.42E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | mDEW | 1.68E+01 | 2.53E+02 | 1.34E+02 | 1.49E+02 | 9.43E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | BSD | 7.08E+00 | 1.33E+02 | 1.28E+02 | 7.38E+01 | 6.21E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | QRDE | 2.78E+02 | 6.01E+02 | 5.77E+02 | 5.01E+02 | 1.21E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | BDE | 5.09E+00 | 1.18E+01 | 9.27E+00 | 8.61E+00 | 2.54E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | dFDBLSHADE | 1.77E+00 | 3.59E+00 | 2.69E+00 | 2.68E+00 | 9.14E−01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | BeSD | 9.02E+01 | 2.25E+02 | 1.51E+02 | 1.61E+02 | 5.94E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | JADEGMO | 1.51E+03 | 2.35E+03 | 1.96E+03 | 1.99E+03 | 3.08E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | JADE | 1.77E+03 | 3.63E+03 | 2.55E+03 | 2.69E+03 | 6.84E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | meanDE | 5.19E+00 | 3.65E+02 | 2.22E+02 | 1.94E+02 | 1.29E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | DA2MODE | 1.59E−01 | 7.82E+00 | 2.10E+00 | **2.26E+00** | 1.83E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| F3 | MDE | 2.62E+01 | 4.42E+01 | 3.86E+01 | 3.73E+01 | 6.65E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | WDE | 1.82E+01 | 3.31E+01 | 2.49E+01 | 2.45E+01 | 6.14E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | EODE | 3.47E+01 | 4.88E+01 | 4.57E+01 | 4.39E+01 | 5.75E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | MTDE | 9.23E+00 | 4.14E+01 | 3.55E+01 | 3.08E+01 | 1.28E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | mDEW | 2.90E+01 | 3.20E+01 | 3.06E+01 | 3.06E+01 | 1.10E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | BSD | 2.40E+01 | 2.75E+01 | 2.44E+01 | 2.54E+01 | 1.47E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | QRDE | 2.63E+01 | 3.62E+01 | 3.52E+01 | 3.33E+01 | 3.99E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | BDE | 2.24E+01 | 2.73E+01 | 2.42E+01 | 2.44E+01 | 1.90E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | dFDBLSHADE | 1.40E+00 | 2.18E+01 | 2.59E+00 | **7.98E+00** | 9.04E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | BeSD | 2.81E+01 | 3.17E+01 | 2.82E+01 | 2.93E+01 | 1.40E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | JADEGMO | 4.28E+01 | 6.16E+01 | 4.61E+01 | 4.91E+01 | 6.80E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | JADE | 4.88E+01 | 1.24E+02 | 5.19E+01 | 7.35E+01 | 3.18E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | meanDE | 2.55E+01 | 3.45E+01 | 2.90E+01 | 2.95E+01 | 3.11E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | DA2MODE | 2.04E+01 | 2.51E+01 | 2.13E+01 | 2.18E+01 | 1.32E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| F4 | MDE | 9.61E−01 | 4.17E+00 | 1.12E+00 | 1.30E+00 | 5.79E−01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | WDE | 1.45E+00 | 2.26E+00 | 1.74E+00 | 1.78E+00 | 3.06E−01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | EODE | 1.44E+00 | 3.56E+00 | 2.49E+00 | 2.31E+00 | 8.71E−01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | MTDE | 1.29E+00 | 1.84E+00 | 1.45E+00 | 1.50E+00 | 2.19E−01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | mDEW | 1.13E+00 | 1.23E+00 | 1.21E+00 | 1.20E+00 | 2.96E−02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | BSD | 1.11E+00 | 1.58E+00 | 1.23E+00 | 1.30E+00 | 1.82E−01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | QRDE | 1.36E+00 | 2.13E+00 | 1.66E+00 | 1.69E+00 | 2.90E−01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | BDE | 6.81E−01 | 1.09E+00 | 8.48E−01 | 8.75E−01 | 1.44E−01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | dFDBLSHADE | 7.31E−01 | 8.45E−01 | 7.65E−01 | 7.72E−01 | 4.68E−02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | BeSD | 1.52E+00 | 1.83E+00 | 1.71E+00 | 1.71E+00 | 1.19E−01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | JADEGMO | 1.98E+00 | 8.68E+02 | 4.42E+00 | 2.06E+02 | 3.72E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | JADE | 1.66E+00 | 3.33E+00 | 2.72E+00 | 2.59E+00 | 6.19E−01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | meanDE | 1.39E+00 | 2.94E+00 | 1.70E+00 | 1.82E+00 | 4.66E−01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | DA2MODE | 5.46E−01 | 8.23E−01 | 6.77E−01 | **6.79E−01** | 7.27E−02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| F5 | MDE | 3.45E+03 | 2.21E+05 | 6.45E+04 | 6.30E+04 | 6.05E+04 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | WDE | 4.28E+02 | 5.19E+02 | 4.77E+02 | 4.68E+02 | 3.59E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | EODE | 4.47E+02 | 1.37E+03 | 6.69E+02 | 7.55E+02 | 3.31E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | MTDE | 1.72E+01 | 3.40E+02 | 1.30E+02 | 1.28E+02 | 1.21E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | mDEW | 1.92E+02 | 2.92E+02 | 2.12E+02 | 2.27E+02 | 4.11E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | BSD | 1.81E+03 | 5.10E+04 | 1.36E+04 | 2.02E+04 | 1.93E+04 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | QRDE | 3.75E+04 | 2.87E+05 | 1.29E+05 | 1.52E+05 | 9.37E+04 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | BDE | 1.77E+02 | 2.57E+03 | 4.23E+02 | 5.57E+02 | 4.91E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | dFDBLSHADE | 1.47E+03 | 1.25E+04 | 2.43E+03 | 5.27E+03 | 4.18E+03 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | BeSD | 1.30E+02 | 3.38E+02 | 2.68E+02 | 2.46E+02 | 7.97E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | JADEGMO | 7.57E+02 | 1.97E+03 | 1.25E+03 | 1.22E+03 | 2.32E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | JADE | 4.96E+02 | 5.10E+03 | 1.85E+03 | 2.44E+03 | 1.66E+03 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | meanDE | 4.93E+01 | 8.87E+02 | 4.58E+02 | 4.20E+02 | 2.78E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | DA2MODE | 3.40E+00 | 1.65E+02 | 2.37E+01 | **3.96E+01** | 4.51E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| F6 | MDE | 9.52E−01 | 7.70E+00 | 2.19E+00 | 4.29E+00 | 3.08E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | WDE | 1.78E+00 | 1.94E+00 | 1.78E+00 | 1.84E+00 | 7.15E−02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | EODE | 2.57E+01 | 1.96E+02 | 2.71E+01 | 7.17E+01 | 7.60E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | MTDE | 2.03E+00 | 1.30E+01 | 7.06E+00 | 7.12E+00 | 4.85E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | mDEW | 1.09E+00 | 1.59E+00 | 1.56E+00 | 1.44E+00 | 2.15E−01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | BSD | 1.28E+00 | 1.98E+00 | 1.54E+00 | 1.53E+00 | 1.98E−01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | QRDE | 2.99E+01 | 2.99E+02 | 5.64E+01 | 1.13E+02 | 1.10E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | BDE | 2.65E−01 | 1.29E+00 | 6.02E−01 | **6.45E−01** | 3.97E−01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | dFDBLSHADE | 4.47E−01 | 6.43E+00 | 7.07E−01 | 2.15E+00 | 2.63E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | BeSD | 1.67E+00 | 2.14E+00 | 1.74E+00 | 1.87E+00 | 1.85E−01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | JADEGMO | 1.38E+01 | 3.82E+02 | 2.36E+02 | 2.23E+02 | 9.91E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | JADE | 1.82E+01 | 3.65E+02 | 6.44E+01 | 7.89E+01 | 7.53E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | meanDE | 2.57E+00 | 1.22E+02 | 1.21E+02 | 6.59E+01 | 6.02E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | DA2MODE | 6.61E−01 | 3.58E+00 | 1.89E+00 | 1.95E+00 | 6.13E−01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |

(*continued on next page*)

**Table B.8** (*continued*).

| Fun | Alg. | Error | | | | | Function evaluations | | | | | SR (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No. | Name | Best | Worst | Median | Mean | SD | Best | Worst | Median | Mean | SD | |
| F7 | MDE | 4.72E+02 | 1.46E+04 | 7.79E+03 | 8.07E+03 | 4.60E+03 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | WDE | 4.90E+01 | 2.16E+02 | 2.11E+02 | 1.73E+02 | 6.42E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | EODE | 4.18E+01 | 3.42E+02 | 2.73E+02 | 1.95E+02 | 1.23E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | MTDE | 8.87E+00 | 1.18E+02 | 1.73E+01 | 5.28E+01 | 4.57E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | mDEW | 6.17E+00 | 6.67E+01 | 1.41E+01 | 2.36E+01 | 2.24E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | BSD | 6.83E+02 | 8.21E+03 | 2.44E+03 | 3.42E+03 | 2.66E+03 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | QRDE | 3.31E+03 | 1.36E+06 | 6.07E+03 | 3.90E+05 | 5.97E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | BDE | 9.23E+01 | 7.87E+02 | 2.89E+02 | 3.12E+02 | 2.56E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | dFDBLSHADE | 1.87E+02 | 5.06E+02 | 3.13E+02 | 3.21E+02 | 1.23E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | BeSD | 3.43E+01 | 1.37E+02 | 5.36E+01 | 6.62E+01 | 3.73E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | JADEGMO | 4.37E+01 | 2.27E+05 | 6.15E+02 | 3.08E+04 | 7.81E+04 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | JADE | 1.39E+02 | 1.11E+03 | 4.55E+02 | 5.61E+02 | 3.12E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | meanDE | 1.74E+02 | 3.41E+02 | 2.76E+02 | 2.49E+02 | 6.32E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | DA2MODE | 5.26E−01 | 1.85E+01 | 1.15E+00 | **2.24E+00** | 3.31E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| F8 | MDE | 1.00E+02 | 1.01E+02 | 1.00E+02 | 1.00E+02 | 2.12E−01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | WDE | 9.17E+01 | 1.01E+02 | 1.00E+02 | 9.81E+01 | 3.95E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | EODE | 1.00E+02 | 2.46E+03 | 1.00E+02 | 2.57E+02 | 5.99E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | MTDE | 1.00E+02 | 1.00E+02 | 1.00E+02 | 1.00E+02 | 1.85E−13 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | mDEW | 1.00E+02 | 1.00E+02 | 1.00E+02 | 1.00E+02 | 0.00E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | BSD | 2.03E−02 | 1.00E+02 | 1.00E+02 | **7.59E+01** | 3.92E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | QRDE | 1.00E+02 | 1.00E+02 | 1.00E+02 | 1.00E+02 | 3.38E−13 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | BDE | 1.00E+02 | 1.01E+02 | 1.00E+02 | 1.00E+02 | 5.40E−01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | dFDBLSHADE | 1.00E+02 | 1.03E+02 | 1.02E+02 | 1.01E+02 | 9.62E−01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | BeSD | 1.00E+02 | 1.00E+02 | 1.00E+02 | 1.00E+02 | 0.00E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | JADEGMO | 1.00E+02 | 2.74E+03 | 1.01E+02 | 2.45E+02 | 5.01E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | JADE | 1.00E+02 | 1.02E+02 | 1.01E+02 | 1.01E+02 | 9.08E−01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | meanDE | 1.00E+02 | 1.01E+02 | 1.00E+02 | 1.00E+02 | 5.16E−01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | DA2MODE | 1.00E+02 | 1.00E+02 | 1.00E+02 | 1.00E+02 | 8.30E−14 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| F9 | MDE | 4.26E+02 | 4.56E+02 | 4.43E+02 | 4.42E+02 | 1.13E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | WDE | 1.01E+02 | 4.53E+02 | 1.02E+02 | **2.63E+02** | 1.76E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | EODE | 4.03E+02 | 4.26E+02 | 4.24E+02 | 4.17E+02 | 9.88E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | MTDE | 4.07E+02 | 4.33E+02 | 4.18E+02 | 4.19E+02 | 9.57E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | mDEW | 2.00E+02 | 4.43E+02 | 4.33E+02 | 3.69E+02 | 1.04E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | BSD | 1.00E+02 | 4.29E+02 | 4.17E+02 | 3.55E+02 | 1.30E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | QRDE | 4.35E+02 | 4.70E+02 | 4.50E+02 | 4.50E+02 | 1.24E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | BDE | 4.22E+02 | 4.43E+02 | 4.34E+02 | 4.32E+02 | 7.63E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | dFDBLSHADE | 4.01E+02 | 4.09E+02 | 4.05E+02 | 4.05E+02 | 3.12E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | BeSD | 3.77E+02 | 4.27E+02 | 4.06E+02 | 4.00E+02 | 1.51E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | JADEGMO | 4.46E+02 | 5.76E+02 | 4.67E+02 | 4.77E+02 | 3.64E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | JADE | 4.27E+02 | 4.84E+02 | 4.37E+02 | 4.45E+02 | 2.12E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | meanDE | 3.95E+02 | 4.14E+02 | 4.13E+02 | 4.08E+02 | 6.89E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | DA2MODE | 4.02E+02 | 4.07E+02 | 4.04E+02 | 4.04E+02 | 1.29E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| F10 | MDE | 4.14E+02 | 4.91E+02 | 4.14E+02 | 4.30E+02 | 2.72E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | WDE | 3.99E+02 | 4.01E+02 | 4.00E+02 | 4.00E+02 | 8.29E−01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | EODE | 4.14E+02 | 4.95E+02 | 4.14E+02 | 4.22E+02 | 2.48E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | MTDE | 4.14E+02 | 4.14E+02 | 4.14E+02 | 4.14E+02 | 1.49E−02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | mDEW | 1.00E+02 | 4.10E+02 | 3.99E+02 | **3.24E+02** | 1.37E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | BSD | 4.61E+02 | 4.96E+02 | 4.93E+02 | 4.86E+02 | 1.54E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | QRDE | 4.14E+02 | 4.14E+02 | 4.14E+02 | 4.14E+02 | 5.06E−02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | BDE | 3.99E+02 | 4.14E+02 | 4.14E+02 | 4.10E+02 | 6.39E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | dFDBLSHADE | 4.14E+02 | 4.62E+02 | 4.14E+02 | 4.27E+02 | 2.15E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | BeSD | 4.48E+02 | 4.93E+02 | 4.60E+02 | 4.72E+02 | 2.00E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | JADEGMO | 4.10E+02 | 4.62E+02 | 4.14E+02 | 4.35E+02 | 2.48E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | JADE | 4.11E+02 | 4.75E+02 | 4.14E+02 | 4.37E+02 | 2.69E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | meanDE | 4.14E+02 | 4.88E+02 | 4.27E+02 | 4.34E+02 | 1.94E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | DA2MODE | 4.06E+02 | 4.06E+02 | 4.06E+02 | 4.06E+02 | 5.82E−03 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| F11 | MDE | 0.00E+00 | 0.00E+00 | 0.00E+00 | **0.00E+00** | 0.00E+00 | 2.97E+05 | 3.72E+05 | 3.25E+05 | 3.33E+05 | 2.26E+04 | 100.00 |
| | WDE | 3.25E+00 | 6.41E+00 | 5.53E+00 | 4.99E+00 | 1.17E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | EODE | 0.00E+00 | 0.00E+00 | 0.00E+00 | **0.00E+00** | 0.00E+00 | 1.54E+05 | 1.74E+05 | 1.66E+05 | 1.64E+05 | 6.85E+03 | 100.00 |
| | MTDE | 0.00E+00 | 0.00E+00 | 0.00E+00 | **0.00E+00** | 0.00E+00 | 1.33E+05 | 1.48E+05 | 1.38E+05 | 1.38E+05 | 3.90E+03 | 100.00 |
| | mDEW | 0.00E+00 | 0.00E+00 | 0.00E+00 | **0.00E+00** | 0.00E+00 | 2.74E+05 | 2.96E+05 | 2.90E+05 | 2.84E+05 | 9.70E+03 | 100.00 |
| | BSD | 0.00E+00 | 1.45E−06 | 0.00E+00 | 3.99E−07 | 6.48E−07 | 4.87E+05 | 5.00E+05 | 4.94E+05 | 4.95E+05 | 5.48E+03 | 53.33 |
| | QRDE | 0.00E+00 | 0.00E+00 | 0.00E+00 | **0.00E+00** | 0.00E+00 | 2.96E+05 | 3.32E+05 | 3.00E+05 | 3.09E+05 | 1.49E+04 | 100.00 |
| | BDE | 0.00E+00 | 0.00E+00 | 0.00E+00 | **0.00E+00** | 0.00E+00 | 2.60E+05 | 3.24E+05 | 2.95E+05 | 2.92E+05 | 2.25E+04 | 100.00 |
| | dFDBLSHADE | 0.00E+00 | 1.62E−08 | 0.00E+00 | 4.31E−09 | 7.27E−09 | 3.87E+05 | 5.00E+05 | 3.95E+05 | 4.31E+05 | 4.71E+04 | 73.33 |
| | BeSD | 0.00E+00 | 0.00E+00 | 0.00E+00 | **0.00E+00** | 0.00E+00 | 2.85E+05 | 3.52E+05 | 3.24E+05 | 3.30E+05 | 1.69E+04 | 100.00 |
| | JADEGMO | 1.35E−03 | 5.70E+02 | 7.56E−01 | 1.63E+02 | 2.40E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | JADE | 0.00E+00 | 1.20E+03 | 0.00E+00 | 2.64E+02 | 4.59E+02 | 3.88E+04 | 5.00E+05 | 4.55E+04 | 1.66E+05 | 2.05E+05 | 73.33 |
| | meanDE | 0.00E+00 | 0.00E+00 | 0.00E+00 | **0.00E+00** | 0.00E+00 | 3.22E+05 | 3.39E+05 | 3.39E+05 | 3.32E+05 | 7.93E+03 | 100.00 |
| | DA2MODE | 0.00E+00 | 0.00E+00 | 0.00E+00 | **0.00E+00** | 0.00E+00 | 7.68E+04 | 8.13E+04 | 7.87E+04 | 7.86E+04 | 9.07E+02 | 100.00 |
| F12 | MDE | 4.91E+01 | 4.91E+01 | 4.91E+01 | 4.91E+01 | 4.28E−14 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | WDE | 1.18E−01 | 3.04E+01 | 4.09E+00 | 1.05E+01 | 1.24E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | EODE | 1.38E−02 | 4.91E+01 | 4.91E+01 | 3.11E+01 | 2.40E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | MTDE | 4.49E+01 | 4.91E+01 | 4.49E+01 | 4.66E+01 | 2.09E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | mDEW | 8.13E−01 | 5.75E+00 | 5.07E+00 | 4.28E+00 | 1.91E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | BSD | 4.91E+01 | 7.16E+01 | 4.91E+01 | 5.51E+01 | 1.01E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | QRDE | 4.91E+01 | 4.91E+01 | 4.91E+01 | 4.91E+01 | 2.49E−13 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | BDE | 2.00E−06 | 4.91E+01 | 4.91E+01 | 4.42E+01 | 1.50E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | dFDBLSHADE | 4.91E+01 | 4.91E+01 | 4.91E+01 | 4.91E+01 | 8.14E−12 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | BeSD | 3.36E−03 | 4.91E+01 | 4.49E+01 | 3.33E+01 | 2.22E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | JADEGMO | 6.67E+00 | 5.35E+01 | 4.49E+01 | 3.70E+01 | 1.88E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | JADE | 4.91E+01 | 1.18E+02 | 1.00E+02 | 9.04E+01 | 2.62E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | meanDE | 6.94E−05 | 4.91E+01 | 4.03E+00 | 1.55E+01 | 2.07E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | DA2MODE | 0.00E+00 | 0.00E+00 | 0.00E+00 | **0.00E+00** | 0.00E+00 | 2.06E+05 | 2.32E+05 | 2.21E+05 | 2.21E+05 | 5.01E+03 | 100.00 |

(*continued on next page*)

**Table B.8** (*continued*).

| Fun | Alg. | Error | | | | | Function evaluations | | | | | SR (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No. | Name | Best | Worst | Median | Mean | SD | Best | Worst | Median | Mean | SD | |
| F13 | MDE | 0.00E+00 | 0.00E+00 | 0.00E+00 | **0.00E+00** | 0.00E+00 | 4.32E+04 | 1.10E+05 | 4.85E+04 | 6.24E+04 | 2.41E+04 | 100.00 |
| | WDE | 2.85E−02 | 1.13E−01 | 6.17E−02 | 6.47E−02 | 3.13E−02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | EODE | 2.54E−06 | 3.54E−04 | 5.95E−05 | 1.13E−04 | 1.49E−04 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | MTDE | 5.72E−06 | 4.98E−04 | 1.97E−04 | 1.85E−04 | 1.84E−04 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | mDEW | 0.00E+00 | 7.97E−08 | 0.00E+00 | 2.13E−08 | 3.59E−08 | 1.75E+05 | 5.00E+05 | 1.76E+05 | 2.62E+05 | 1.46E+05 | 73.33 |
| | BSD | 0.00E+00 | 0.00E+00 | 0.00E+00 | **0.00E+00** | 0.00E+00 | 7.82E+04 | 8.99E+04 | 8.16E+04 | 8.37E+04 | 4.59E+03 | 100.00 |
| | QRDE | 0.00E+00 | 0.00E+00 | 0.00E+00 | **0.00E+00** | 0.00E+00 | 3.93E+04 | 4.00E+04 | 3.97E+04 | 3.96E+04 | 2.87E+02 | 100.00 |
| | BDE | 0.00E+00 | 0.00E+00 | 0.00E+00 | **0.00E+00** | 0.00E+00 | 1.19E+05 | 1.30E+05 | 1.24E+05 | 1.24E+05 | 3.66E+03 | 100.00 |
| | dFDBLSHADE | 1.98E−03 | 3.92E−01 | 5.83E−02 | 5.54E−02 | 6.88E−02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | BeSD | 0.00E+00 | 0.00E+00 | 0.00E+00 | **0.00E+00** | 0.00E+00 | 3.16E+05 | 3.45E+05 | 3.27E+05 | 3.28E+05 | 1.23E+04 | 100.00 |
| | JADEGMO | 4.66E−02 | 1.78E+01 | 2.02E−01 | 1.60E+00 | 3.76E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | JADE | 1.11E−04 | 9.68E+00 | 7.29E−04 | 1.20E+00 | 3.14E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | meanDE | 2.87E−06 | 8.82E−04 | 1.28E−04 | 1.65E−04 | 2.52E−04 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | DA2MODE | 0.00E+00 | 0.00E+00 | 0.00E+00 | **0.00E+00** | 0.00E+00 | 1.39E+05 | 1.46E+05 | 1.44E+05 | 1.43E+05 | 1.67E+03 | 100.00 |
| F14 | MDE | 1.29E+01 | 2.19E+01 | 1.79E+01 | 1.77E+01 | 3.22E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | WDE | 4.18E+01 | 4.88E+01 | 4.68E+01 | 4.63E+01 | 2.45E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | EODE | 1.49E+01 | 4.18E+01 | 1.89E+01 | 2.18E+01 | 7.56E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | MTDE | 1.79E+01 | 3.78E+01 | 2.14E+01 | 2.56E+01 | 8.35E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | mDEW | 3.98E+01 | 4.97E+01 | 4.58E+01 | 4.47E+01 | 3.90E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | BSD | 3.18E+01 | 5.77E+01 | 4.08E+01 | 4.53E+01 | 1.05E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | QRDE | 2.39E+01 | 6.73E+01 | 3.98E+01 | 4.18E+01 | 1.58E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | BDE | 2.19E+01 | 3.58E+01 | 2.98E+01 | 2.96E+01 | 5.19E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | dFDBLSHADE | 4.98E+00 | 7.96E+00 | 6.97E+00 | 6.57E+00 | 1.10E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | BeSD | 1.85E+01 | 2.38E+01 | 2.22E+01 | 2.17E+01 | 2.04E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | JADEGMO | 2.40E+01 | 5.05E+01 | 3.70E+01 | 3.68E+01 | 1.02E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | JADE | 2.43E+01 | 7.83E+01 | 4.72E+01 | 4.76E+01 | 1.87E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | meanDE | 7.96E+00 | 1.99E+01 | 1.69E+01 | 1.45E+01 | 4.86E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | DA2MODE | 9.95E−01 | 4.98E+00 | 3.48E+00 | **3.28E+00** | 1.28E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| F15 | MDE | 0.00E+00 | 4.24E+00 | 1.79E−01 | 5.04E−01 | 8.20E−01 | 9.86E+04 | 5.00E+05 | 5.00E+05 | 4.06E+05 | 1.73E+05 | 23.33 |
| | WDE | 7.24E+02 | 9.24E+02 | 7.85E+02 | 8.18E+02 | 7.74E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | EODE | 0.00E+00 | 0.00E+00 | 0.00E+00 | **0.00E+00** | 0.00E+00 | 2.92E+04 | 4.22E+04 | 3.27E+04 | 3.44E+04 | 5.05E+03 | 100.00 |
| | MTDE | 0.00E+00 | 1.43E+00 | 0.00E+00 | 2.62E−01 | 5.32E−01 | 1.06E+05 | 5.00E+05 | 1.18E+05 | 2.80E+05 | 1.96E+05 | 56.67 |
| | mDEW | 0.00E+00 | 0.00E+00 | 0.00E+00 | **0.00E+00** | 0.00E+00 | 1.87E+05 | 2.13E+05 | 2.00E+05 | 2.01E+05 | 9.80E+03 | 100.00 |
| | BSD | 5.87E+01 | 2.10E+02 | 1.08E+02 | 1.16E+02 | 5.23E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | QRDE | 0.00E+00 | 0.00E+00 | 0.00E+00 | **0.00E+00** | 0.00E+00 | 3.38E+04 | 3.95E+04 | 3.42E+04 | 3.54E+04 | 2.06E+03 | 100.00 |
| | BDE | 8.95E−02 | 6.15E+00 | 1.45E+00 | 2.52E+00 | 2.19E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | dFDBLSHADE | 1.18E+00 | 1.09E+01 | 3.16E+00 | 4.19E+00 | 3.64E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | BeSD | 0.00E+00 | 0.00E+00 | 0.00E+00 | **0.00E+00** | 0.00E+00 | 2.33E+05 | 2.67E+05 | 2.46E+05 | 2.48E+05 | 1.21E+04 | 100.00 |
| | JADEGMO | 1.79E−01 | 2.14E+01 | 1.82E+00 | 4.32E+00 | 5.65E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | JADE | 6.33E−01 | 1.58E+02 | 1.79E+00 | 3.71E+01 | 5.21E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | meanDE | 0.00E+00 | 5.44E−01 | 0.00E+00 | 1.45E−01 | 2.45E−01 | 3.09E+05 | 5.00E+05 | 3.99E+05 | 4.02E+05 | 9.24E+04 | 73.33 |
| | DA2MODE | 0.00E+00 | 0.00E+00 | 0.00E+00 | **0.00E+00** | 0.00E+00 | 6.96E+04 | 7.34E+04 | 7.11E+04 | 7.11E+04 | 8.57E+02 | 100.00 |
| F16 | MDE | 1.00E+02 | 7.38E+03 | 1.63E+02 | 3.07E+03 | 3.28E+03 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | WDE | 1.24E+01 | 2.10E+01 | 1.78E+01 | 1.68E+01 | 3.23E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | EODE | 1.18E+02 | 6.71E+03 | 2.90E+03 | 3.27E+03 | 2.46E+03 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | MTDE | 3.12E+00 | 7.20E+01 | 3.03E+01 | 3.47E+01 | 2.20E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | mDEW | 1.44E+01 | 3.80E+01 | 2.13E+01 | 2.28E+01 | 8.26E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | BSD | 7.03E+01 | 3.16E+03 | 9.12E+02 | 1.15E+03 | 1.29E+03 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | QRDE | 5.64E+01 | 2.30E+04 | 1.84E+04 | 1.18E+04 | 9.92E+03 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | BDE | 3.36E+01 | 1.38E+03 | 7.74E+01 | 4.22E+02 | 5.82E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | dFDBLSHADE | 3.07E+01 | 9.46E+01 | 7.53E+01 | 6.38E+01 | 2.45E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | BeSD | 9.35E+00 | 6.36E+01 | 3.01E+01 | 3.36E+01 | 1.92E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | JADEGMO | 8.96E+01 | 4.10E+02 | 2.05E+02 | 2.20E+02 | 1.04E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | JADE | 8.97E+00 | 2.01E+04 | 6.31E+01 | 4.81E+03 | 7.01E+03 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | meanDE | 2.82E+01 | 7.43E+01 | 4.43E+01 | 4.96E+01 | 1.95E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | DA2MODE | 2.81E−01 | 2.28E+00 | 4.77E−01 | **5.62E−01** | 4.14E−01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| F17 | MDE | 2.63E+01 | 4.57E+01 | 3.23E+01 | 3.40E+01 | 7.54E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | WDE | 2.29E+01 | 3.00E+01 | 2.53E+01 | 2.59E+01 | 2.73E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | EODE | 2.26E+01 | 3.81E+01 | 3.02E+01 | 2.92E+01 | 6.19E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | MTDE | 2.11E+01 | 2.80E+01 | 2.20E+01 | 2.38E+01 | 2.50E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | mDEW | 1.31E+00 | 2.44E+01 | 1.11E+01 | 1.27E+01 | 9.23E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | BSD | 1.33E+01 | 2.58E+01 | 2.32E+01 | 2.13E+01 | 4.20E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | QRDE | 2.61E+01 | 6.46E+01 | 4.60E+01 | 4.64E+01 | 1.44E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | BDE | 2.30E+00 | 2.10E+01 | 4.29E+00 | **8.35E+00** | 7.82E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | dFDBLSHADE | 5.47E+00 | 2.47E+01 | 1.20E+01 | 1.43E+01 | 7.31E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | BeSD | 1.39E+01 | 2.61E+01 | 2.44E+01 | 2.20E+01 | 5.00E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | JADEGMO | 2.46E+01 | 5.41E+01 | 4.89E+01 | 4.16E+01 | 1.06E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | JADE | 2.78E+01 | 1.31E+02 | 5.12E+01 | 6.56E+01 | 3.84E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | meanDE | 2.02E+01 | 2.95E+01 | 2.24E+01 | 2.47E+01 | 3.27E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | DA2MODE | 2.01E+00 | 2.09E+01 | 1.70E+01 | 1.27E+01 | 8.06E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| F18 | MDE | 2.05E+01 | 2.15E+01 | 2.10E+01 | 2.10E+01 | 3.90E−01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | WDE | 2.06E+01 | 2.09E+01 | 2.08E+01 | 2.07E+01 | 9.16E−02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | EODE | 2.18E+01 | 2.58E+01 | 2.26E+01 | 2.33E+01 | 1.60E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | MTDE | 2.04E+01 | 2.12E+01 | 2.10E+01 | 2.08E+01 | 3.56E−01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | mDEW | 2.05E+01 | 2.13E+01 | 2.08E+01 | 2.08E+01 | 1.68E−01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | BSD | 2.06E+01 | 2.12E+01 | 2.09E+01 | 2.09E+01 | 2.53E−01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | QRDE | 2.32E+01 | 2.97E+01 | 2.43E+01 | 2.51E+01 | 2.38E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | BDE | 2.04E+01 | 2.10E+01 | 2.08E+01 | 2.07E+01 | 2.36E−01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | dFDBLSHADE | 9.85E+00 | 2.09E+01 | 2.03E+01 | 1.87E+01 | 4.03E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | BeSD | 2.11E+01 | 2.18E+01 | 2.17E+01 | 2.15E+01 | 2.64E−01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | JADEGMO | 2.50E+01 | 3.82E+01 | 2.66E+01 | 2.88E+01 | 5.09E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | JADE | 2.31E+01 | 2.77E+01 | 2.63E+01 | 2.55E+01 | 1.75E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | meanDE | 1.29E+00 | 2.19E+01 | 2.15E+01 | **1.62E+01** | 9.14E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | DA2MODE | 1.42E+01 | 2.09E+01 | 2.06E+01 | 1.98E+01 | 1.86E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |

(*continued on next page*)

**Table B.8** (*continued*).

| Fun | Alg. | Error | | | | | Function evaluations | | | | | SR (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No. | Name | Best | Worst | Median | Mean | SD | Best | Worst | Median | Mean | SD | |
| F19 | MDE | 1.81E+02 | 1.81E+02 | 1.81E+02 | 1.81E+02 | 2.25E−13 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | WDE | 1.00E+02 | 1.81E+02 | 1.00E+02 | **1.38E+02** | 4.09E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | EODE | 1.81E+02 | 1.81E+02 | 1.81E+02 | 1.81E+02 | 8.67E−14 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | MTDE | 1.81E+02 | 1.81E+02 | 1.81E+02 | 1.81E+02 | 5.06E−13 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | mDEW | 1.00E+02 | 1.81E+02 | 1.81E+02 | 1.75E+02 | 2.05E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | BSD | 1.81E+02 | 1.81E+02 | 1.81E+02 | 1.81E+02 | 2.33E−13 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | QRDE | 1.81E+02 | 1.81E+02 | 1.81E+02 | 1.81E+02 | 5.27E−04 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | BDE | 1.81E+02 | 1.81E+02 | 1.81E+02 | 1.81E+02 | 2.02E−13 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | dFDBLSHADE | 1.81E+02 | 1.81E+02 | 1.81E+02 | 1.81E+02 | 3.94E−13 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | BeSD | 1.81E+02 | 1.81E+02 | 1.81E+02 | 1.81E+02 | 2.05E−13 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | JADEGMO | 1.81E+02 | 1.81E+02 | 1.81E+02 | 1.81E+02 | 2.26E−04 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | JADE | 1.81E+02 | 2.27E+02 | 1.81E+02 | 2.01E+02 | 2.35E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | meanDE | 1.81E+02 | 1.81E+02 | 1.81E+02 | 1.81E+02 | 8.67E−02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | DA2MODE | 1.65E+02 | 1.65E+02 | 1.65E+02 | 1.65E+02 | 0.00E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| F20 | MDE | 1.27E+01 | 1.01E+02 | 1.00E+02 | 6.18E+01 | 4.22E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | WDE | 2.14E+00 | 6.62E+00 | 4.42E+00 | 4.78E+00 | 1.47E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | EODE | 1.00E+02 | 2.85E+02 | 2.34E+02 | 1.85E+02 | 8.31E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | MTDE | 1.00E+02 | 1.00E+02 | 1.00E+02 | 1.00E+02 | 4.92E−02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | mDEW | 1.56E−01 | 2.50E−01 | 2.19E−01 | **2.25E−01** | 3.11E−02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | BSD | 2.86E−01 | 1.00E+02 | 1.11E+01 | 4.04E+01 | 4.66E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | QRDE | 1.01E+02 | 2.47E+02 | 1.24E+02 | 1.48E+02 | 6.15E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | BDE | 1.00E+02 | 1.01E+02 | 1.00E+02 | 1.00E+02 | 4.75E−02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | dFDBLSHADE | 1.00E+02 | 1.00E+02 | 1.00E+02 | 1.00E+02 | 4.89E−02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | BeSD | 1.00E+02 | 1.01E+02 | 1.00E+02 | 1.00E+02 | 3.92E−02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | JADEGMO | 1.61E+02 | 3.00E+03 | 2.94E+02 | 1.18E+03 | 1.10E+03 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | JADE | 1.00E+02 | 1.97E+03 | 1.07E+02 | 5.39E+02 | 8.01E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | meanDE | 1.00E+02 | 2.27E+02 | 1.00E+02 | 1.32E+02 | 5.32E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | DA2MODE | 1.00E+02 | 1.00E+02 | 1.00E+02 | 1.00E+02 | 2.61E−02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| F21 | MDE | 3.00E+02 | 3.00E+02 | 3.00E+02 | 3.00E+02 | 2.82E−11 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | WDE | 1.04E−01 | 7.20E−01 | 2.80E−01 | 3.79E−01 | 2.30E−01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | EODE | 3.00E+02 | 4.00E+02 | 3.00E+02 | 3.10E+02 | 3.05E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | MTDE | 3.00E+02 | 4.00E+02 | 4.00E+02 | 3.73E+02 | 4.50E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | mDEW | 0.00E+00 | 1.07E−01 | 0.00E+00 | **2.13E−02** | 4.34E−02 | 2.81E+05 | 5.00E+05 | 3.08E+05 | 3.90E+05 | 1.05E+05 | 53.33 |
| | BSD | 3.40E−01 | 3.00E+02 | 1.10E+01 | 1.34E+02 | 1.48E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | QRDE | 3.00E+02 | 3.00E+02 | 3.00E+02 | 3.00E+02 | 3.48E−13 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | BDE | 3.00E+02 | 4.00E+02 | 3.00E+02 | 3.47E+02 | 5.07E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | dFDBLSHADE | 0.00E+00 | 4.00E+02 | 3.00E+02 | 2.03E+02 | 1.47E+02 | 2.57E+05 | 5.00E+05 | 5.00E+05 | 4.21E+05 | 1.13E+05 | 33.33 |
| | BeSD | 3.00E+02 | 4.00E+02 | 3.00E+02 | 3.27E+02 | 4.50E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | JADEGMO | 3.00E+02 | 4.00E+02 | 3.00E+02 | 3.27E+02 | 4.50E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | JADE | 0.00E+00 | 1.43E+03 | 3.00E+02 | 3.69E+02 | 3.94E+02 | 2.15E+04 | 5.00E+05 | 5.00E+05 | 3.72E+05 | 2.15E+05 | 26.67 |
| | meanDE | 3.00E+02 | 3.01E+02 | 3.00E+02 | 3.00E+02 | 4.48E−01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | DA2MODE | 3.00E+02 | 4.00E+02 | 3.00E+02 | 3.17E+02 | 3.79E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| F22 | MDE | 2.37E+02 | 2.45E+02 | 2.37E+02 | 2.40E+02 | 3.14E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | WDE | 2.46E+02 | 2.56E+02 | 2.53E+02 | 2.52E+02 | 3.87E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | EODE | 2.33E+02 | 2.65E+02 | 2.48E+02 | 2.48E+02 | 1.00E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | MTDE | 2.34E+02 | 2.45E+02 | 2.40E+02 | 2.40E+02 | 3.60E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | mDEW | 2.40E+02 | 2.47E+02 | 2.45E+02 | 2.44E+02 | 2.73E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | BSD | 2.46E+02 | 2.72E+02 | 2.52E+02 | 2.55E+02 | 1.03E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | QRDE | 2.37E+02 | 2.57E+02 | 2.41E+02 | 2.44E+02 | 7.05E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | BDE | 2.35E+02 | 2.51E+02 | 2.40E+02 | 2.41E+02 | 6.28E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | dFDBLSHADE | 2.46E+02 | 2.57E+02 | 2.47E+02 | 2.49E+02 | 4.25E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | BeSD | 2.34E+02 | 2.47E+02 | 2.44E+02 | 2.42E+02 | 4.67E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | JADEGMO | 2.45E+02 | 3.62E+02 | 2.47E+02 | 2.74E+02 | 4.65E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | JADE | 2.46E+02 | 2.84E+02 | 2.48E+02 | 2.57E+02 | 1.62E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | meanDE | 2.35E+02 | 2.63E+02 | 2.58E+02 | 2.54E+02 | 1.10E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | DA2MODE | 2.00E+02 | 2.00E+02 | 2.00E+02 | **2.00E+02** | 2.91E−04 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |

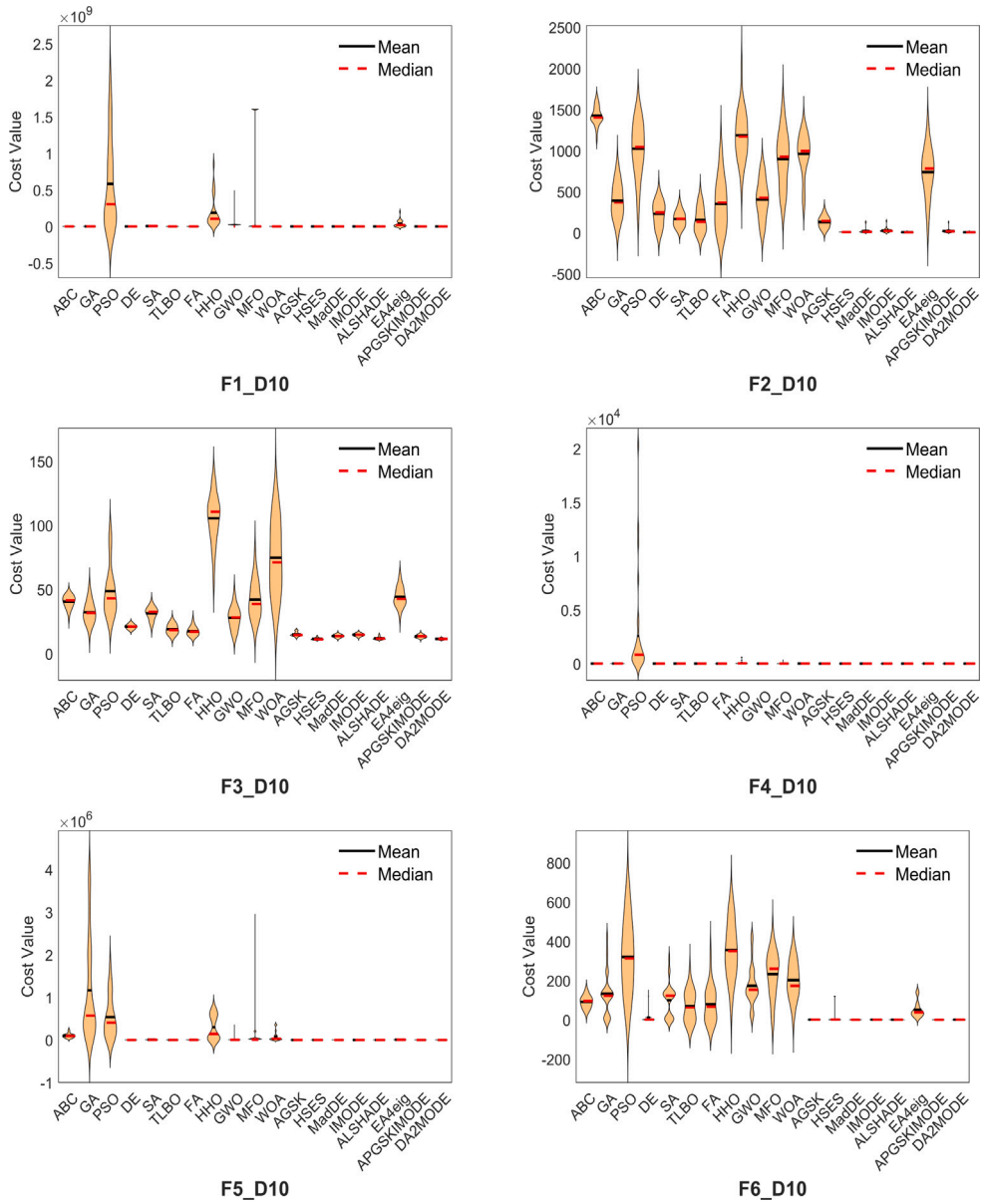



**Fig. C.1a.** Violin plots for the best fitness in 30 runs for all the algorithms in CEC2020-2022, F1–F6 (10D).

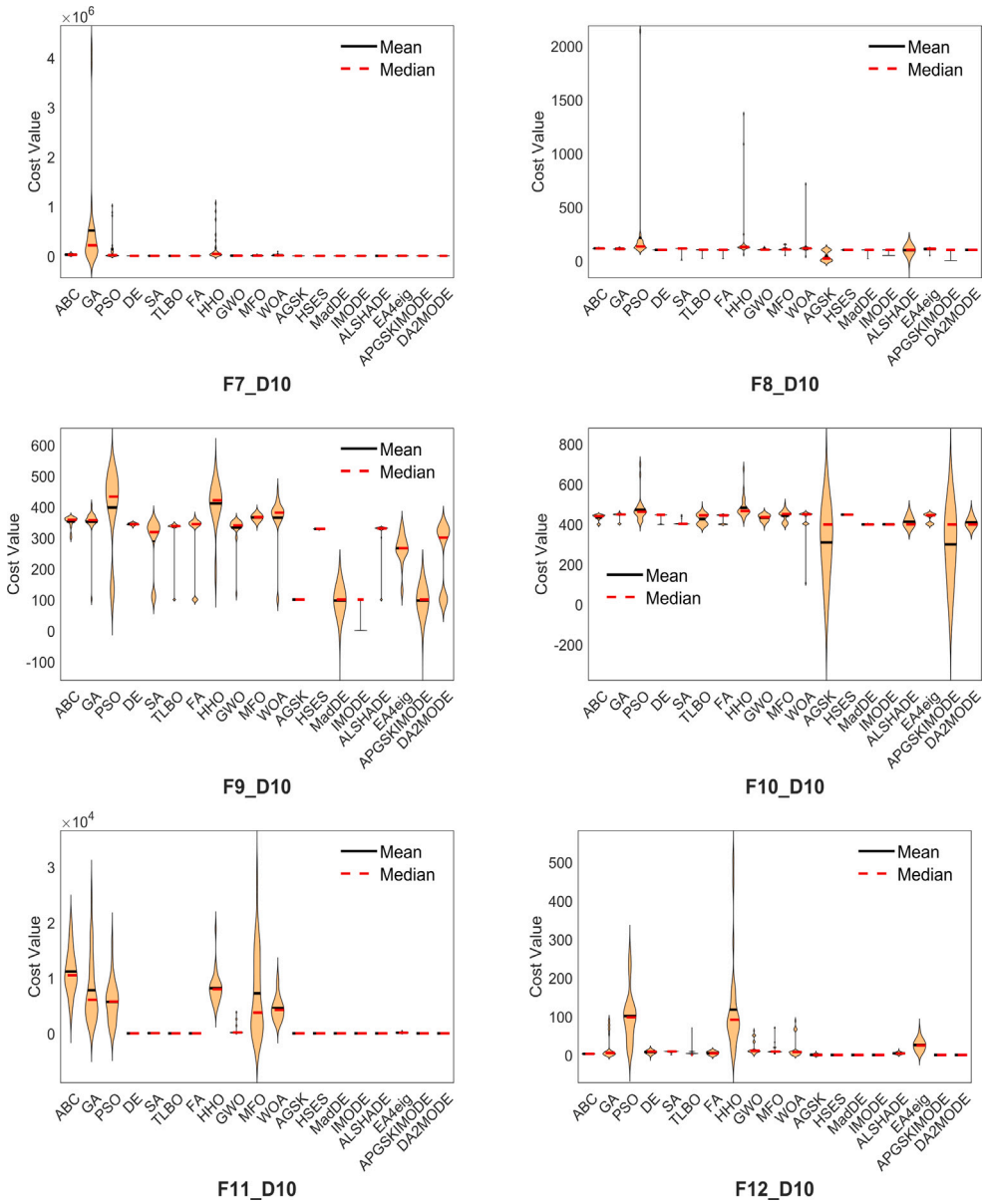



**Fig. C.1b.** Violin plots for best fitness in 30 runs for all algorithms in CEC2020-2022, F7–F12 (10D).

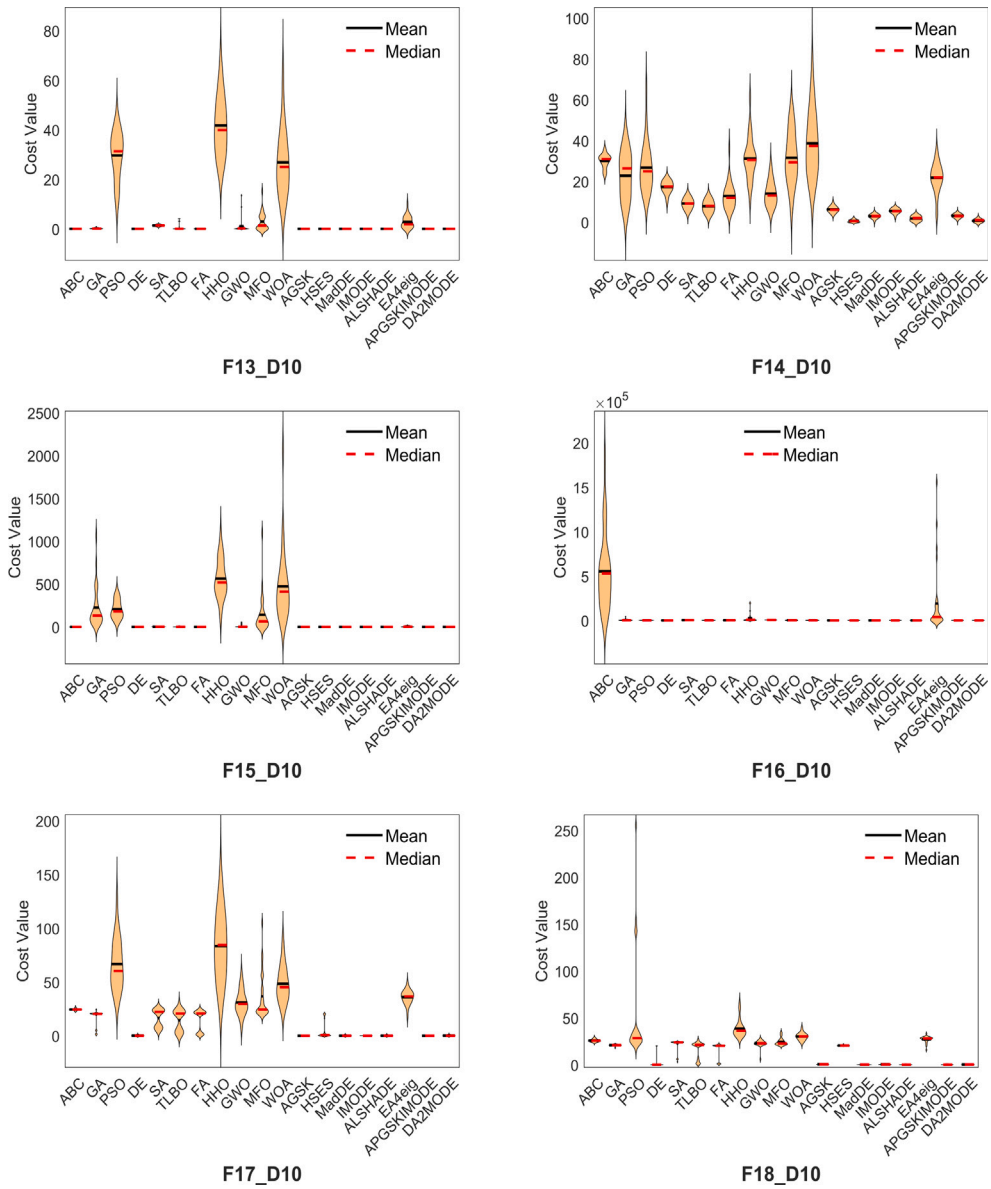



**Fig. C.1c.** Violin plots for best fitness in 30 runs for all algorithms in CEC2020-2022, F13–F18 (10D).

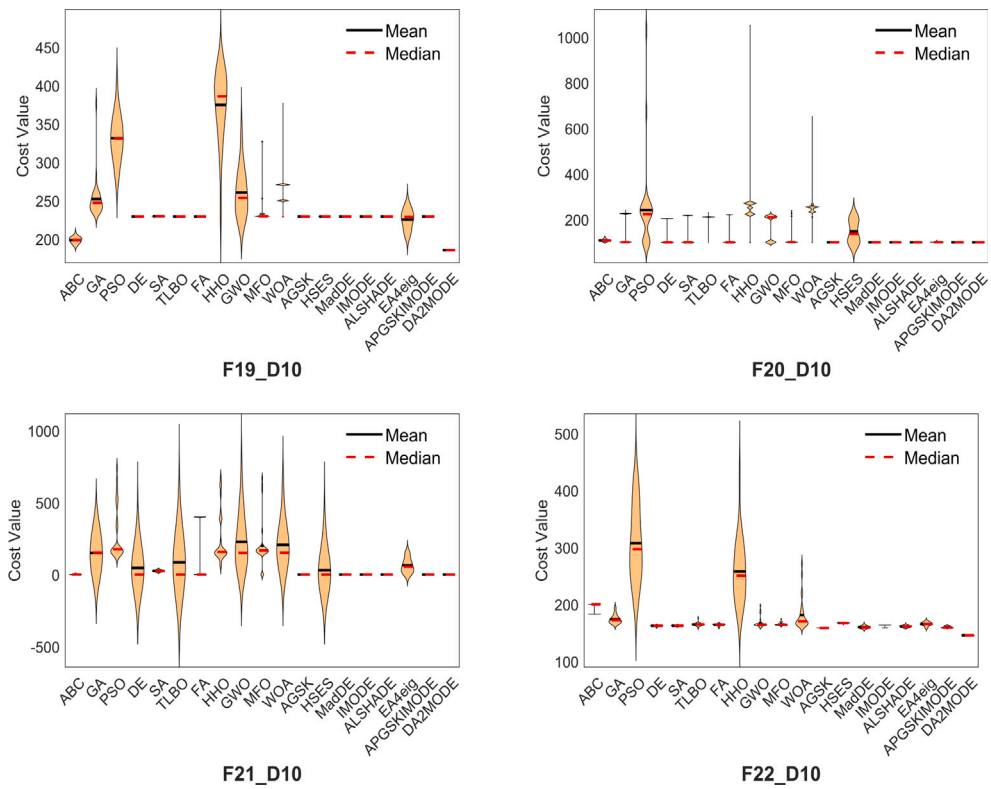



**Fig. C.1d.** Violin plots for best fitness in 30 runs for all algorithms in CEC2020-2022, F19–F12 (10D).

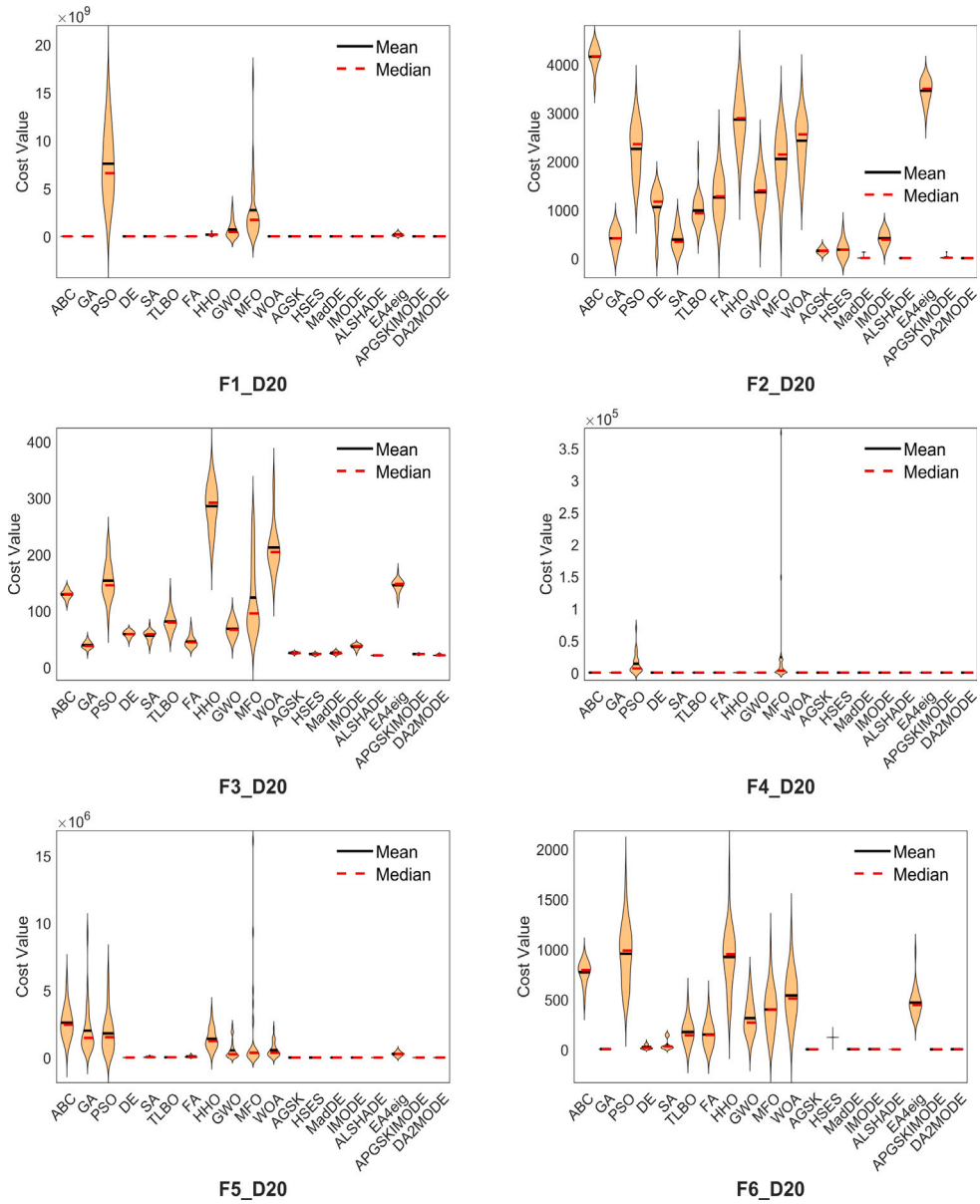



**Fig. C.2a.** Violin plots for the best fitness in 30 runs for all the algorithms in CEC2020-2022, F1-F6 (20D).

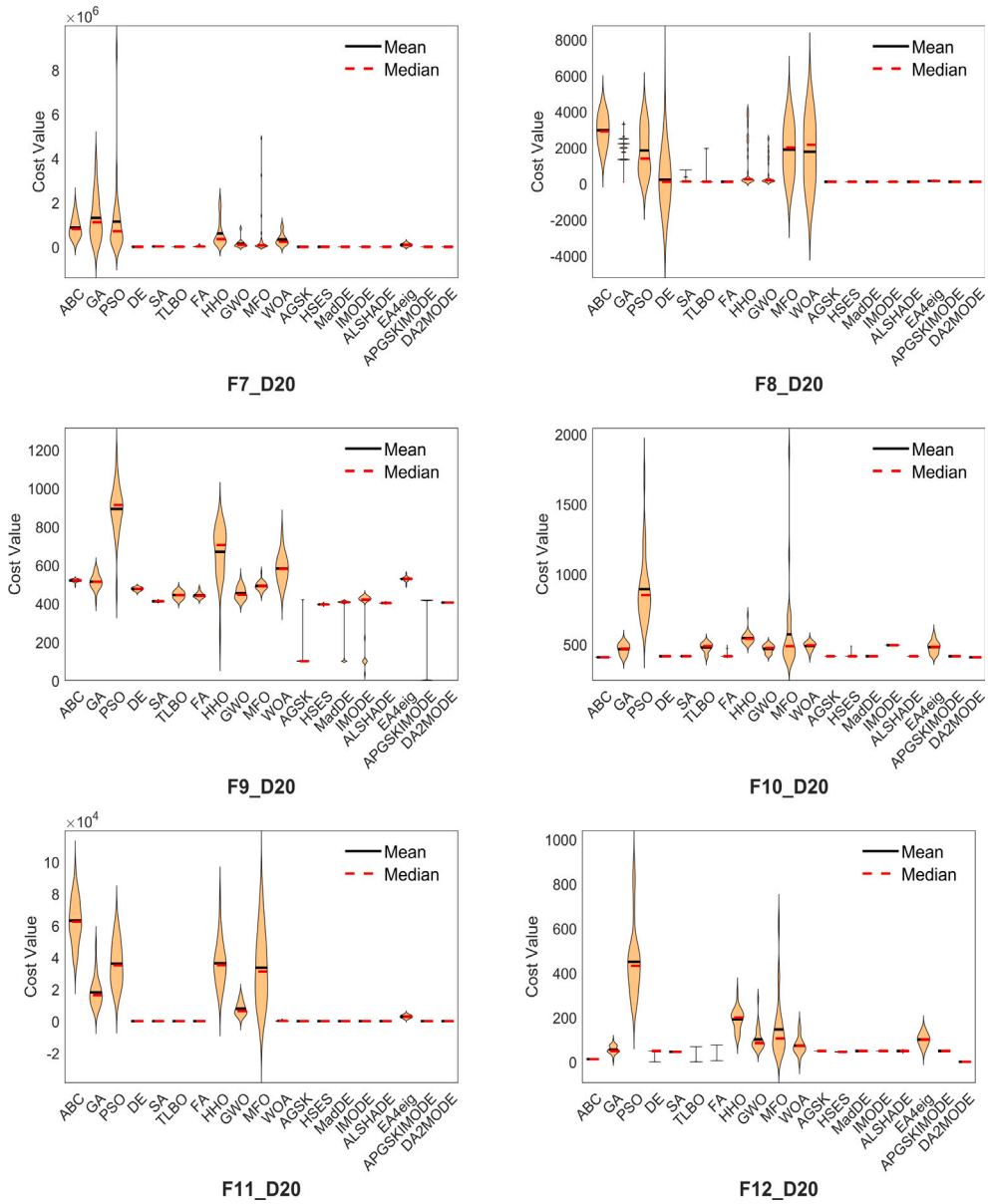



**Fig. C.2b.** Violin plots for best fitness in 30 runs for all algorithms in CEC2020-2022, F7-F12 (20D).

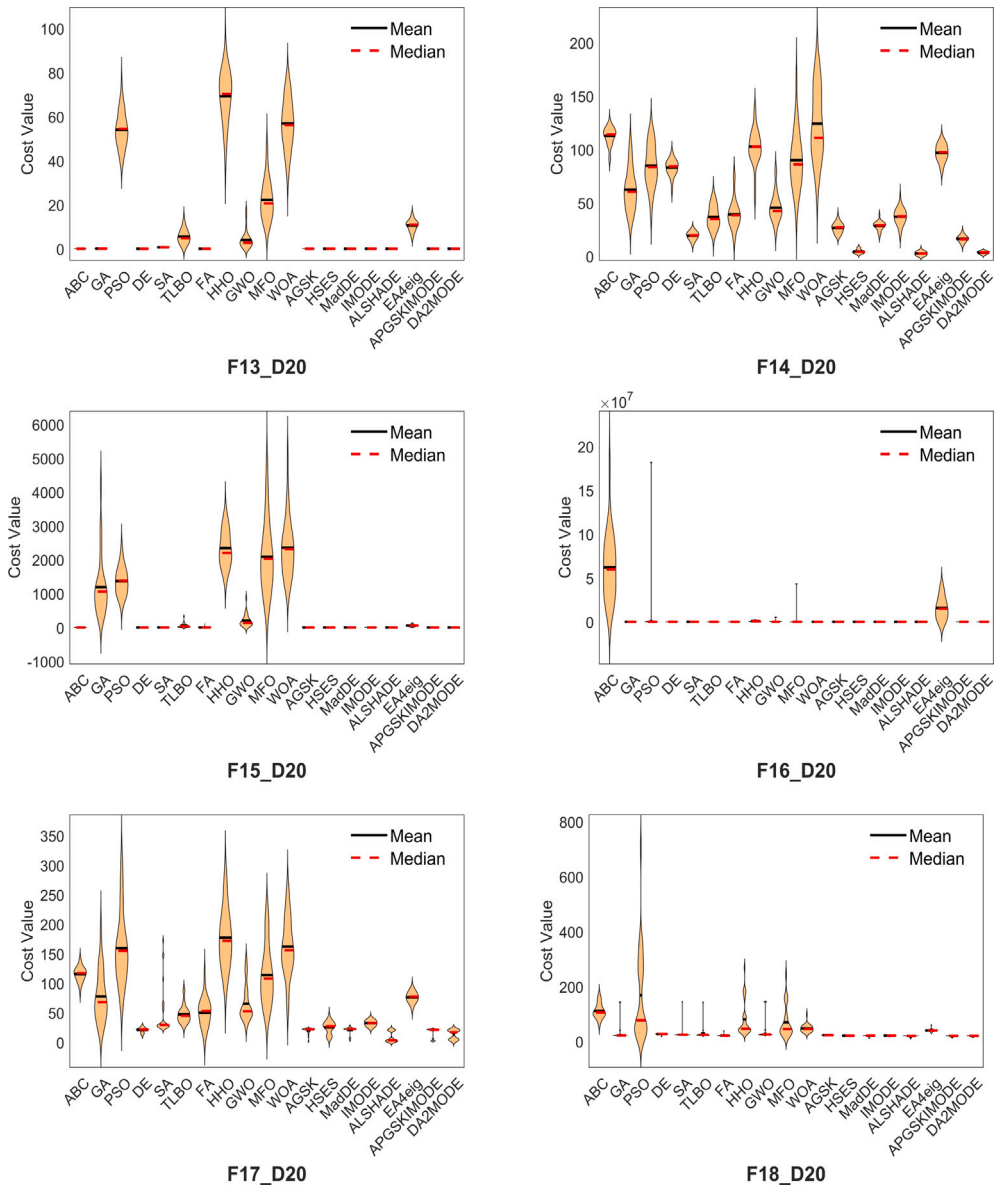



**Fig. C.2c.** Violin plots for best fitness in 30 runs for all algorithms in CEC2020-2022, F13-F18 (20D).

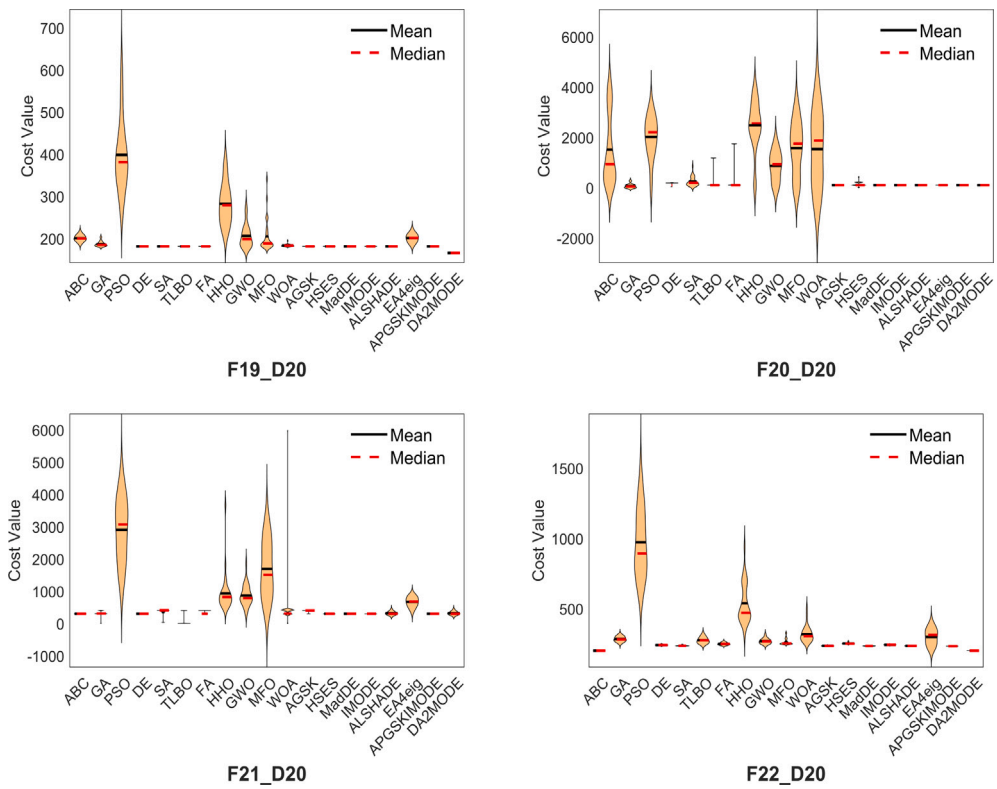



**Fig. C.2d.** Violin plots for best fitness in 30 runs for all algorithms in CEC2020-2022, F19-F22 (20D).

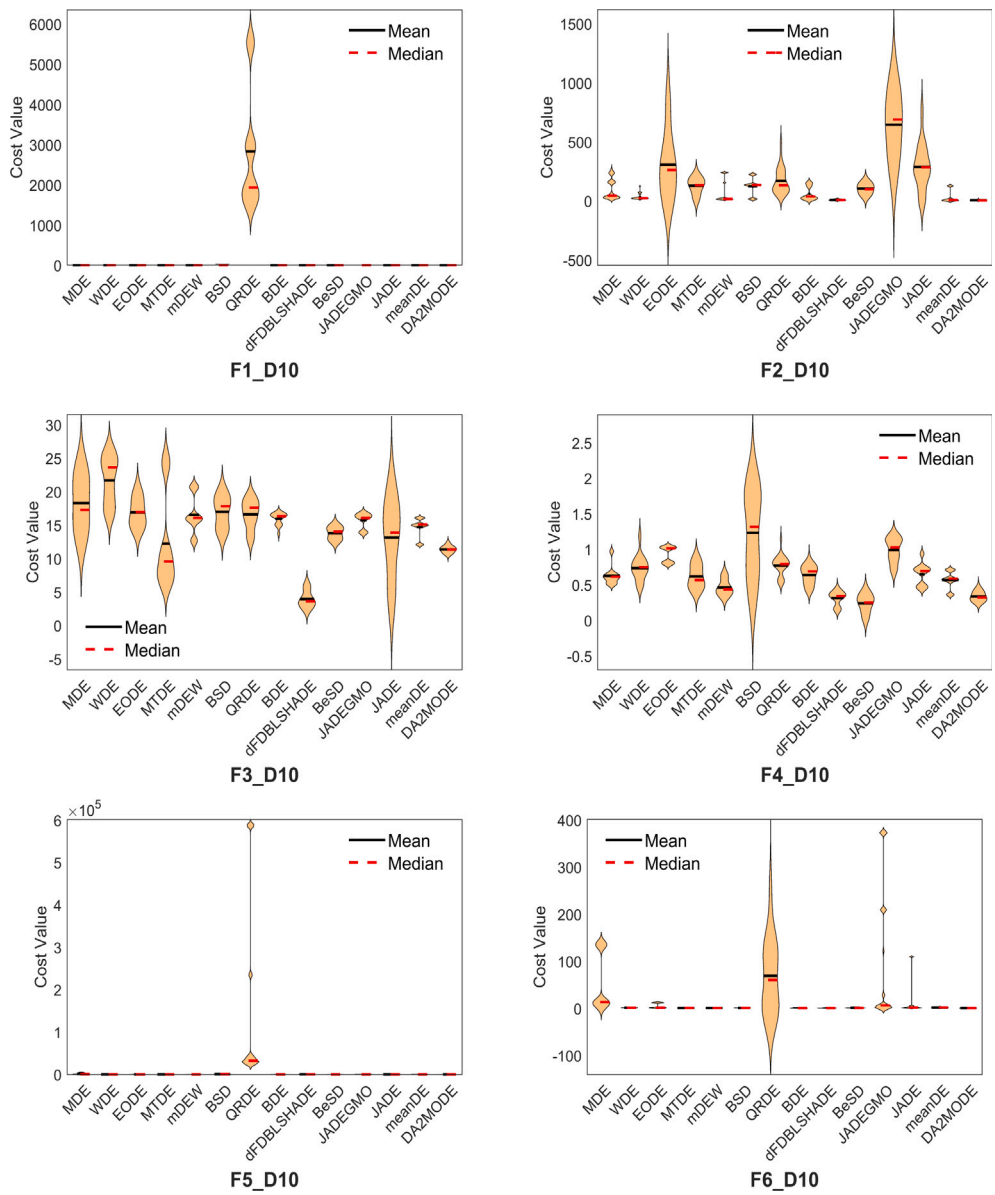



**Fig. C.3a.** Violin plots for the best fitness in 30 runs for all the 14 DE variants in CEC2020-2022, F1-F6 (10D).

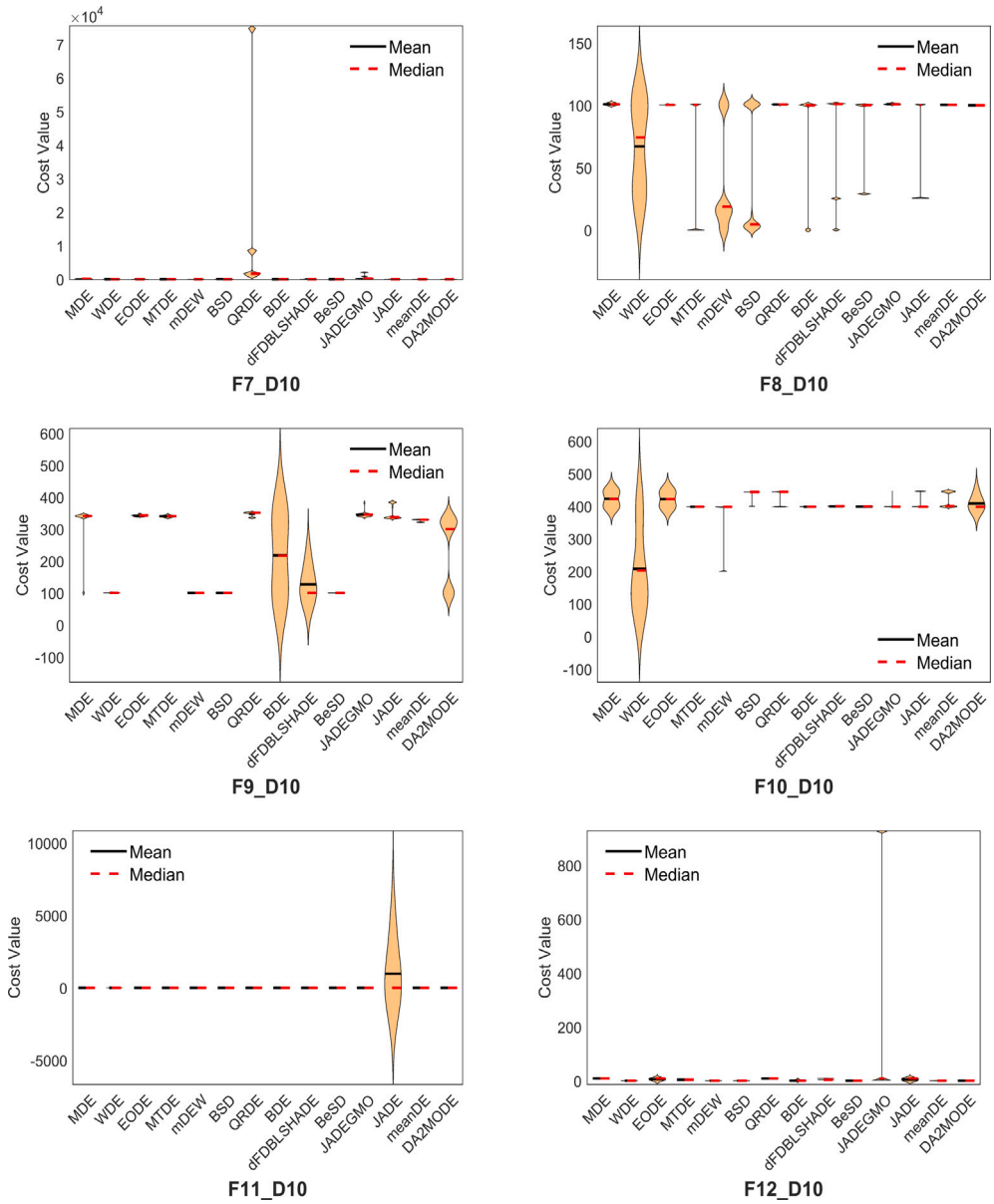



**Fig. C.3b.** Violin plots for best fitness in 30 runs for all 14 DE variants in CEC2020-2022, F7-F12 (10D).

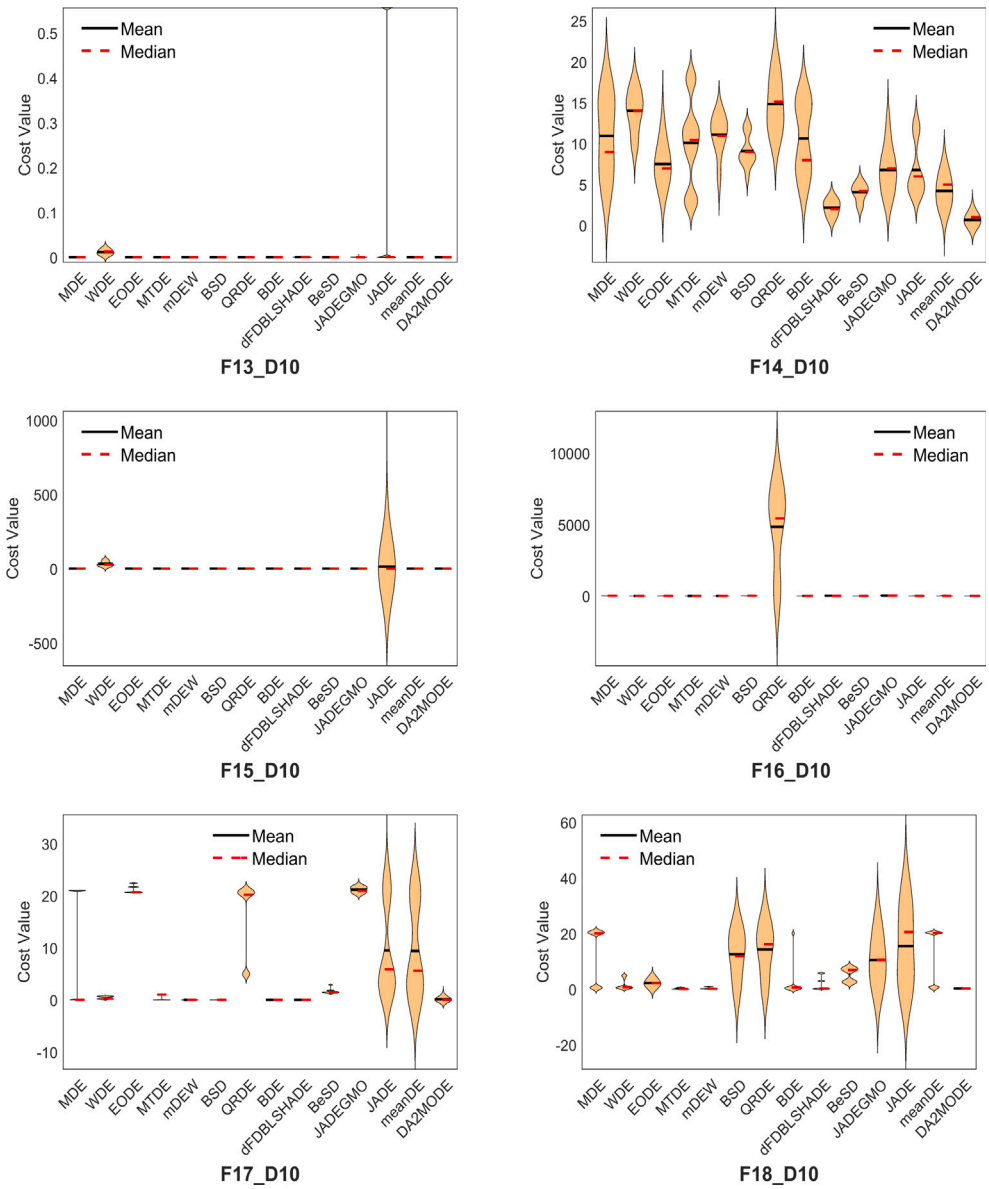



**Fig. C.3c.** Violin plots for best fitness in 30 runs for all 14 DE variants in CEC2020-2022, F13-F18 (10D).

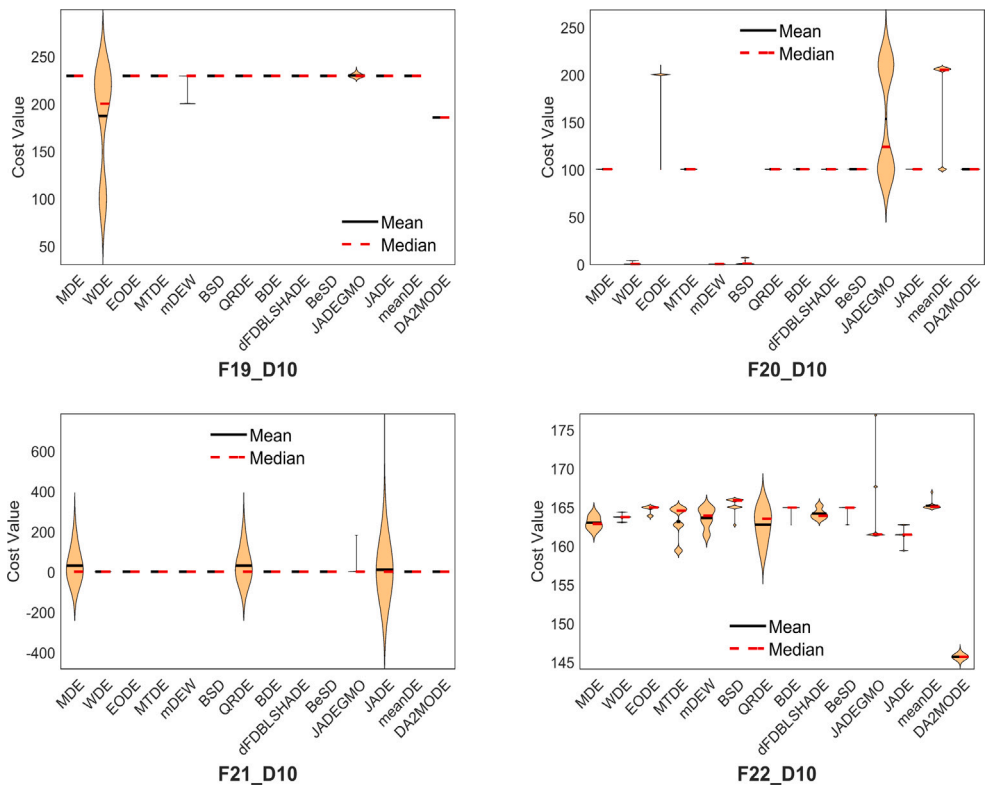



**Fig. C.3d.** Violin plots for best fitness in 30 runs for all 14 DE variants in CEC2020-2022, F19-F12 (10D).

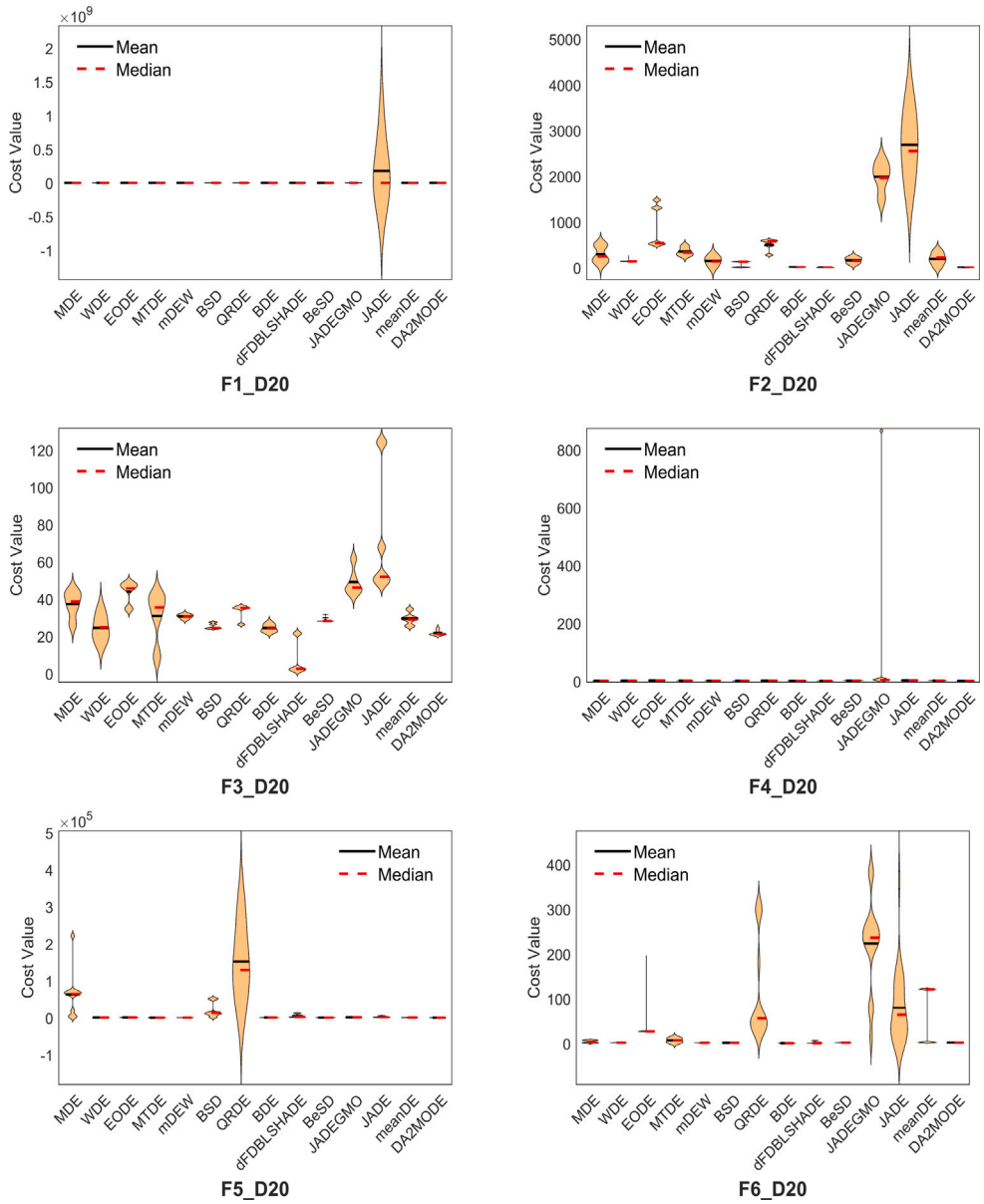



**Fig. C.4a.** Violin plots for the best fitness in 30 runs for all the 14 DE variants in CEC2020-2022, F1-F6 (20D).

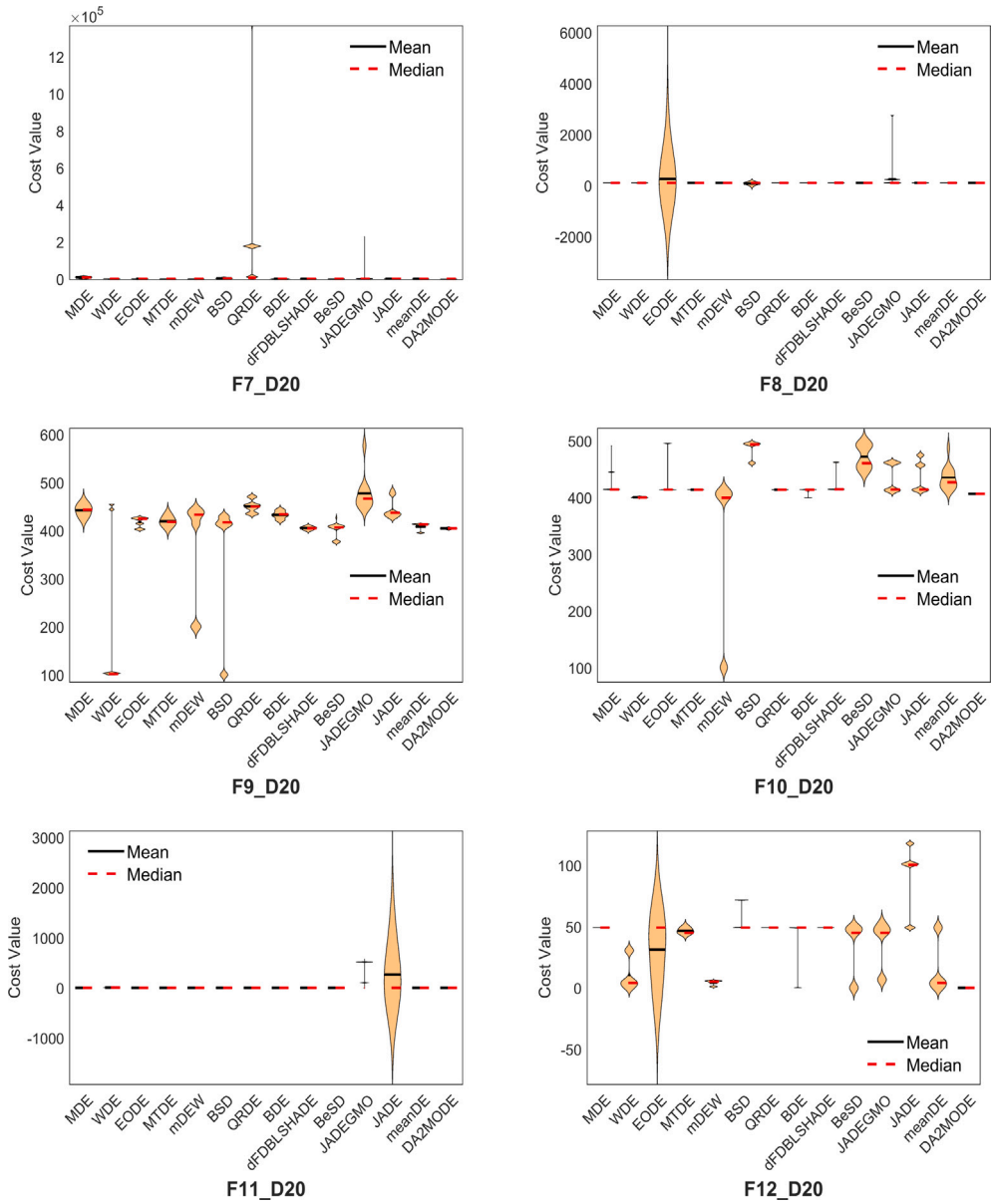



**Fig. C.4b.** Violin plots for best fitness in 30 runs for all 14 DE variants in CEC2020-2022, F7-F12 (20D).

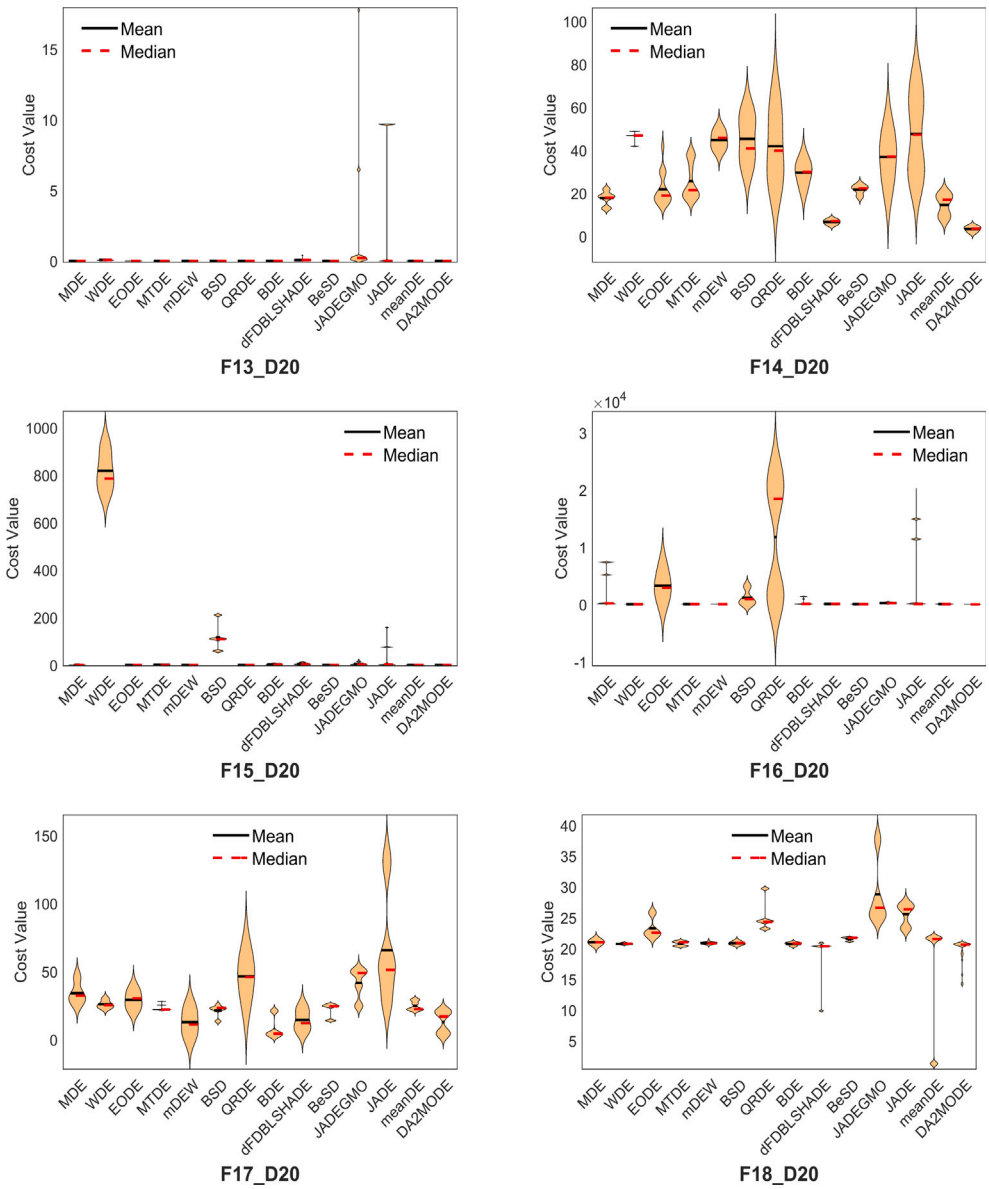



**Fig. C.4c.** Violin plots for best fitness in 30 runs for all 14 DE variants in CEC2020-2022, F13-F18 (20D).

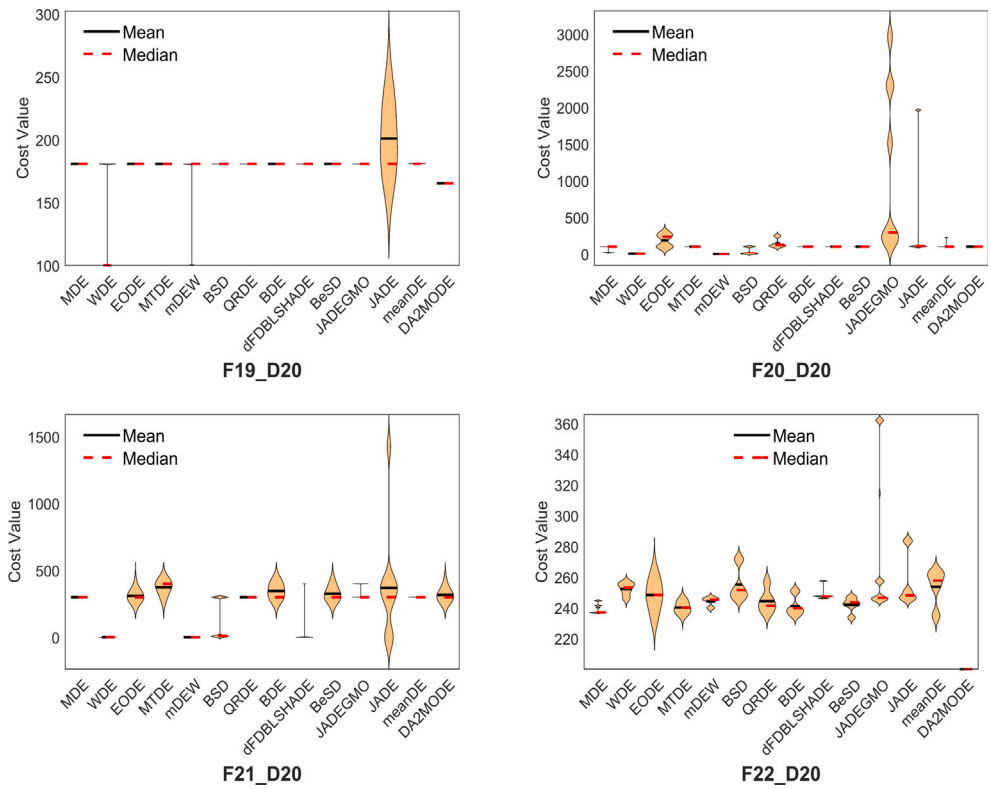



**Fig. C.4d.** Violin plots for best fitness in 30 runs for all 14 DE variants in CEC2020-2022, F19-F22 (20D).

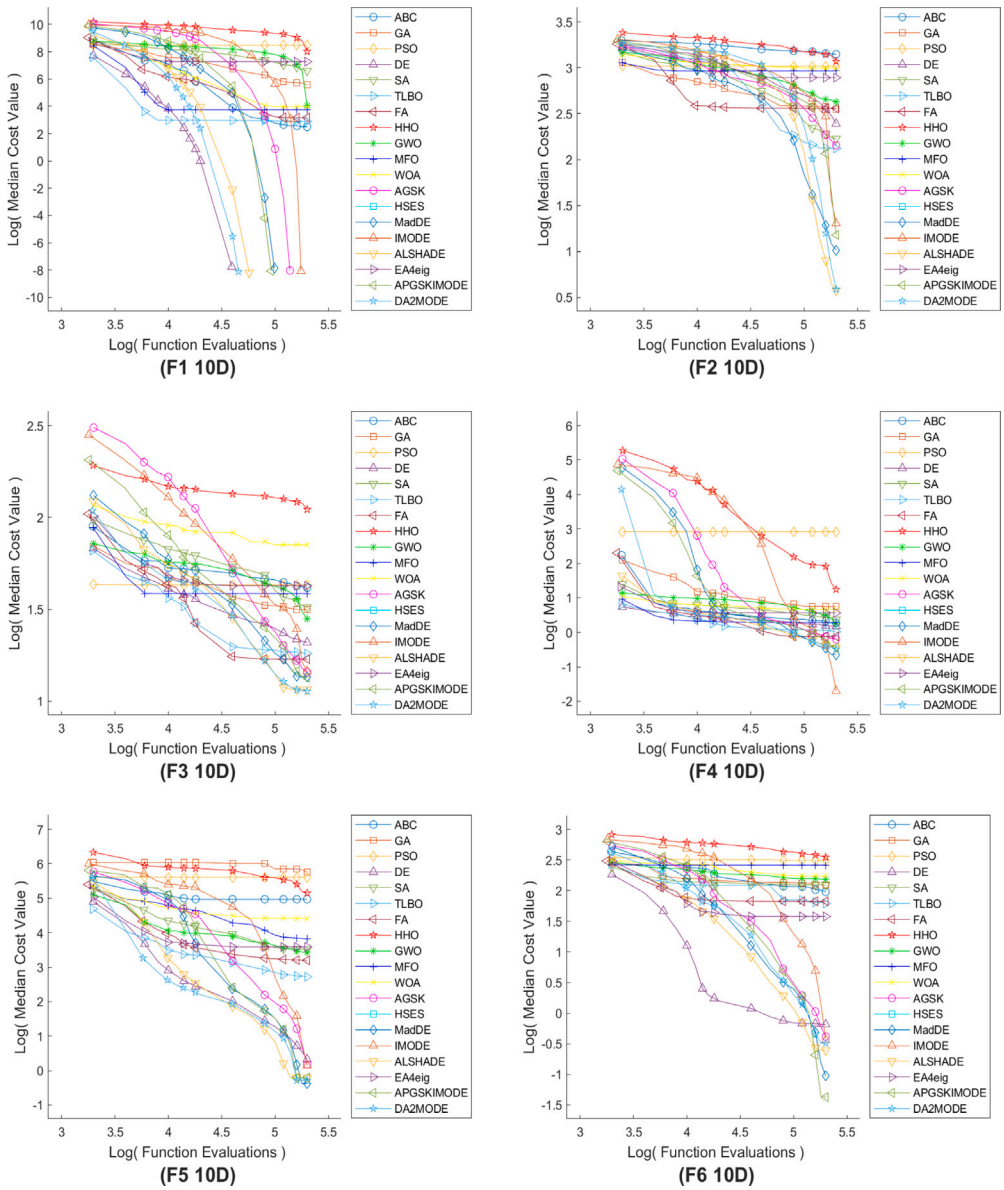



**Fig. D.5a.** Convergence for median fitness in 30 runs, all algorithms in CEC2020-2022, F1-F6 (10 Dim).

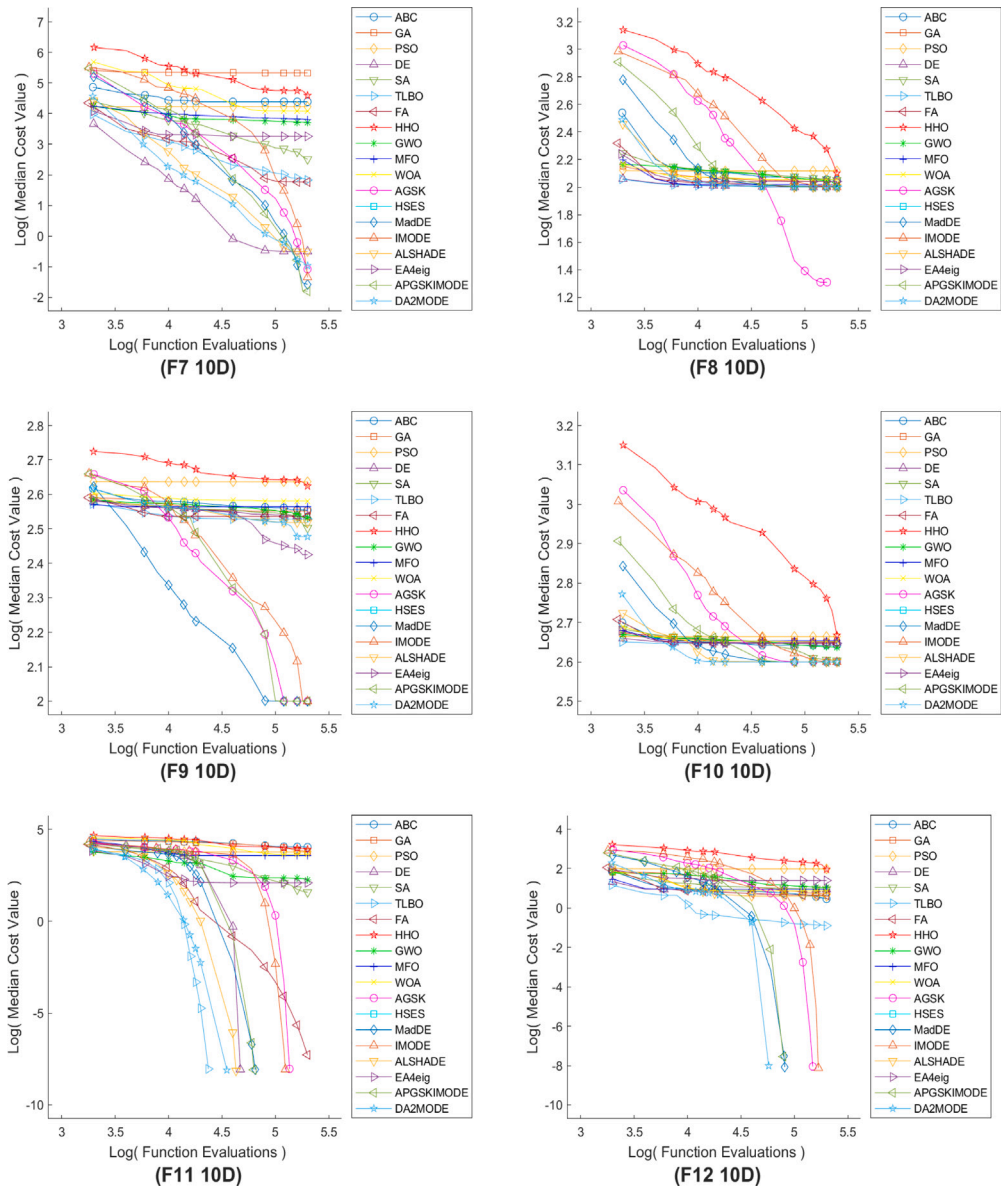



**Fig. D.5b.** Convergence for median fitness in 30 runs, all algorithms in CEC2020-2022, F7-F12 (10 Dim).

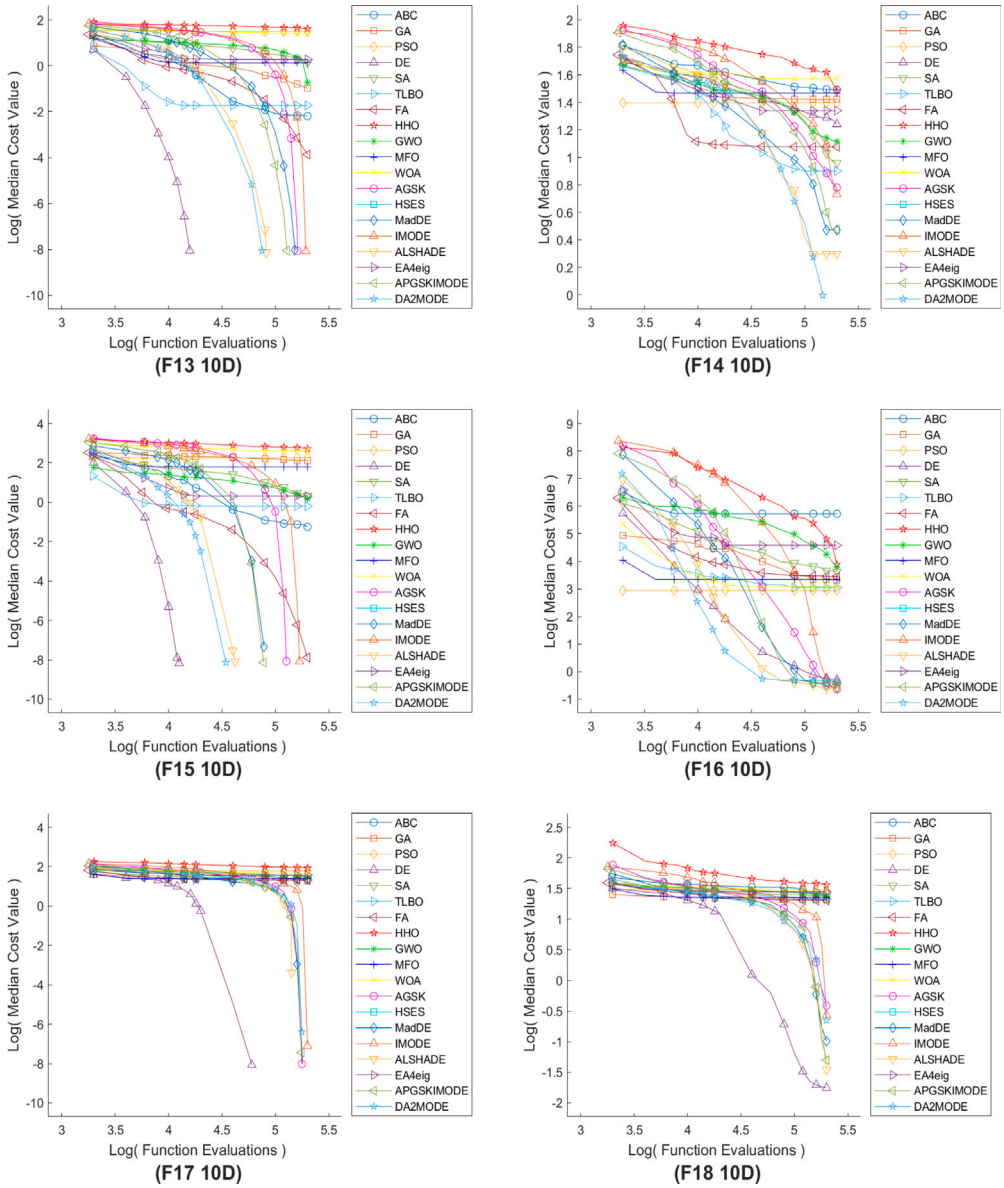



**Fig. D.5c.** Convergence for median fitness in 30 runs, all algorithms in CEC2020-2022, F13-F18 (10 Dim).

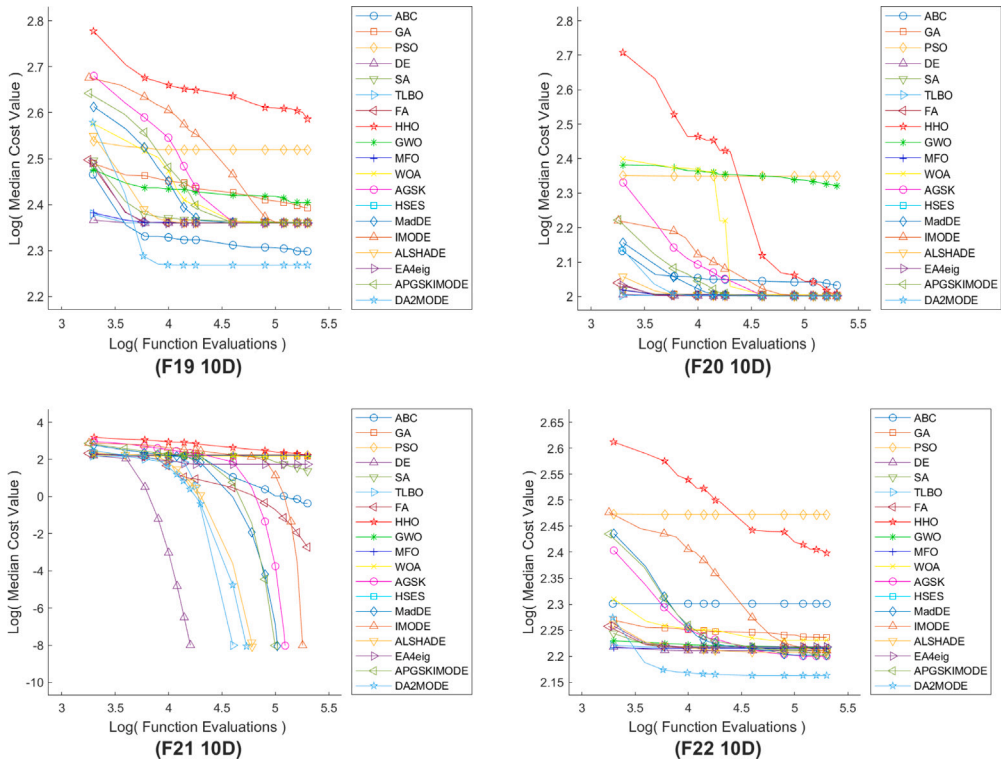



**Fig. D.5d.** Convergence for median fitness in 30 runs, all algorithms in CEC2020-2022, F19-F22 (10 Dim).

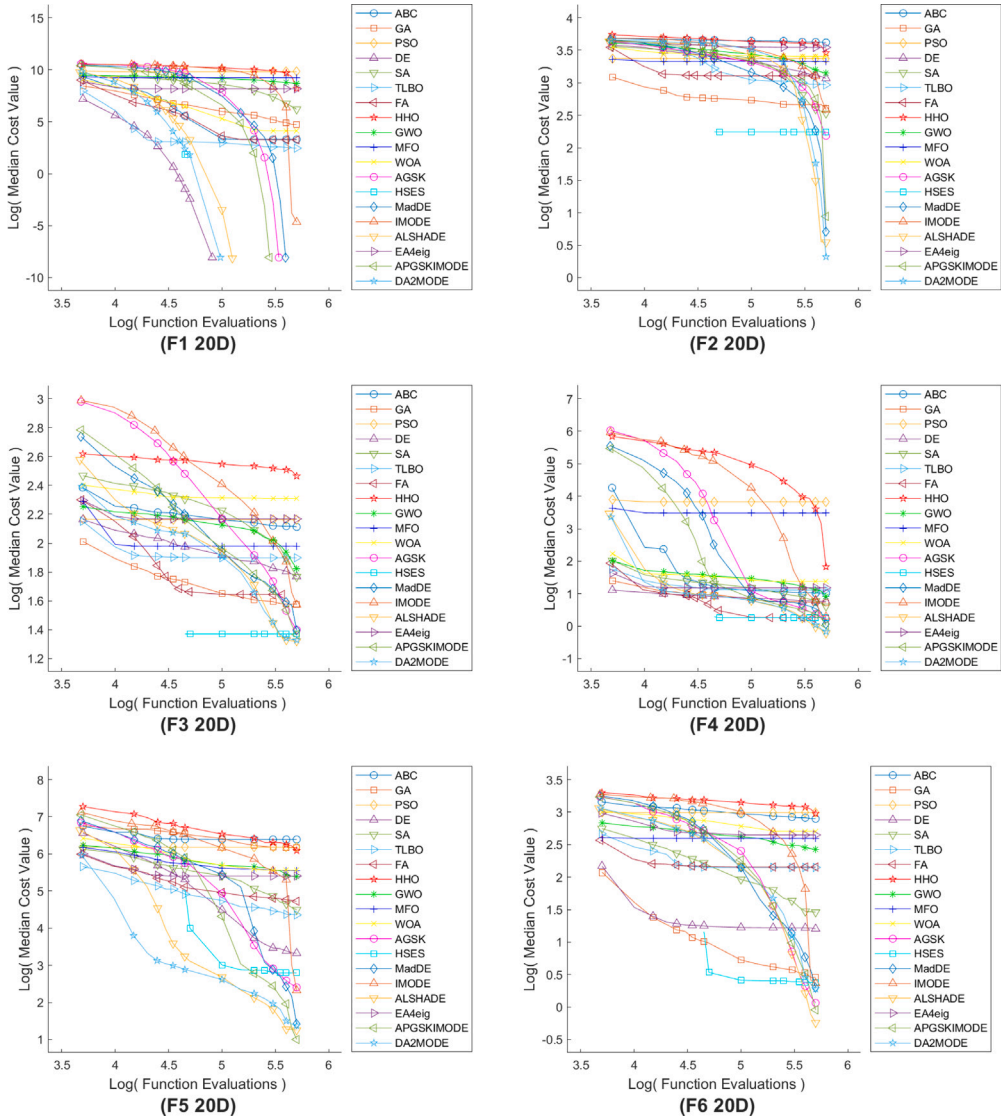



**Fig. D.6a.** Convergence plots for median fitness in 30 runs for all algorithms in CEC2020-2022, F1-F6 (20 Dim).

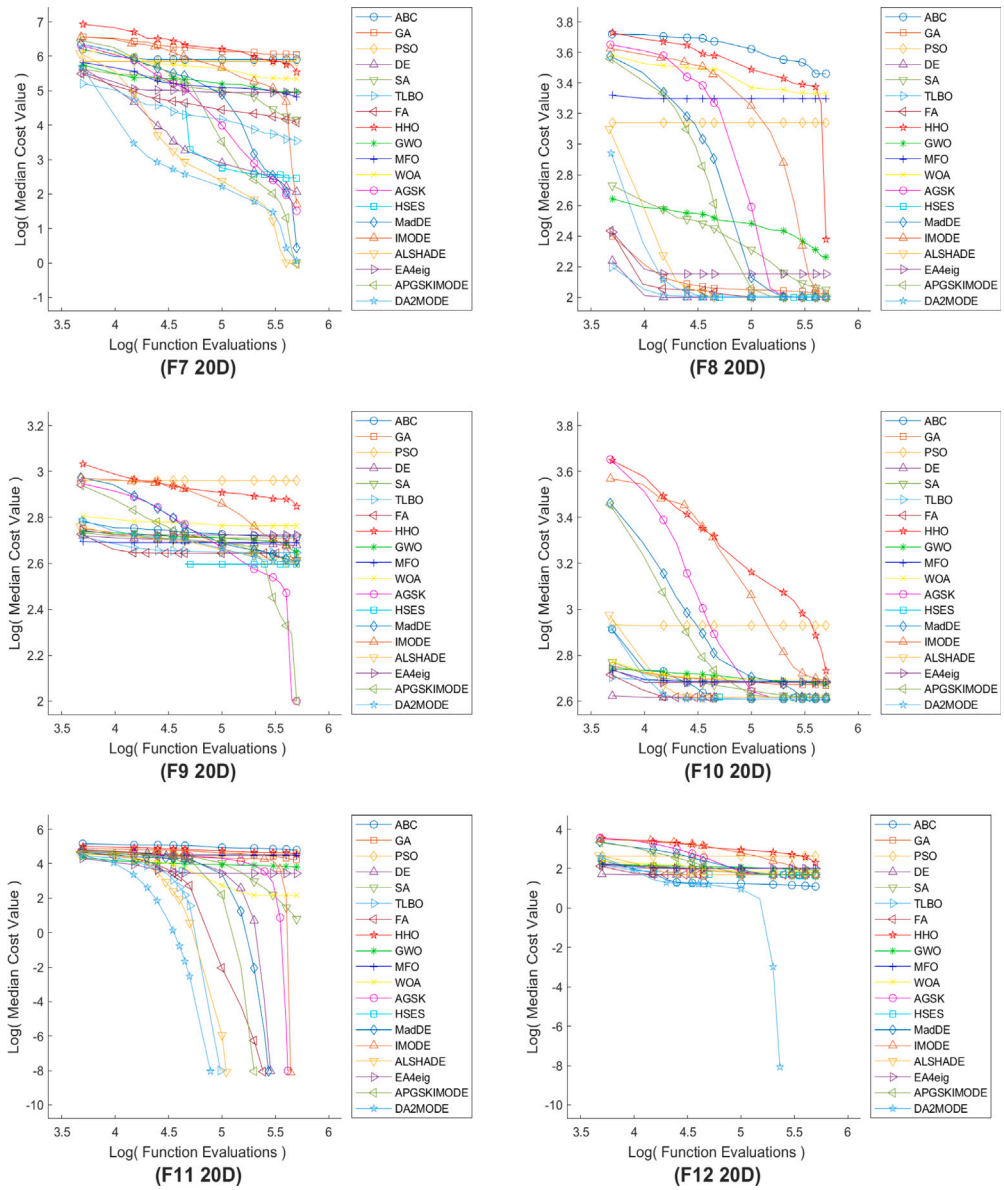



**Fig. D.6b.** Convergence for median fitness, 30 runs for all algorithms in CEC2020-2022, F7-F12(20 Dim).

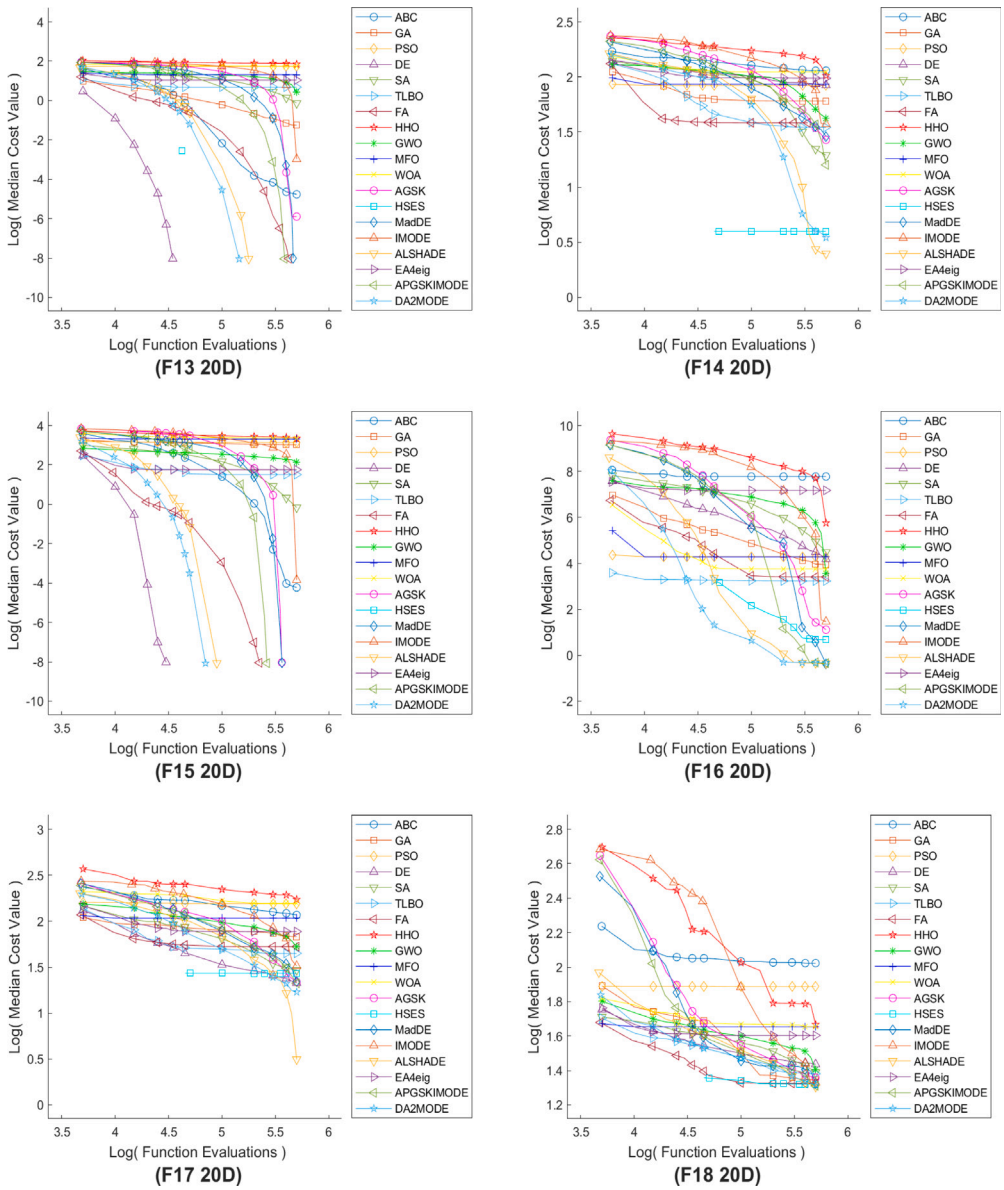



**Fig. D.6c.** Convergence for median fitness in 30 runs, all algorithms in CEC2020-2022, F13-F18(20 Dim).

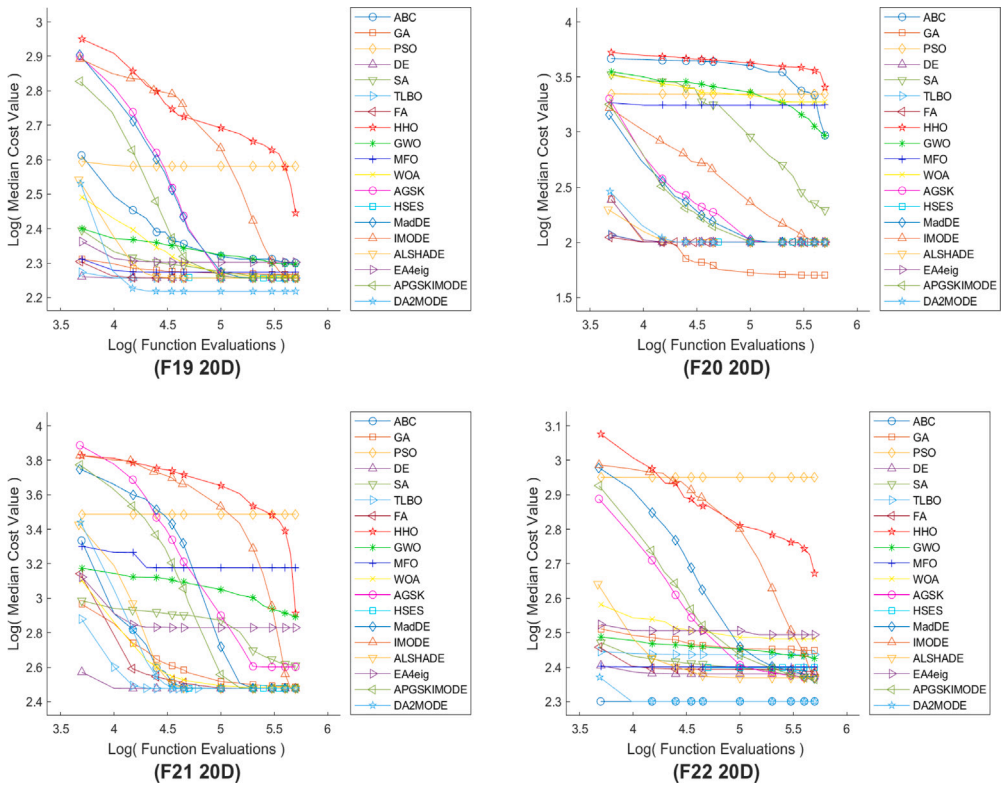



**Fig. D.6d.** Convergence for median fitness in 30 runs, all algorithms in CEC2020-2022, F19-F22(20 Dim).

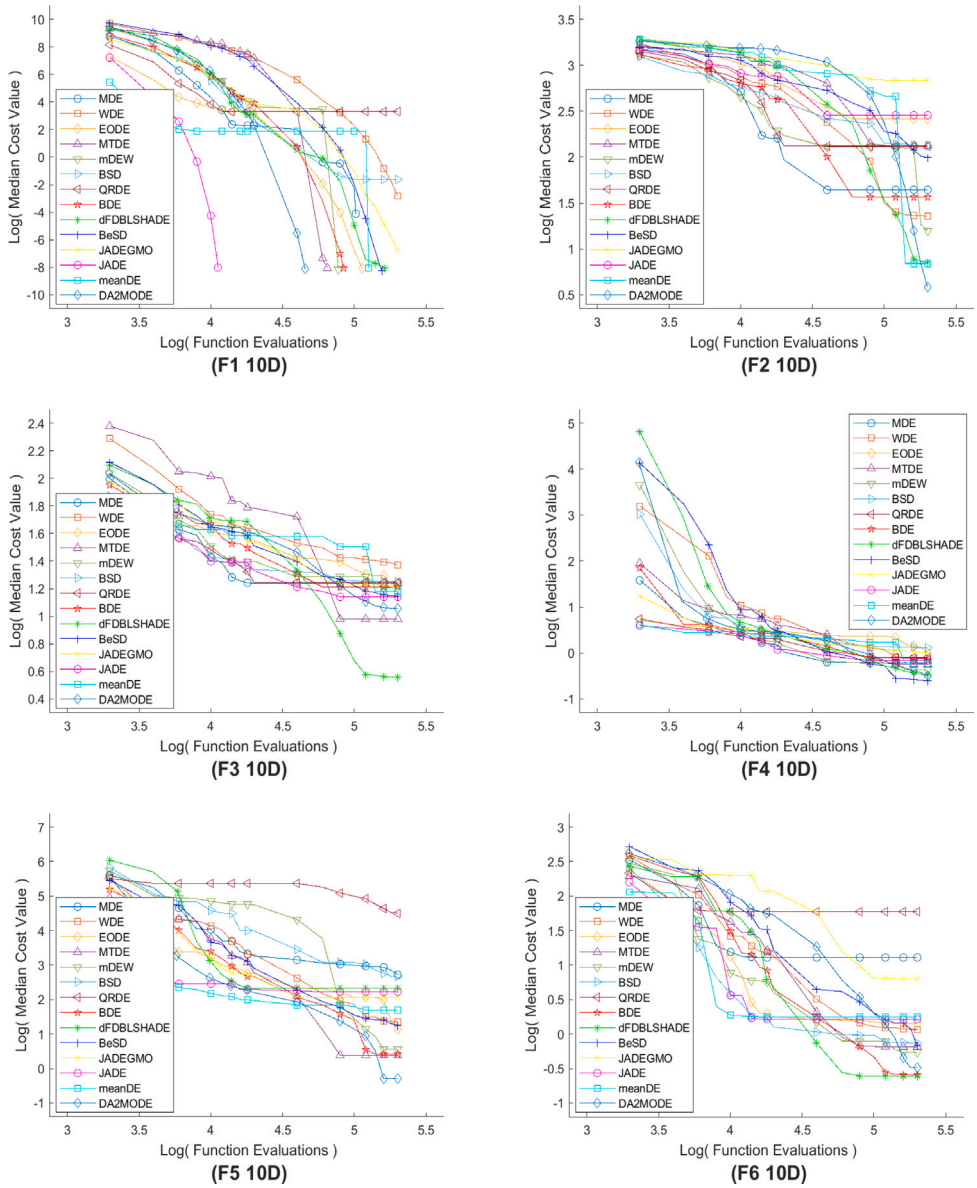



**Fig. D.7a.** Convergence for median fitness in 30 runs, 14 DE variants in CEC2020-2022, F1-F6 (10 Dim).

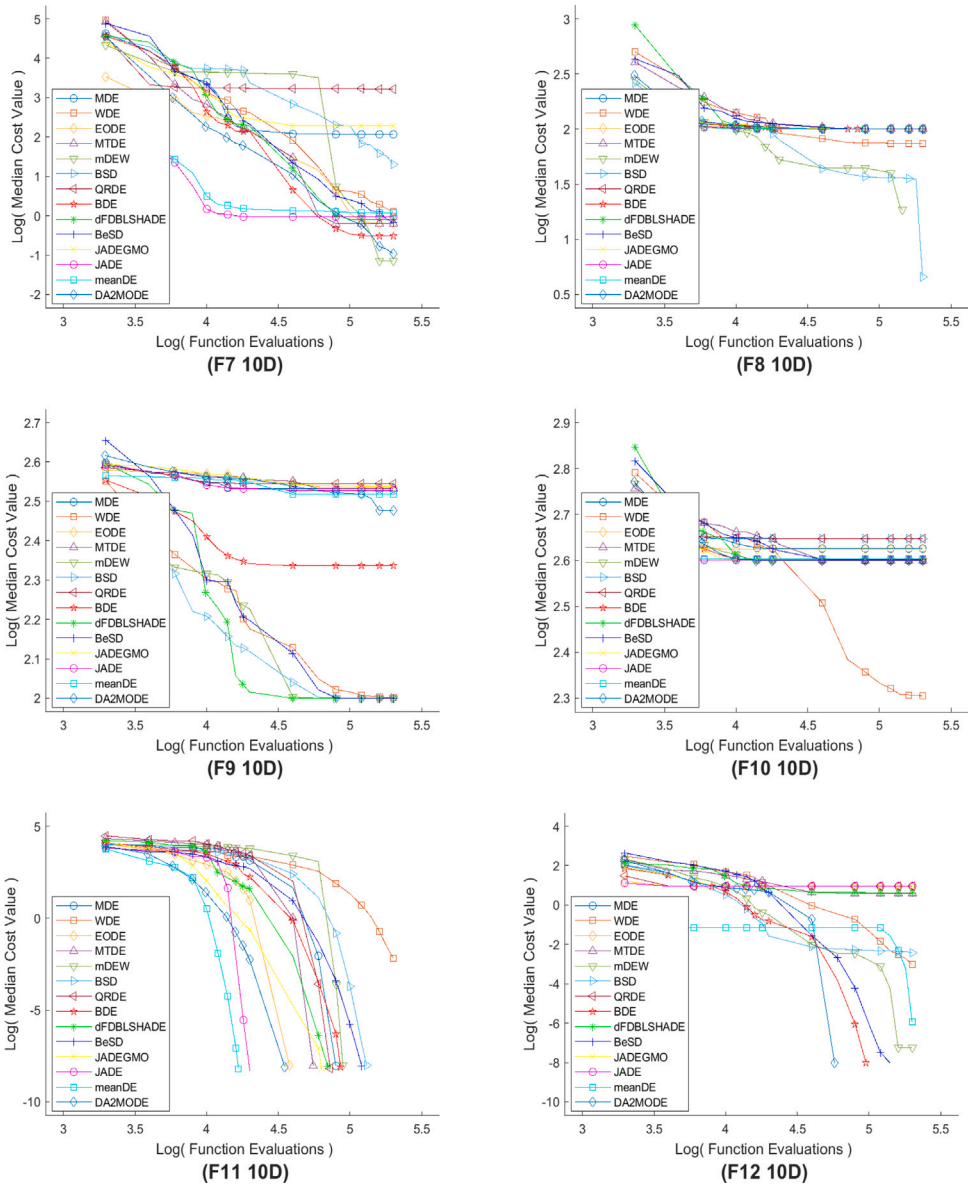



**Fig. D.7b.** Convergence for median fitness in 30 runs, 14 DE variants in CEC2020-2022, F7-F12 (10 Dim).

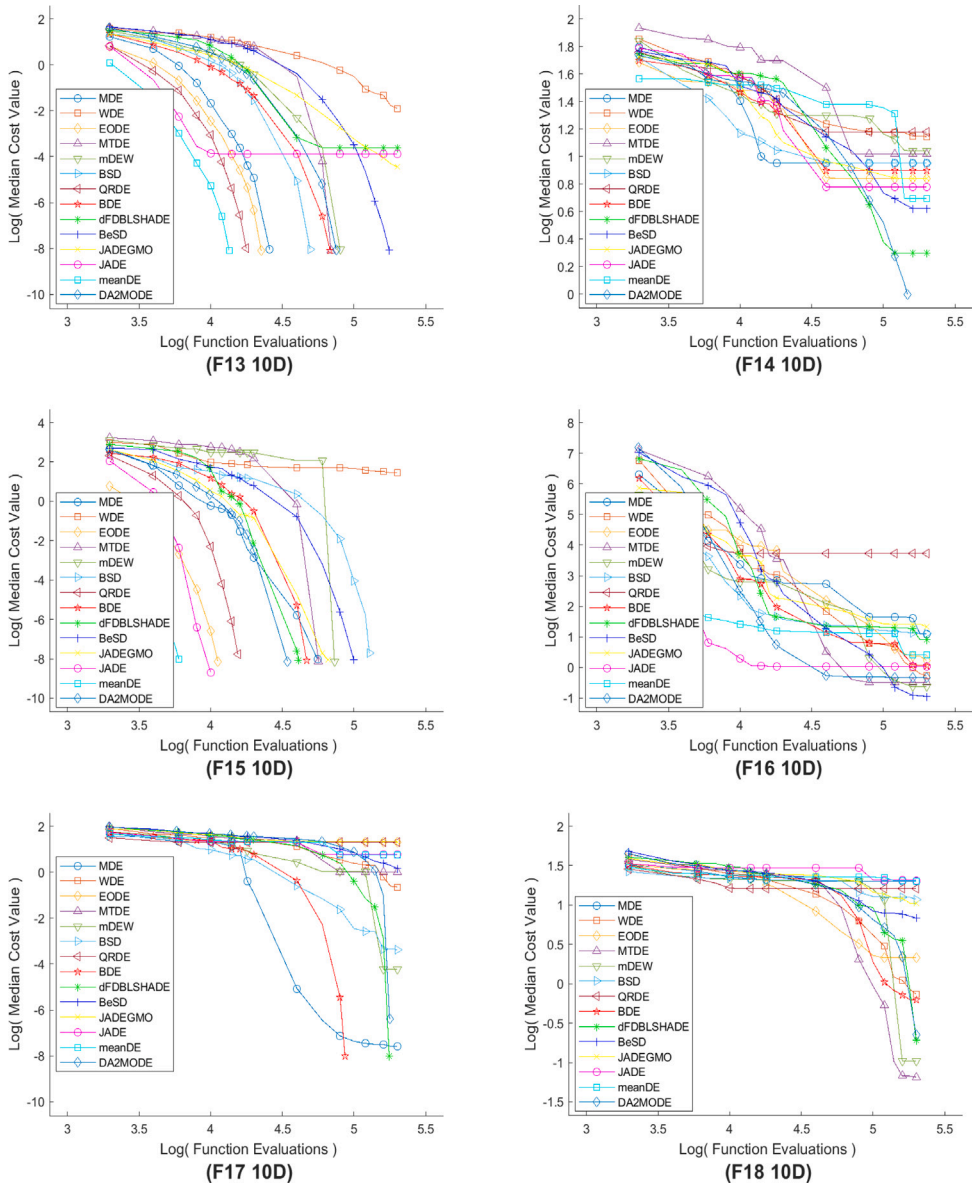



**Fig. D.7c.** Convergence for median fitness in 30 runs, 14 DE variants in CEC2020- 2022, F13-F18 (10 Dim).

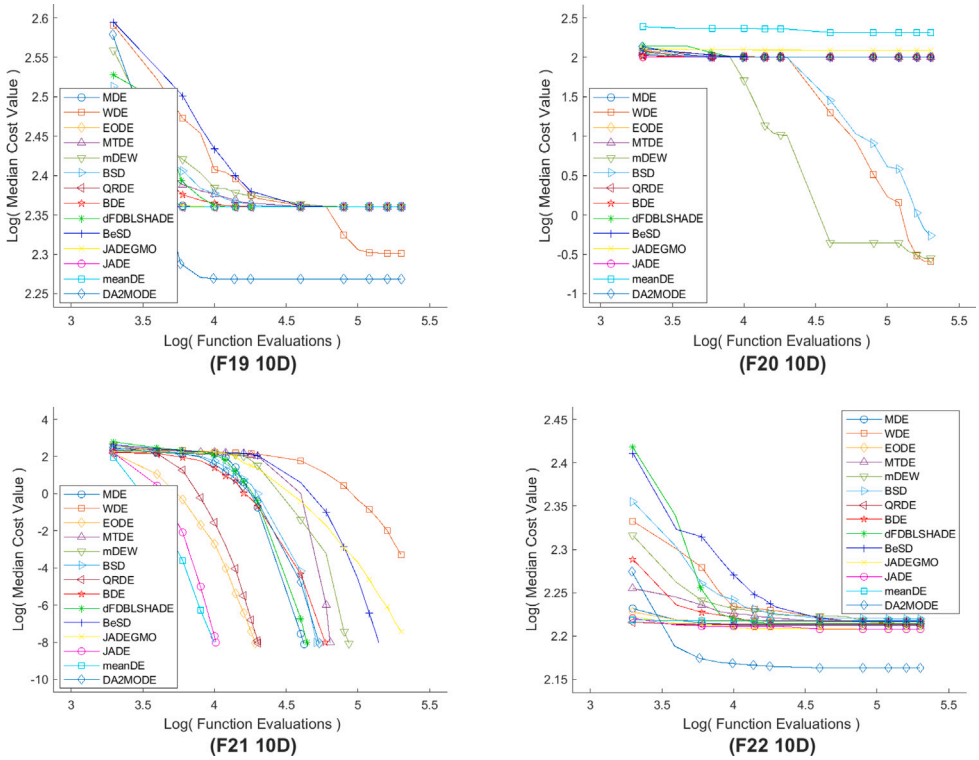



**Fig. D.7d.** Convergence for median fitness in 30 runs, 14 DE variants in CEC2020-2022, F19-F22 (10 Dim).

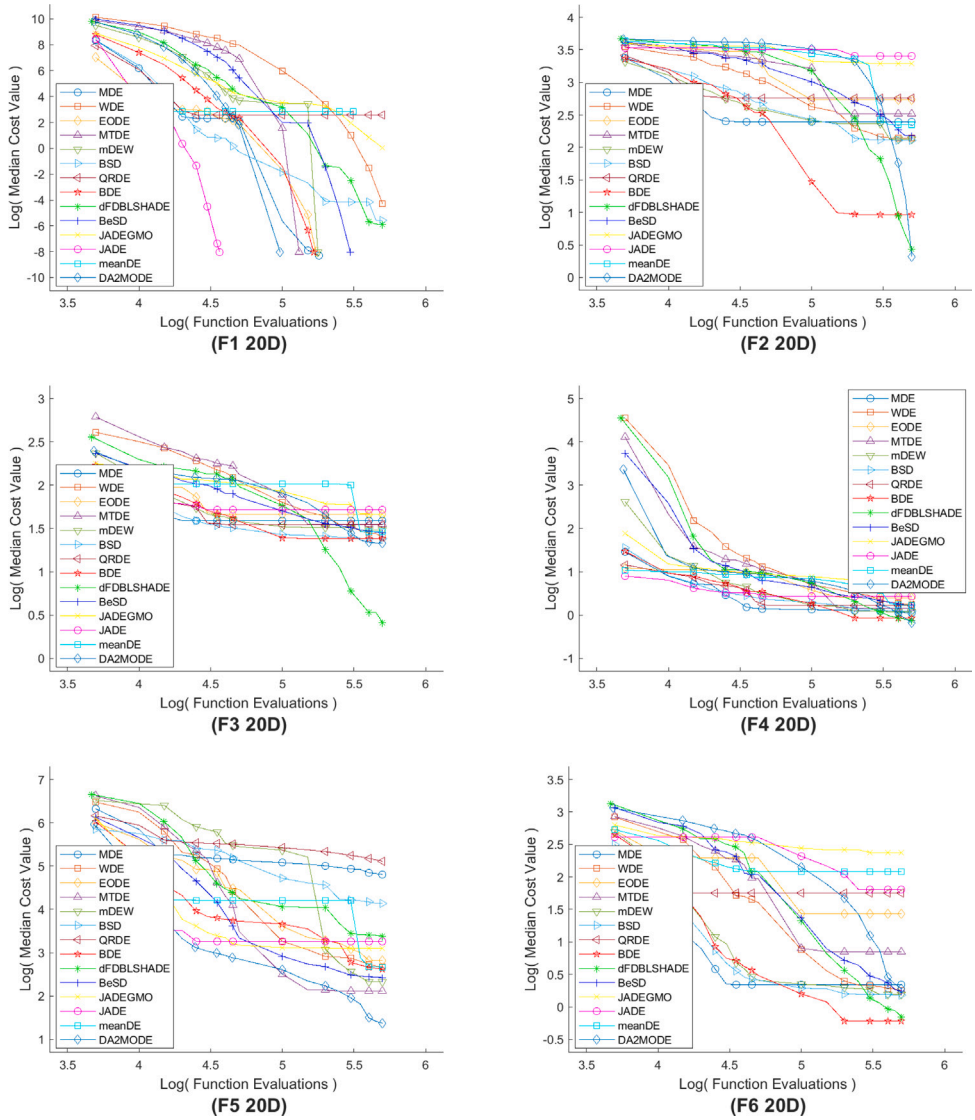



**Fig. D.8a.** Convergence plots for median fitness in 30 runs for 14 DE variants in CEC2020-2022, F1-F6 (20 Dim).

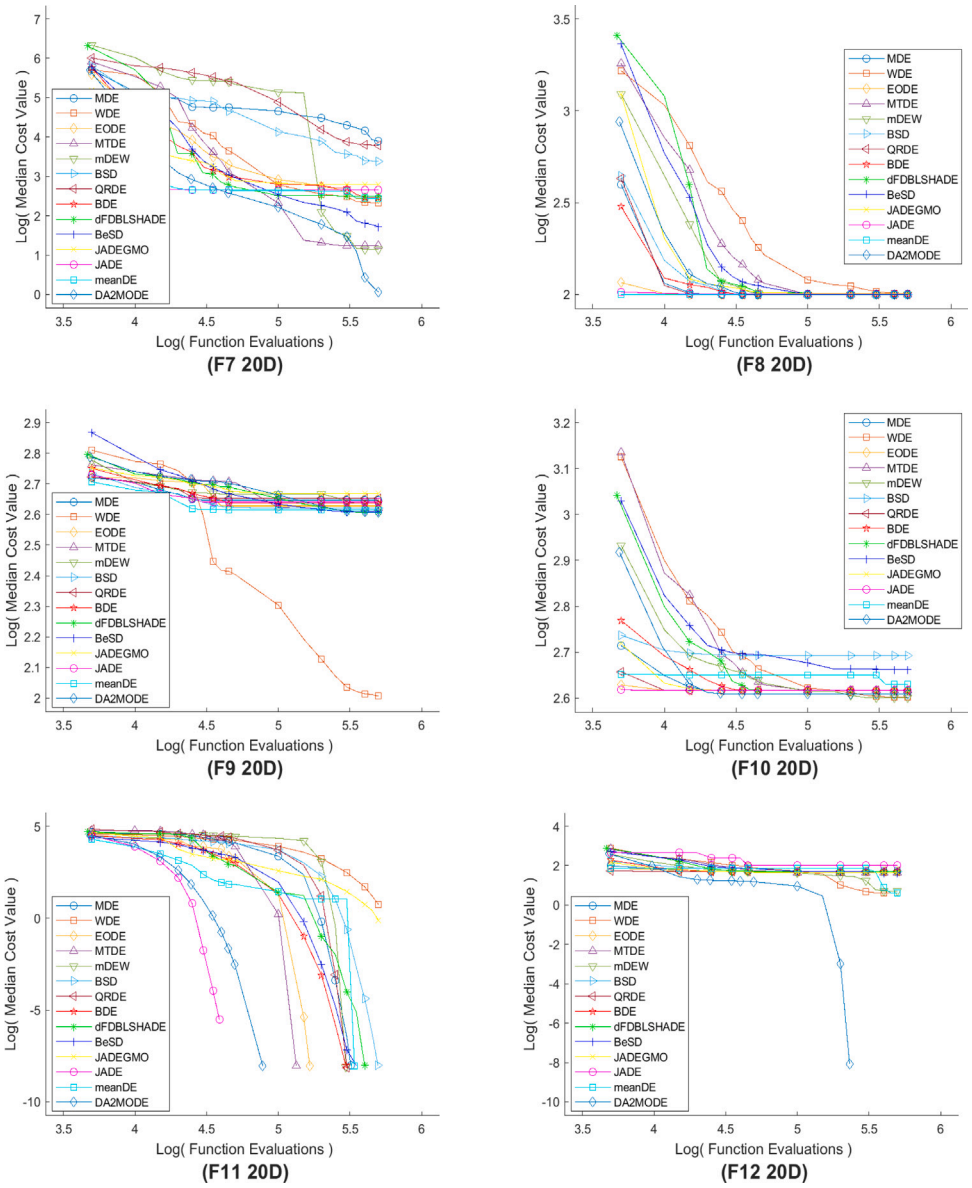



**Fig. D.8b.** Convergence for median fitness, 30 runs for 14 DE variants in CEC2020-2022, F7-F12(20 Dim).

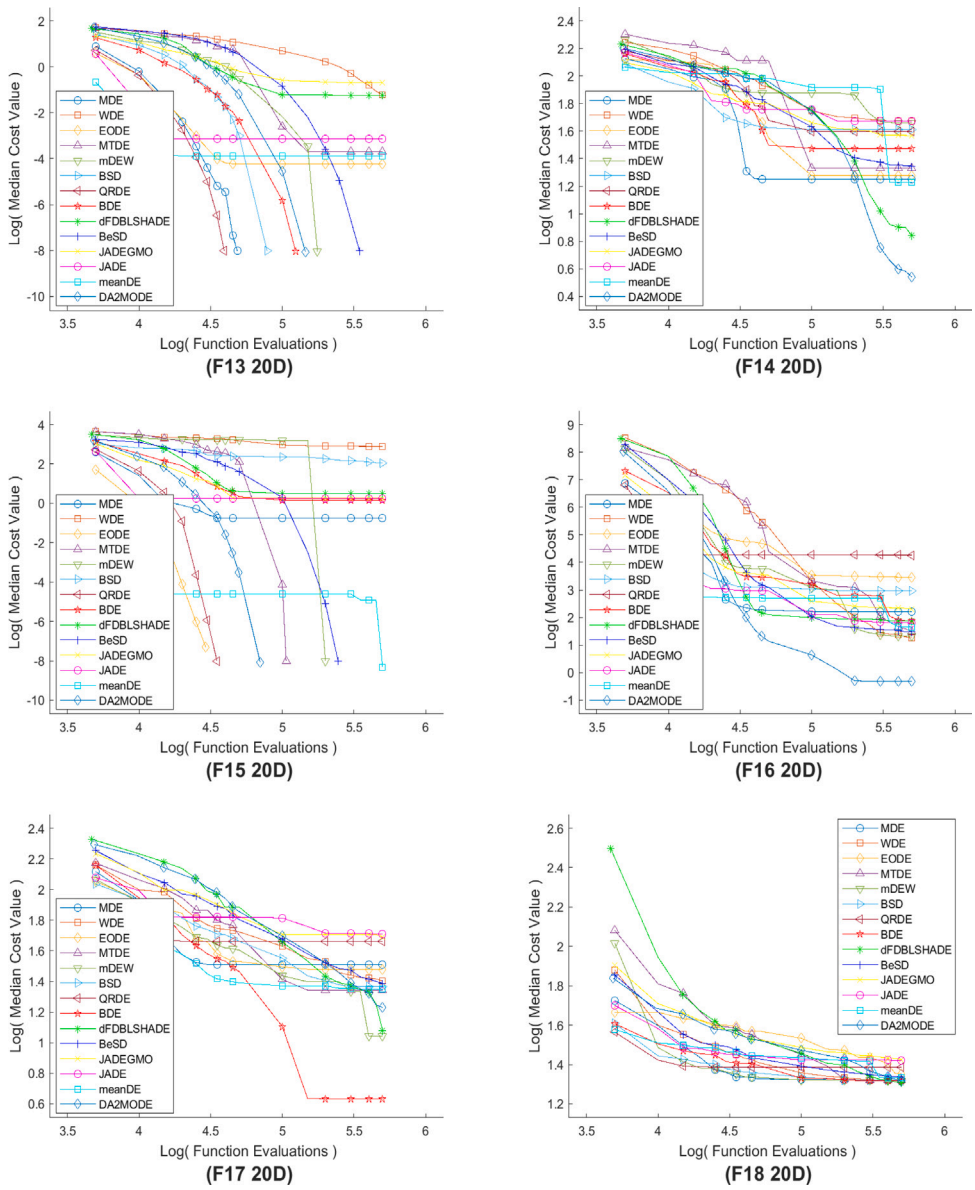



**Fig. D.8c.** Convergence for median fitness in 30 runs, 14 DE variants in CEC2020-2022, F13-F18(20 Dim).

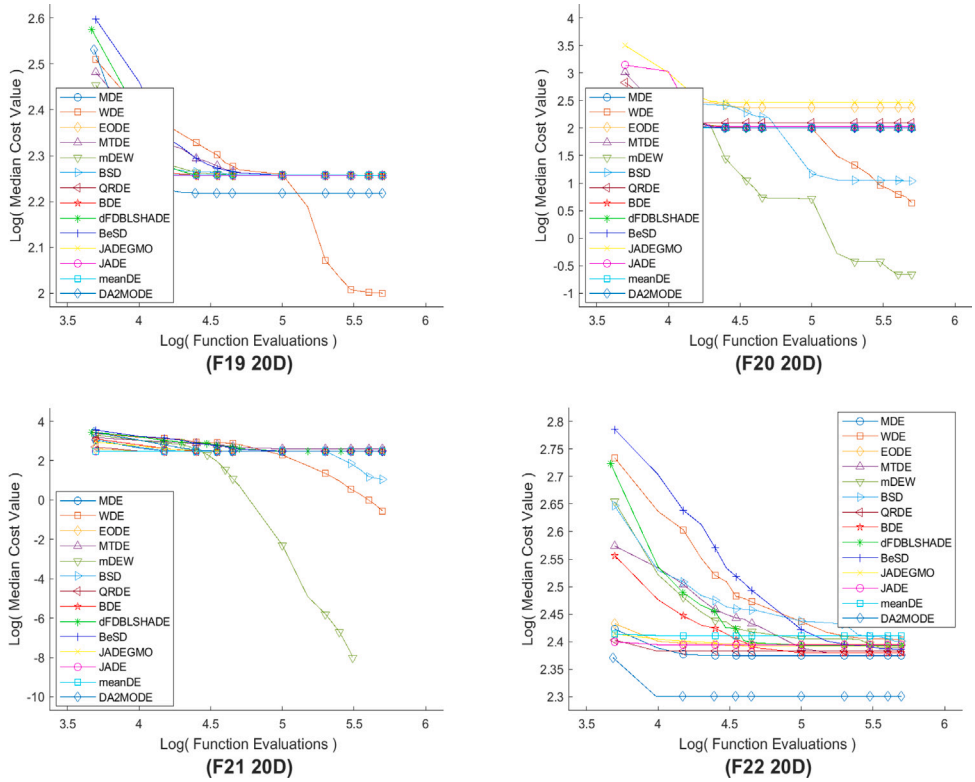



**Fig. D.8d.** Convergence for median fitness in 30 runs, 14 DE variants in CEC2020- 2022, F19-F22(20 Dim).

**Table E.9**
The results metrics for the error and function evaluation metrics for 21 algorithms, CEC2017–2018 (F1-F3, 30 Dim).

| Fun | Alg. | Error | | | | | Function evaluations | | | | | SR (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No. | Name | Best | Worst | Median | Mean | SD | Best | Worst | Median | Mean | SD | |
| | ABC | 2.42E+01 | 1.10E+04 | 3.29E+02 | 2.37E+03 | 3.65E+03 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | GA | 1.71E+05 | 1.67E+06 | 6.46E+05 | 5.89E+05 | 3.88E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | PSO | 1.43E+10 | 2.98E+10 | 1.85E+10 | 1.97E+10 | 3.79E+09 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | DE | 0.00E+00 | 0.00E+00 | 0.00E+00 | **0.00E+00** | 0.00E+00 | 1.90E+05 | 2.53E+05 | 2.18E+05 | 2.22E+05 | 1.41E+04 | 100.00 |
| | SA | 7.35E+07 | 1.58E+08 | 1.16E+08 | 1.12E+08 | 2.31E+07 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | TLBO | 5.68E−01 | 1.44E+04 | 1.59E+03 | 2.33E+03 | 2.65E+03 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | BAS | 9.94E+10 | 1.65E+11 | 1.44E+11 | 1.43E+11 | 1.98E+10 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | FA | 1.28E+02 | 2.01E+04 | 4.01E+03 | 5.21E+03 | 5.01E+03 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | HHO | 1.86E+09 | 9.74E+09 | 4.30E+09 | 4.92E+09 | 2.05E+09 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | GWO | 1.03E+08 | 6.12E+09 | 1.79E+09 | 2.23E+09 | 1.79E+09 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| F1 | MFO | 2.42E+08 | 3.96E+10 | 7.72E+09 | 9.82E+09 | 6.90E+09 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | WOA | 7.46E+05 | 1.20E+07 | 2.37E+06 | 3.49E+06 | 2.79E+06 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | CMAES | 1.22E+01 | 3.48E+10 | 3.09E+03 | 4.31E+09 | 1.05E+10 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | AGSK | 3.18E−08 | 3.69E−03 | 1.91E−05 | 3.02E−04 | 7.03E−04 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | HSES | 0.00E+00 | 0.00E+00 | 0.00E+00 | **0.00E+00** | 0.00E+00 | 5.82E+04 | 9.85E+04 | 5.97E+04 | 6.12E+04 | 7.49E+03 | 100.00 |
| | MadDE | 5.53E+02 | 2.46E+03 | 1.51E+03 | 1.48E+03 | 4.85E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | IMODE | 9.35E−03 | 1.01E−02 | 1.01E−02 | 9.89E−03 | 3.19E−04 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | ALSHADE | 0.00E+00 | 0.00E+00 | 0.00E+00 | **0.00E+00** | 0.00E+00 | 1.70E+05 | 1.81E+05 | 1.77E+05 | 1.76E+05 | 2.38E+03 | 100.00 |
| | EA4eig | 7.72E+07 | 1.18E+09 | 6.72E+08 | 6.37E+08 | 2.64E+08 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | APGSKIMODE | 1.15E−04 | 8.48E−02 | 4.92E−03 | 1.01E−02 | 1.48E−02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | DA2MODE | 0.00E+00 | 0.00E+00 | 0.00E+00 | **0.00E+00** | 0.00E+00 | 1.38E+05 | 1.57E+05 | 1.51E+05 | 1.51E+05 | 4.21E+03 | 100.00 |
| | ABC | 9.42E+04 | 1.48E+05 | 1.29E+05 | 1.27E+05 | 1.20E+04 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | GA | 4.33E+04 | 1.66E+05 | 8.29E+04 | 9.16E+04 | 2.90E+04 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | PSO | 5.46E+04 | 2.05E+05 | 1.07E+05 | 1.08E+05 | 2.74E+04 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | DE | 6.59E+03 | 1.80E+04 | 1.25E+04 | 1.26E+04 | 2.91E+03 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | SA | 9.59E+03 | 1.89E+05 | 5.37E+04 | 6.35E+04 | 4.23E+04 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | TLBO | 0.00E+00 | 6.61E−08 | 0.00E+00 | 1.27E−08 | 2.39E−08 | 2.51E+05 | 3.00E+05 | 2.79E+05 | 2.79E+05 | 1.70E+04 | 68.63 |
| | BAS | 1.61E+05 | 8.60E+10 | 3.69E+08 | 1.68E+10 | 3.11E+10 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | FA | 9.01E−06 | 1.86E+01 | 3.05E−03 | 4.84E−01 | 2.60E+00 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | HHO | 7.44E+04 | 3.64E+05 | 9.04E+04 | 1.20E+05 | 7.71E+04 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | GWO | 1.53E+04 | 4.45E+04 | 3.38E+04 | 3.15E+04 | 8.61E+03 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| F2 | MFO | 1.43E+03 | 3.01E+05 | 1.07E+05 | 1.07E+05 | 5.95E+04 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | WOA | 8.00E+04 | 2.50E+05 | 1.53E+05 | 1.50E+05 | 4.65E+04 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | CMAES | 1.13E+05 | 3.00E+05 | 1.89E+05 | 1.96E+05 | 4.04E+04 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | AGSK | 1.33E+01 | 9.08E+02 | 2.25E+02 | 2.99E+02 | 2.32E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | HSES | 0.00E+00 | 0.00E+00 | 0.00E+00 | **0.00E+00** | 0.00E+00 | 5.64E+04 | 9.60E+04 | 5.81E+04 | 6.01E+04 | 8.47E+03 | 100.00 |
| | MadDE | 1.72E−03 | 3.03E−01 | 2.40E−02 | 5.32E−02 | 6.38E−02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | IMODE | 1.74E−07 | 1.97E−07 | 1.94E−07 | 1.92E−07 | 5.21E−09 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | ALSHADE | 0.00E+00 | 0.00E+00 | 0.00E+00 | **0.00E+00** | 0.00E+00 | 1.59E+05 | 1.72E+05 | 1.65E+05 | 1.65E+05 | 3.17E+03 | 100.00 |
| | EA4eig | 1.18E+04 | 5.30E+04 | 3.04E+04 | 3.33E+04 | 1.11E+04 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | APGSKIMODE | 0.00E+00 | 3.37E−06 | 1.28E−08 | 1.01E−07 | 4.71E−07 | 2.83E+05 | 3.00E+05 | 3.00E+05 | 2.97E+05 | 4.47E+03 | 45.10 |
| | DA2MODE | 0.00E+00 | 0.00E+00 | 0.00E+00 | **0.00E+00** | 0.00E+00 | 1.22E+05 | 1.38E+05 | 1.29E+05 | 1.29E+05 | 3.37E+03 | 100.00 |
| | ABC | 8.66E+01 | 1.15E+02 | 8.74E+01 | 9.11E+01 | 9.35E+00 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | GA | 7.61E+00 | 1.78E+02 | 1.09E+02 | 9.57E+01 | 4.65E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | PSO | 1.98E+03 | 8.04E+03 | 3.37E+03 | 3.85E+03 | 1.85E+03 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | DE | 5.86E+01 | 8.94E+01 | 5.86E+01 | 5.99E+01 | 5.81E+00 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | SA | 9.52E+01 | 9.96E+01 | 9.59E+01 | 9.70E+01 | 1.63E+00 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | TLBO | 4.21E−02 | 1.13E+02 | 7.24E+01 | 6.74E+01 | 2.55E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | BAS | 3.07E+04 | 8.04E+04 | 5.86E+04 | 5.70E+04 | 1.43E+04 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | FA | 4.02E+00 | 1.18E+02 | 8.67E+01 | 8.59E+01 | 1.66E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | HHO | 3.16E+02 | 2.76E+03 | 1.09E+03 | 1.25E+03 | 7.97E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | GWO | 8.59E+01 | 2.86E+02 | 1.81E+02 | 1.79E+02 | 6.19E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| F3 | MFO | 1.87E+02 | 5.81E+03 | 6.83E+02 | 9.55E+02 | 1.01E+03 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | WOA | 9.08E+01 | 1.97E+02 | 1.36E+02 | 1.42E+02 | 2.77E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | CMAES | 8.66E+02 | 6.32E+03 | 2.20E+03 | 2.55E+03 | 1.22E+03 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | AGSK | 5.86E+01 | 5.86E+01 | 5.86E+01 | 5.86E+01 | 8.23E−13 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | HSES | 0.00E+00 | 3.99E+00 | 3.99E+00 | 2.66E+00 | 1.90E+00 | 5.98E+04 | 3.00E+05 | 3.00E+05 | 2.28E+05 | 1.04E+05 | 33.33 |
| | MadDE | 7.21E+01 | 8.96E+01 | 7.34E+01 | 7.50E+01 | 3.65E+00 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | IMODE | 0.00E+00 | 6.41E+01 | 3.99E+00 | 4.94E+00 | 1.22E+01 | 2.59E+05 | 3.00E+05 | 3.00E+05 | 2.89E+05 | 1.57E+04 | 35.29 |
| | ALSHADE | 5.86E+01 | 5.86E+01 | 5.86E+01 | 5.86E+01 | 0.00E+00 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | EA4eig | 2.08E+02 | 5.45E+02 | 3.53E+02 | 3.70E+02 | 1.04E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | APGSKIMODE | 4.81E+00 | 1.12E+02 | 7.34E+01 | 7.82E+01 | 1.83E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | DA2MODE | 5.17E−06 | 4.12E+00 | 9.58E−02 | **1.31E+00** | 1.84E+00 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | ABC | 1.96E+02 | 2.27E+02 | 2.16E+02 | 2.14E+02 | 8.86E+00 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | GA | 1.89E+01 | 1.41E+02 | 8.00E+01 | 8.47E+01 | 2.69E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | PSO | 1.84E+02 | 3.39E+02 | 2.54E+02 | 2.71E+02 | 4.87E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | DE | 1.21E+02 | 1.81E+02 | 1.60E+02 | 1.61E+02 | 1.22E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | SA | 7.19E+01 | 1.13E+02 | 9.28E+01 | 9.30E+01 | 9.60E+00 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | TLBO | 7.36E+01 | 1.56E+02 | 1.11E+02 | 1.15E+02 | 2.08E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | BAS | 5.46E+02 | 7.79E+02 | 6.52E+02 | 6.57E+02 | 7.38E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | FA | 3.98E+01 | 1.04E+02 | 6.17E+01 | 6.38E+01 | 1.29E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | HHO | 2.65E+02 | 3.96E+02 | 3.39E+02 | 3.47E+02 | 3.16E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | GWO | 6.96E+01 | 1.68E+02 | 1.02E+02 | 1.00E+02 | 1.79E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| F4 | MFO | 1.32E+02 | 2.80E+02 | 1.95E+02 | 1.99E+02 | 4.65E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | WOA | 1.76E+02 | 4.27E+02 | 2.41E+02 | 2.61E+02 | 7.49E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | CMAES | 1.09E+01 | 4.04E+02 | 2.88E+02 | 2.21E+02 | 1.35E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | AGSK | 5.82E+01 | 8.41E+01 | 7.05E+01 | 7.20E+01 | 6.48E+00 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | HSES | 1.99E+00 | 1.49E+01 | 7.96E+00 | 8.08E+00 | 2.46E+00 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | MadDE | 5.64E+01 | 9.25E+01 | 7.61E+01 | 7.51E+01 | 1.03E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | IMODE | 6.17E+01 | 1.32E+02 | 1.10E+02 | 1.03E+02 | 2.20E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | ALSHADE | 0.00E+00 | 9.95E+00 | 2.99E+00 | **3.54E+00** | 2.35E+00 | 2.60E+05 | 3.00E+05 | 3.00E+05 | 2.99E+05 | 7.50E+03 | 3.92 |
| | EA4eig | 1.59E+02 | 2.16E+02 | 1.95E+02 | 1.94E+02 | 1.23E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | APGSKIMODE | 4.33E+01 | 1.03E+02 | 6.54E+01 | 6.52E+01 | 1.42E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | DA2MODE | 5.12E+00 | 1.72E+01 | 8.94E+00 | 9.40E+00 | 2.31E+00 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | ABC | 1.27E−04 | 1.35E−03 | 3.90E−04 | 5.11E−04 | 3.11E−04 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | GA | 2.38E−02 | 1.02E+00 | 1.22E−01 | 1.58E−01 | 1.46E−01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | PSO | 4.46E+01 | 6.66E+01 | 6.06E+01 | 5.85E+01 | 4.96E+00 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | DE | 0.00E+00 | 0.00E+00 | 0.00E+00 | **0.00E+00** | 0.00E+00 | 5.38E+04 | 6.11E+04 | 5.80E+04 | 5.75E+04 | 1.86E+03 | 100.00 |
| | SA | 3.99E+00 | 5.66E+00 | 5.15E+00 | 4.96E+00 | 4.99E−01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | TLBO | 4.74E+00 | 2.13E+01 | 1.54E+01 | 1.40E+01 | 4.25E+00 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | BAS | 1.08E+02 | 1.61E+02 | 1.32E+02 | 1.32E+02 | 1.08E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | FA | 2.06E−06 | 2.42E−01 | 4.18E−06 | 1.90E−02 | 6.58E−02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | HHO | 5.93E+01 | 8.95E+01 | 7.75E+01 | 7.90E+01 | 8.30E+00 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | GWO | 1.67E+00 | 1.76E+01 | 6.30E+00 | 6.65E+00 | 3.10E+00 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| F5 | MFO | 2.23E+01 | 6.34E+01 | 4.20E+01 | 4.31E+01 | 1.01E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | WOA | 5.46E+01 | 9.04E+01 | 6.90E+01 | 7.10E+01 | 8.52E+00 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | CMAES | 0.00E+00 | 7.19E+01 | 5.10E+01 | 3.46E+01 | 3.11E+01 | 1.06E+05 | 3.00E+05 | 3.00E+05 | 2.89E+05 | 4.34E+04 | 5.88 |
| | AGSK | 1.25E−04 | 5.04E−03 | 7.54E−04 | 9.58E−04 | 8.36E−04 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | HSES | 0.00E+00 | 3.49E−07 | 0.00E+00 | 2.17E−08 | 6.20E−08 | 4.79E+04 | 3.00E+05 | 5.17E+04 | 1.07E+05 | 9.73E+04 | 80.39 |
| | MadDE | 2.00E−02 | 1.03E−01 | 5.14E−02 | 5.40E−02 | 1.75E−02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | IMODE | 1.02E+01 | 2.16E+01 | 1.40E+01 | 1.52E+01 | 3.48E+00 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | ALSHADE | 0.00E+00 | 0.00E+00 | 0.00E+00 | **0.00E+00** | 0.00E+00 | 1.84E+05 | 1.93E+05 | 1.88E+05 | 1.89E+05 | 2.06E+03 | 100.00 |
| | EA4eig | 8.05E+00 | 2.05E+01 | 1.55E+01 | 1.38E+01 | 3.62E+00 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |

(*continued on next page*)

**Table E.9** (*continued*).

| Fun | Alg. | Error | | | | | Function evaluations | | | | | SR (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No. | Name | Best | Worst | Median | Mean | SD | Best | Worst | Median | Mean | SD | |
| | APGSKIMODE | 3.94E−05 | 5.27E−04 | 1.15E−04 | 1.37E−04 | 8.10E−05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | DA2MODE | 0.00E+00 | 2.00E−06 | 0.00E+00 | 1.10E−07 | 3.21E−07 | 1.64E+05 | 3.00E+05 | 1.72E+05 | 2.08E+05 | 5.80E+04 | 72.55 |
| | ABC | 1.96E+02 | 2.77E+02 | 2.61E+02 | 2.61E+02 | 1.34E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | GA | 1.15E+02 | 1.91E+02 | 1.50E+02 | 1.52E+02 | 1.92E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | PSO | 2.72E+02 | 5.98E+02 | 4.08E+02 | 4.13E+02 | 9.02E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | DE | 1.68E+02 | 2.12E+02 | 1.94E+02 | 1.93E+02 | 1.04E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | SA | 1.82E+02 | 2.35E+02 | 2.19E+02 | 2.15E+02 | 1.02E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | TLBO | 9.87E+01 | 2.45E+02 | 1.77E+02 | 1.82E+02 | 5.34E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | BAS | 2.47E+03 | 3.19E+03 | 2.89E+03 | 2.82E+03 | 2.11E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | FA | 6.86E+01 | 1.01E+02 | 8.01E+01 | 8.11E+01 | 8.72E+00 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | HHO | 5.72E+02 | 8.08E+02 | 6.96E+02 | 6.87E+02 | 6.18E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | GWO | 9.99E+01 | 2.40E+02 | 1.64E+02 | 1.63E+02 | 4.19E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| F6 | MFO | 1.34E+02 | 1.16E+03 | 3.23E+02 | 3.90E+02 | 2.35E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | WOA | 3.83E+02 | 6.60E+02 | 5.28E+02 | 5.29E+02 | 7.59E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | CMAES | 4.63E+01 | 2.05E+02 | 1.91E+02 | 1.70E+02 | 4.98E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | AGSK | 9.68E+01 | 1.35E+02 | 1.18E+02 | 1.18E+02 | 8.95E+00 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | HSES | 3.32E+01 | 4.92E+01 | 3.77E+01 | 3.86E+01 | 3.53E+00 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | MadDE | 7.30E+01 | 1.24E+02 | 1.05E+02 | 1.05E+02 | 1.06E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | IMODE | 1.76E+02 | 2.21E+02 | 1.92E+02 | 1.93E+02 | 1.31E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | ALSHADE | 3.25E+01 | 5.12E+01 | 3.57E+01 | **3.59E+01** | 2.57E+00 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | EA4eig | 2.07E+02 | 2.99E+02 | 2.56E+02 | 2.54E+02 | 2.40E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | APGSKIMODE | 7.07E+01 | 1.29E+02 | 9.59E+01 | 9.72E+01 | 1.56E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | DA2MODE | 3.42E+01 | 4.14E+01 | 3.83E+01 | 3.83E+01 | 1.62E+00 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | ABC | 1.89E+02 | 2.31E+02 | 2.10E+02 | 2.12E+02 | 1.04E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | GA | 5.51E+01 | 1.34E+02 | 9.27E+01 | 9.40E+01 | 2.26E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | PSO | 1.08E+02 | 2.61E+02 | 1.95E+02 | 1.89E+02 | 3.72E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | DE | 1.34E+02 | 1.79E+02 | 1.62E+02 | 1.62E+02 | 1.08E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | SA | 6.33E+01 | 1.19E+02 | 9.52E+01 | 9.41E+01 | 1.45E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | TLBO | 5.67E+01 | 1.09E+02 | 8.16E+01 | 8.00E+01 | 1.34E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | BAS | 5.52E+02 | 7.14E+02 | 6.46E+02 | 6.29E+02 | 4.05E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | FA | 4.28E+01 | 9.84E+01 | 6.27E+01 | 6.26E+01 | 1.77E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | HHO | 2.05E+02 | 3.07E+02 | 2.62E+02 | 2.57E+02 | 2.50E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | GWO | 5.73E+01 | 1.45E+02 | 8.76E+01 | 8.70E+01 | 2.08E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| F7 | MFO | 1.06E+02 | 2.97E+02 | 1.96E+02 | 1.94E+02 | 4.98E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | WOA | 1.29E+02 | 2.91E+02 | 1.97E+02 | 2.09E+02 | 4.02E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | CMAES | 1.09E+01 | 3.51E+02 | 1.64E+02 | 1.46E+02 | 1.05E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | AGSK | 4.08E+01 | 8.76E+01 | 7.69E+01 | 7.60E+01 | 7.74E+00 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | HSES | 2.98E+00 | 2.39E+01 | 7.96E+00 | 7.90E+00 | 2.97E+00 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | MadDE | 4.09E+01 | 8.33E+01 | 6.83E+01 | 6.85E+01 | 8.35E+00 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | IMODE | 6.27E+01 | 1.36E+02 | 9.15E+01 | 8.85E+01 | 1.18E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | ALSHADE | 0.00E+00 | 1.49E+01 | 2.99E+00 | **3.46E+00** | 2.47E+00 | 2.32E+05 | 3.00E+05 | 3.00E+05 | 2.96E+05 | 1.54E+04 | 5.88 |
| | EA4eig | 1.55E+02 | 2.16E+02 | 1.85E+02 | 1.87E+02 | 1.30E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | APGSKIMODE | 3.24E+01 | 8.88E+01 | 6.53E+01 | 6.21E+01 | 1.28E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | DA2MODE | 4.95E+00 | 1.71E+01 | 1.01E+01 | 9.95E+00 | 2.56E+00 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | ABC | 7.81E+00 | 1.30E+02 | 2.05E+01 | 3.19E+01 | 3.36E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | GA | 1.66E+02 | 2.76E+03 | 6.46E+02 | 7.52E+02 | 5.48E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | PSO | 2.92E+03 | 5.44E+03 | 4.14E+03 | 3.99E+03 | 7.36E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | DE | 0.00E+00 | 0.00E+00 | 0.00E+00 | **0.00E+00** | 0.00E+00 | 3.95E+04 | 4.55E+04 | 4.22E+04 | 4.18E+04 | 1.36E+03 | 100.00 |
| | SA | 3.41E+01 | 6.65E+01 | 5.25E+01 | 5.15E+01 | 8.10E+00 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | TLBO | 9.35E+01 | 1.78E+03 | 7.00E+02 | 8.02E+02 | 5.01E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | BAS | 1.51E+04 | 2.79E+04 | 2.31E+04 | 2.23E+04 | 2.70E+03 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | FA | 0.00E+00 | 6.29E+01 | 2.27E+00 | 7.94E+00 | 1.50E+01 | 2.38E+05 | 3.00E+05 | 3.00E+05 | 2.88E+05 | 2.40E+04 | 19.61 |
| | HHO | 6.92E+03 | 1.28E+04 | 9.20E+03 | 9.84E+03 | 1.53E+03 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | GWO | 2.00E+02 | 4.32E+03 | 8.03E+02 | 1.25E+03 | 1.10E+03 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| F8 | MFO | 3.22E+03 | 1.04E+04 | 5.82E+03 | 6.15E+03 | 1.70E+03 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | WOA | 2.89E+03 | 1.24E+04 | 5.88E+03 | 6.79E+03 | 2.61E+03 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | CMAES | 0.00E+00 | 4.54E−01 | 0.00E+00 | 1.07E−02 | 6.46E−02 | 2.26E+04 | 3.00E+05 | 2.40E+04 | 3.48E+04 | 5.41E+04 | 96.08 |
| | AGSK | 0.00E+00 | 1.72E+00 | 1.79E−01 | 3.17E−01 | 3.22E−01 | 2.59E+05 | 3.00E+05 | 3.00E+05 | 2.94E+05 | 1.38E+04 | 17.65 |
| | HSES | 0.00E+00 | 0.00E+00 | 0.00E+00 | **0.00E+00** | 0.00E+00 | 3.20E+04 | 3.43E+04 | 3.29E+04 | 3.31E+04 | 5.49E+02 | 100.00 |
| | MadDE | 1.76E−01 | 4.41E+00 | 8.99E−01 | 1.08E+00 | 8.30E−01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | IMODE | 7.30E+02 | 2.03E+03 | 1.29E+03 | 1.32E+03 | 4.09E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | ALSHADE | 0.00E+00 | 0.00E+00 | 0.00E+00 | **0.00E+00** | 0.00E+00 | 1.12E+05 | 1.23E+05 | 1.17E+05 | 1.17E+05 | 2.26E+03 | 100.00 |
| | EA4eig | 9.12E+01 | 5.87E+02 | 2.67E+02 | 2.72E+02 | 1.11E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | APGSKIMODE | 0.00E+00 | 1.54E−04 | 2.40E−07 | 7.35E−06 | 2.58E−05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 4.06E+01 | 1.96 |
| | DA2MODE | 0.00E+00 | 0.00E+00 | 0.00E+00 | **0.00E+00** | 0.00E+00 | 9.68E+04 | 1.04E+05 | 9.95E+04 | 9.95E+04 | 1.63E+03 | 100.00 |
| | ABC | 6.82E+03 | 7.56E+03 | 7.20E+03 | 7.20E+03 | 2.12E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | GA | 1.91E+03 | 3.51E+03 | 2.74E+03 | 2.76E+03 | 4.49E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | PSO | 3.65E+03 | 6.30E+03 | 4.39E+03 | 4.51E+03 | 6.09E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | DE | 5.91E+03 | 6.97E+03 | 6.53E+03 | 6.50E+03 | 2.78E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | SA | 1.19E+03 | 3.37E+03 | 2.93E+03 | 2.75E+03 | 4.08E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | TLBO | 2.11E+03 | 7.20E+03 | 4.96E+03 | 4.71E+03 | 1.76E+03 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | BAS | 8.29E+03 | 1.03E+04 | 9.33E+03 | 9.44E+03 | 4.23E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | FA | 2.29E+03 | 4.85E+03 | 3.45E+03 | 3.35E+03 | 6.60E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | HHO | 5.00E+03 | 7.53E+03 | 6.34E+03 | 6.18E+03 | 8.30E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | GWO | 1.75E+03 | 4.00E+03 | 2.82E+03 | 2.94E+03 | 6.00E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| F9 | MFO | 2.74E+03 | 6.11E+03 | 4.28E+03 | 4.40E+03 | 7.48E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | WOA | 3.55E+03 | 6.74E+03 | 4.85E+03 | 5.02E+03 | 8.57E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | CMAES | 6.50E+03 | 7.57E+03 | 6.94E+03 | 6.97E+03 | 2.70E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | AGSK | 3.25E+03 | 4.30E+03 | 3.72E+03 | 3.72E+03 | 2.27E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | HSES | 4.65E+02 | 1.87E+03 | 1.14E+03 | **1.16E+03** | 4.07E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | MadDE | 1.45E+03 | 2.73E+03 | 2.40E+03 | 2.37E+03 | 2.66E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | IMODE | 2.26E+03 | 3.61E+03 | 2.96E+03 | 3.00E+03 | 4.54E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | ALSHADE | 1.03E+03 | 2.55E+03 | 1.53E+03 | 1.55E+03 | 2.79E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | EA4eig | 5.93E+03 | 7.55E+03 | 6.99E+03 | 6.81E+03 | 4.80E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | APGSKIMODE | 2.39E+03 | 4.53E+03 | 3.74E+03 | 3.72E+03 | 4.40E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | DA2MODE | 8.91E+02 | 2.07E+03 | 1.53E+03 | 1.53E+03 | 2.46E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | ABC | 1.94E+02 | 4.61E+02 | 3.53E+02 | 3.41E+02 | 7.06E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | GA | 2.28E+02 | 1.63E+04 | 1.96E+03 | 4.08E+03 | 5.07E+03 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | PSO | 9.40E+02 | 9.48E+03 | 3.89E+03 | 3.66E+03 | 2.00E+03 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | DE | 4.82E+01 | 1.42E+02 | 1.00E+02 | 9.45E+01 | 3.10E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | SA | 1.03E+02 | 2.18E+02 | 1.79E+02 | 1.69E+02 | 3.56E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | TLBO | 5.66E+01 | 2.20E+02 | 1.52E+02 | 1.48E+02 | 3.48E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | BAS | 1.43E+04 | 4.35E+06 | 5.23E+04 | 2.64E+05 | 8.70E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | FA | 2.21E+01 | 2.28E+02 | 8.75E+01 | 1.06E+02 | 5.98E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | HHO | 1.53E+03 | 7.89E+03 | 3.48E+03 | 3.54E+03 | 1.04E+03 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | GWO | 1.92E+02 | 2.92E+03 | 3.44E+02 | 7.36E+02 | 7.96E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| F10 | MFO | 3.70E+02 | 1.16E+04 | 7.55E+02 | 2.78E+03 | 3.12E+03 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | WOA | 1.98E+02 | 7.61E+02 | 3.32E+02 | 3.48E+02 | 1.08E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | CMAES | 1.93E+03 | 4.23E+04 | 2.20E+04 | 2.10E+04 | 9.66E+03 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | AGSK | 9.22E+00 | 7.50E+01 | 2.18E+01 | 2.45E+01 | 1.11E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | HSES | 9.95E−01 | 6.89E+01 | 5.97E+00 | 2.06E+01 | 2.59E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | MadDE | 2.90E+01 | 9.79E+01 | 6.35E+01 | 6.51E+01 | 1.80E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | IMODE | 4.08E+01 | 2.34E+02 | 1.02E+02 | 1.13E+02 | 4.70E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | ALSHADE | 0.00E+00 | 6.50E+01 | 3.98E+00 | 1.64E+01 | 2.45E+01 | 2.70E+05 | 3.00E+05 | 3.00E+05 | 2.99E+05 | 4.19E+03 | 1.96 |

(*continued on next page*)

**Table E.9** (*continued*).

| Fun | Alg. | Error | | | | | Function evaluations | | | | | SR (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No. | Name | Best | Worst | Median | Mean | SD | Best | Worst | Median | Mean | SD | |
| | EA4eig | 2.46E+02 | 6.01E+02 | 4.02E+02 | 4.24E+02 | 8.03E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | APGSKIMODE | 6.16E+00 | 7.98E+01 | 1.47E+01 | 2.06E+01 | 1.78E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | DA2MODE | 4.56E−01 | 1.23E+01 | 3.99E+00 | **4.02E+00** | 2.06E+00 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | ABC | 2.20E+06 | 1.00E+07 | 5.80E+06 | 5.83E+06 | 1.98E+06 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | GA | 3.71E+05 | 1.65E+07 | 3.76E+06 | 4.25E+06 | 3.91E+06 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | PSO | 2.18E+08 | 3.63E+09 | 2.31E+09 | 2.15E+09 | 6.14E+08 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | DE | 4.75E+04 | 4.80E+06 | 2.38E+05 | 9.06E+05 | 1.26E+06 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | SA | 3.96E+06 | 1.90E+07 | 9.86E+06 | 1.05E+07 | 3.16E+06 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | TLBO | 9.64E+03 | 4.11E+05 | 2.82E+04 | 6.65E+04 | 1.15E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | BAS | 1.60E+10 | 4.49E+10 | 2.86E+10 | 2.90E+10 | 6.47E+09 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | FA | 2.48E+04 | 3.30E+05 | 1.09E+05 | 1.08E+05 | 6.45E+04 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | HHO | 8.42E+07 | 1.04E+09 | 3.71E+08 | 4.44E+08 | 2.81E+08 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | GWO | 1.54E+06 | 2.74E+08 | 1.56E+07 | 4.14E+07 | 7.19E+07 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| F11 | MFO | 4.03E+05 | 4.77E+09 | 3.65E+07 | 7.86E+08 | 1.62E+09 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | WOA | 7.16E+06 | 1.02E+08 | 3.98E+07 | 4.67E+07 | 2.83E+07 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | CMAES | 7.46E+08 | 6.31E+09 | 3.59E+09 | 3.59E+09 | 1.41E+09 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | AGSK | 1.62E+03 | 5.49E+04 | 1.17E+04 | 1.32E+04 | 8.99E+03 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | HSES | 2.29E+02 | 1.54E+03 | 8.79E+02 | 8.85E+02 | 2.99E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | MadDE | 1.42E+04 | 2.77E+05 | 7.83E+04 | 9.44E+04 | 6.64E+04 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | IMODE | 5.72E+02 | 1.86E+03 | 8.26E+02 | 1.03E+03 | 3.40E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | ALSHADE | 3.43E+02 | 1.69E+03 | 1.03E+03 | 1.02E+03 | 3.22E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | EA4eig | 1.11E+07 | 3.14E+08 | 1.40E+08 | 1.75E+08 | 8.73E+07 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | APGSKIMODE | 1.43E+03 | 1.02E+04 | 4.69E+03 | 5.06E+03 | 1.92E+03 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | DA2MODE | 1.23E+02 | 1.26E+03 | 5.80E+02 | **6.13E+02** | 2.43E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | ABC | 5.23E+02 | 2.99E+04 | 1.04E+04 | 1.25E+04 | 6.65E+03 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | GA | 5.91E+04 | 4.54E+05 | 1.32E+05 | 1.80E+05 | 1.21E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | PSO | 4.31E+04 | 1.39E+10 | 1.32E+09 | 1.95E+09 | 3.14E+09 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | DE | 1.79E+03 | 6.10E+04 | 4.80E+03 | 1.38E+04 | 1.91E+04 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | SA | 2.88E+05 | 2.39E+06 | 9.64E+05 | 1.21E+06 | 7.30E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | TLBO | 6.68E+02 | 6.15E+04 | 8.92E+03 | 1.68E+04 | 1.82E+04 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | BAS | 9.52E+09 | 5.25E+10 | 2.75E+10 | 3.07E+10 | 1.10E+10 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | FA | 2.19E+02 | 5.09E+04 | 4.04E+03 | 1.91E+04 | 2.03E+04 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | HHO | 1.41E+06 | 3.47E+07 | 8.85E+06 | 1.19E+07 | 9.46E+06 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | GWO | 1.64E+04 | 2.69E+07 | 7.44E+04 | 2.79E+06 | 7.80E+06 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| F12 | MFO | 9.72E+03 | 1.79E+09 | 3.19E+05 | 5.93E+07 | 2.89E+08 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | WOA | 2.45E+04 | 4.53E+05 | 1.22E+05 | 1.37E+05 | 7.81E+04 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | CMAES | 3.13E+08 | 5.78E+09 | 2.62E+09 | 2.88E+09 | 1.56E+09 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | AGSK | 1.45E+01 | 1.67E+02 | 5.87E+01 | 6.94E+01 | 3.60E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | HSES | 3.10E+01 | 1.75E+02 | 7.56E+01 | 8.73E+01 | 3.30E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | MadDE | 4.14E+02 | 5.23E+03 | 1.28E+03 | 1.52E+03 | 8.70E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | IMODE | 1.92E+02 | 8.32E+02 | 3.94E+02 | 4.35E+02 | 1.89E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | ALSHADE | 9.95E−01 | 2.44E+01 | 1.80E+01 | 1.66E+01 | 5.95E+00 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | EA4eig | 3.33E+06 | 2.13E+08 | 4.51E+07 | 4.94E+07 | 4.44E+07 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | APGSKIMODE | 5.77E+00 | 1.06E+02 | 2.15E+01 | 2.73E+01 | 2.08E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | DA2MODE | 2.05E−01 | 3.51E+01 | 1.69E+01 | **1.60E+01** | 6.48E+00 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | ABC | 9.15E+03 | 9.36E+04 | 5.11E+04 | 5.25E+04 | 2.76E+04 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | GA | 5.54E+04 | 7.68E+06 | 9.15E+05 | 1.13E+06 | 1.30E+06 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | PSO | 1.01E+05 | 4.05E+06 | 7.94E+05 | 1.19E+06 | 1.14E+06 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | DE | 7.38E+01 | 1.15E+02 | 8.06E+01 | 8.62E+01 | 1.16E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | SA | 2.70E+03 | 2.98E+04 | 1.85E+04 | 1.59E+04 | 9.93E+03 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | TLBO | 3.94E+02 | 1.18E+04 | 2.03E+03 | 2.69E+03 | 2.58E+03 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | BAS | 2.20E+07 | 2.61E+08 | 1.01E+08 | 9.74E+07 | 5.67E+07 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | FA | 1.53E+03 | 6.11E+04 | 1.14E+04 | 2.18E+04 | 1.87E+04 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | HHO | 1.98E+05 | 4.66E+06 | 1.65E+06 | 1.97E+06 | 1.24E+06 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | GWO | 3.40E+03 | 4.56E+05 | 4.58E+04 | 9.77E+04 | 1.37E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| F13 | MFO | 1.30E+03 | 1.67E+06 | 6.71E+04 | 2.87E+05 | 4.55E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | WOA | 4.20E+03 | 2.77E+06 | 5.07E+05 | 9.24E+05 | 9.19E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | CMAES | 6.53E+05 | 1.45E+07 | 4.09E+06 | 5.81E+06 | 4.34E+06 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | AGSK | 2.75E+01 | 4.17E+01 | 3.50E+01 | 3.50E+01 | 3.01E+00 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | HSES | 2.90E+01 | 2.26E+02 | 4.98E+01 | 6.20E+01 | 3.68E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | MadDE | 4.64E+01 | 8.06E+01 | 6.42E+01 | 6.27E+01 | 8.28E+00 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | IMODE | 9.37E+01 | 1.77E+02 | 1.36E+02 | 1.38E+02 | 3.15E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | ALSHADE | 6.73E+00 | 2.44E+01 | 2.11E+01 | 2.09E+01 | 2.30E+00 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | EA4eig | 2.77E+02 | 2.73E+05 | 5.44E+04 | 5.90E+04 | 4.29E+04 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | APGSKIMODE | 8.32E+00 | 4.09E+01 | 3.07E+01 | 3.01E+01 | 5.65E+00 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | DA2MODE | 4.42E+00 | 2.50E+01 | 2.15E+01 | **1.90E+01** | 5.97E+00 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | ABC | 7.87E+01 | 7.26E+03 | 9.82E+02 | 1.68E+03 | 1.81E+03 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | GA | 2.49E+03 | 1.88E+05 | 2.68E+04 | 4.06E+04 | 3.68E+04 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | PSO | 4.90E+03 | 1.04E+05 | 1.55E+04 | 2.01E+04 | 2.32E+04 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | DE | 6.64E+01 | 1.50E+02 | 7.89E+01 | 8.51E+01 | 2.30E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | SA | 3.02E+04 | 1.15E+05 | 6.37E+04 | 6.51E+04 | 2.50E+04 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | TLBO | 1.75E+02 | 2.30E+04 | 1.48E+03 | 4.33E+03 | 6.29E+03 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | BAS | 2.17E+09 | 1.25E+10 | 7.59E+09 | 7.55E+09 | 3.53E+09 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | FA | 5.56E+01 | 4.13E+04 | 2.86E+03 | 9.64E+03 | 1.25E+04 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | HHO | 7.16E+04 | 5.27E+06 | 9.01E+05 | 1.26E+06 | 1.51E+06 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | GWO | 1.10E+04 | 9.14E+06 | 3.17E+04 | 2.79E+05 | 1.30E+06 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| F14 | MFO | 1.91E+03 | 1.39E+05 | 4.98E+04 | 6.15E+04 | 3.40E+04 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | WOA | 1.36E+04 | 2.41E+05 | 7.29E+04 | 9.05E+04 | 5.90E+04 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | CMAES | 3.03E+07 | 1.30E+09 | 2.98E+08 | 3.57E+08 | 2.40E+08 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | AGSK | 9.49E+00 | 2.21E+01 | 1.60E+01 | 1.63E+01 | 2.77E+00 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | HSES | 4.71E−01 | 2.52E+01 | 4.30E+00 | 5.08E+00 | 4.12E+00 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | MadDE | 2.46E+01 | 1.48E+02 | 8.92E+01 | 8.54E+01 | 2.97E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | IMODE | 4.61E+01 | 2.32E+02 | 8.78E+01 | 1.02E+02 | 3.92E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | ALSHADE | 4.55E−01 | 7.70E+00 | 2.84E+00 | **3.09E+00** | 1.59E+00 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | EA4eig | 2.33E+04 | 1.84E+07 | 5.19E+06 | 6.54E+06 | 5.65E+06 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | APGSKIMODE | 3.42E+00 | 1.65E+01 | 9.30E+00 | 9.71E+00 | 3.07E+00 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | DA2MODE | 8.75E−01 | 1.02E+01 | 4.18E+00 | 5.01E+00 | 2.52E+00 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | ABC | 1.03E+03 | 1.66E+03 | 1.48E+03 | 1.45E+03 | 1.64E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | GA | 6.45E+02 | 2.02E+03 | 1.15E+03 | 1.25E+03 | 3.78E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | PSO | 1.56E+03 | 3.42E+03 | 2.27E+03 | 2.38E+03 | 5.64E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | DE | 4.74E+02 | 1.04E+03 | 7.82E+02 | 7.93E+02 | 1.48E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | SA | 1.46E+02 | 5.61E+02 | 1.95E+02 | 2.57E+02 | 9.88E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | TLBO | 2.88E+02 | 9.87E+02 | 6.01E+02 | 6.00E+02 | 1.88E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | BAS | 5.75E+03 | 1.50E+04 | 7.90E+03 | 9.19E+03 | 2.72E+03 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | FA | 2.86E+02 | 1.25E+03 | 6.08E+02 | 6.27E+02 | 2.44E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | HHO | 1.95E+03 | 3.56E+03 | 2.77E+03 | 2.69E+03 | 4.99E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | GWO | 3.34E+02 | 1.32E+03 | 7.30E+02 | 7.75E+02 | 2.59E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| F15 | MFO | 7.88E+02 | 2.28E+03 | 1.47E+03 | 1.53E+03 | 3.96E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | WOA | 1.02E+03 | 3.36E+03 | 1.84E+03 | 1.92E+03 | 6.15E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | CMAES | 2.26E+03 | 3.77E+03 | 3.17E+03 | 3.16E+03 | 3.12E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | AGSK | 2.76E+02 | 7.26E+02 | 4.63E+02 | 4.62E+02 | 8.90E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | HSES | 3.19E+00 | 9.14E+02 | 2.99E+02 | 2.87E+02 | 2.16E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | MadDE | 2.61E+02 | 6.77E+02 | 4.70E+02 | 4.69E+02 | 9.38E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | IMODE | 3.53E+02 | 1.00E+03 | 8.07E+02 | 7.57E+02 | 2.12E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | ALSHADE | 4.99E+00 | 2.35E+02 | 1.81E+01 | **2.75E+01** | 3.82E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |

(*continued on next page*)

**Table E.9** (*continued*).

| Fun | Alg. | Error | | | | | Function evaluations | | | | | SR (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No. | Name | Best | Worst | Median | Mean | SD | Best | Worst | Median | Mean | SD | |
| | EA4eig | 1.09E+03 | 2.24E+03 | 1.70E+03 | 1.69E+03 | 3.09E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | APGSKIMODE | 1.42E+02 | 7.63E+02 | 5.31E+02 | 5.20E+02 | 1.18E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | DA2MODE | 1.30E+01 | 2.86E+02 | 4.18E+01 | 7.79E+01 | 7.44E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | ABC | 3.68E+02 | 6.81E+02 | 5.70E+02 | 5.40E+02 | 8.86E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | GA | 8.15E+01 | 1.11E+03 | 6.30E+02 | 6.05E+02 | 2.83E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | PSO | 2.33E+02 | 1.70E+03 | 9.93E+02 | 9.90E+02 | 2.93E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | DE | 5.80E+01 | 2.46E+02 | 1.63E+02 | 1.47E+02 | 6.23E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | SA | 1.03E+02 | 4.41E+02 | 1.44E+02 | 1.78E+02 | 8.16E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | TLBO | 8.97E+01 | 5.63E+02 | 2.99E+02 | 2.94E+02 | 1.43E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | BAS | 4.89E+03 | 2.83E+05 | 1.48E+04 | 4.99E+04 | 6.84E+04 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | FA | 3.15E+01 | 9.69E+02 | 3.44E+02 | 3.72E+02 | 2.38E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | HHO | 4.44E+02 | 1.73E+03 | 1.10E+03 | 1.11E+03 | 3.63E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | GWO | 8.38E+01 | 7.13E+02 | 2.85E+02 | 2.98E+02 | 1.71E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| F16 | MFO | 3.14E+02 | 1.26E+03 | 9.24E+02 | 8.77E+02 | 2.45E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | WOA | 2.26E+02 | 1.34E+03 | 7.56E+02 | 7.70E+02 | 2.54E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | CMAES | 1.01E+03 | 2.08E+03 | 1.78E+03 | 1.77E+03 | 1.85E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | AGSK | 5.90E+01 | 1.61E+02 | 1.10E+02 | 1.11E+02 | 2.10E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | HSES | 2.18E+01 | 4.26E+02 | 2.80E+01 | 4.99E+01 | 8.72E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | MadDE | 4.86E+01 | 9.01E+01 | 7.18E+01 | 7.16E+01 | 9.95E+00 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | IMODE | 1.05E+02 | 3.38E+02 | 2.15E+02 | 2.28E+02 | 8.89E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | ALSHADE | 1.03E+01 | 4.89E+01 | 3.46E+01 | **3.37E+01** | 7.29E+00 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | EA4eig | 2.81E+02 | 8.20E+02 | 4.87E+02 | 4.96E+02 | 1.28E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | APGSKIMODE | 5.59E+01 | 1.90E+02 | 1.03E+02 | 1.03E+02 | 2.94E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | DA2MODE | 2.64E+01 | 7.73E+01 | 4.25E+01 | 4.51E+01 | 1.01E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | ABC | 1.50E+06 | 4.63E+06 | 2.81E+06 | 2.85E+06 | 8.97E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | GA | 2.82E+05 | 1.56E+07 | 1.07E+06 | 2.54E+06 | 3.23E+06 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | PSO | 4.05E+05 | 2.07E+07 | 2.40E+06 | 4.90E+06 | 5.77E+06 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | DE | 1.67E+05 | 3.61E+05 | 2.10E+05 | 2.28E+05 | 5.42E+04 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | SA | 6.07E+04 | 5.72E+05 | 1.34E+05 | 2.11E+05 | 1.47E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | TLBO | 3.34E+04 | 5.83E+05 | 1.69E+05 | 2.11E+05 | 1.48E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | BAS | 2.19E+08 | 1.94E+09 | 1.09E+09 | 9.21E+08 | 5.26E+08 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | FA | 2.50E+04 | 6.02E+05 | 1.04E+05 | 1.91E+05 | 1.79E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | HHO | 4.41E+05 | 4.92E+07 | 1.74E+07 | 1.80E+07 | 1.39E+07 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | GWO | 4.19E+04 | 7.27E+06 | 4.62E+05 | 7.11E+05 | 1.37E+06 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| F17 | MFO | 8.15E+04 | 2.90E+07 | 1.02E+06 | 4.28E+06 | 7.44E+06 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | WOA | 6.65E+04 | 1.52E+07 | 1.68E+06 | 3.37E+06 | 4.13E+06 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | CMAES | 6.45E+06 | 1.19E+08 | 3.97E+07 | 4.72E+07 | 3.05E+07 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | AGSK | 2.55E+01 | 1.96E+02 | 4.58E+01 | 6.05E+01 | 3.80E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | HSES | 3.33E+01 | 1.78E+02 | 9.99E+01 | 1.03E+02 | 3.47E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | MadDE | 4.70E+01 | 3.37E+02 | 9.84E+01 | 1.08E+02 | 4.66E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | IMODE | 6.01E+01 | 1.83E+02 | 8.21E+01 | 9.42E+01 | 3.64E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | ALSHADE | 2.03E+01 | 2.65E+01 | 2.15E+01 | 2.17E+01 | 1.18E+00 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | EA4eig | 7.29E+04 | 3.12E+06 | 1.34E+06 | 1.33E+06 | 9.75E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | APGSKIMODE | 2.18E+01 | 3.99E+01 | 2.79E+01 | 2.84E+01 | 3.83E+00 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | DA2MODE | 2.02E+01 | 2.26E+01 | 2.06E+01 | **2.11E+01** | 6.77E−01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | ABC | 3.67E+02 | 2.16E+04 | 3.38E+03 | 5.27E+03 | 4.71E+03 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | GA | 2.77E+03 | 1.90E+05 | 3.28E+04 | 4.42E+04 | 4.86E+04 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | PSO | 3.77E+03 | 3.44E+06 | 8.81E+04 | 4.16E+05 | 8.61E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | DE | 3.23E+01 | 7.67E+01 | 3.95E+01 | 4.16E+01 | 9.47E+00 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | SA | 9.48E+03 | 1.52E+05 | 3.70E+04 | 5.14E+04 | 4.61E+04 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | TLBO | 4.53E+02 | 3.27E+04 | 5.76E+03 | 9.37E+03 | 8.94E+03 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | BAS | 6.12E+08 | 1.79E+10 | 1.16E+10 | 9.47E+09 | 5.22E+09 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | FA | 2.74E+01 | 5.44E+04 | 1.05E+04 | 1.36E+04 | 1.29E+04 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | HHO | 4.13E+05 | 4.36E+07 | 5.12E+06 | 1.19E+07 | 1.26E+07 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | GWO | 9.42E+03 | 3.32E+07 | 4.27E+05 | 8.06E+06 | 1.33E+07 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| F18 | MFO | 1.86E+03 | 1.79E+08 | 1.39E+05 | 7.23E+06 | 2.71E+07 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | WOA | 1.49E+05 | 9.64E+06 | 1.21E+06 | 2.81E+06 | 2.96E+06 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | CMAES | 2.94E+07 | 9.51E+08 | 3.77E+08 | 4.16E+08 | 2.12E+08 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | AGSK | 4.55E+00 | 1.84E+01 | 1.48E+01 | 1.46E+01 | 2.67E+00 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | HSES | 9.40E+00 | 2.97E+01 | 1.53E+01 | 1.56E+01 | 3.37E+00 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | MadDE | 2.09E+01 | 4.95E+01 | 3.22E+01 | 3.27E+01 | 6.16E+00 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | IMODE | 6.42E+01 | 2.55E+02 | 1.13E+02 | 1.13E+02 | 4.03E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | ALSHADE | 2.65E+00 | 8.94E+00 | 5.08E+00 | **5.30E+00** | 1.59E+00 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | EA4eig | 7.63E+05 | 2.30E+07 | 1.05E+07 | 8.68E+06 | 6.30E+06 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | APGSKIMODE | 6.04E+00 | 1.45E+01 | 1.10E+01 | 1.06E+01 | 1.76E+00 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | DA2MODE | 3.34E+00 | 7.80E+00 | 5.37E+00 | 5.40E+00 | 1.06E+00 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | ABC | 3.47E+02 | 7.90E+02 | 6.19E+02 | 5.87E+02 | 1.35E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | GA | 2.96E+02 | 9.38E+02 | 5.62E+02 | 5.65E+02 | 1.63E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | PSO | 1.65E+02 | 1.12E+03 | 7.74E+02 | 7.77E+02 | 2.47E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | DE | 2.95E+01 | 2.83E+02 | 5.44E+01 | 8.44E+01 | 6.97E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | SA | 7.31E+01 | 3.72E+02 | 1.41E+02 | 1.63E+02 | 7.49E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | TLBO | 1.37E+02 | 5.77E+02 | 2.68E+02 | 2.80E+02 | 9.89E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | BAS | 1.29E+03 | 2.12E+03 | 1.73E+03 | 1.72E+03 | 2.16E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | FA | 4.41E+01 | 6.75E+02 | 2.91E+02 | 2.94E+02 | 1.79E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | HHO | 5.15E+02 | 1.24E+03 | 8.21E+02 | 8.58E+02 | 1.78E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | GWO | 1.27E+02 | 6.78E+02 | 3.46E+02 | 3.58E+02 | 1.31E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| F19 | MFO | 2.76E+02 | 1.06E+03 | 7.25E+02 | 6.87E+02 | 2.08E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | WOA | 3.66E+02 | 1.05E+03 | 6.89E+02 | 7.15E+02 | 1.77E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | CMAES | 5.11E+02 | 1.22E+03 | 8.77E+02 | 8.67E+02 | 1.60E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | AGSK | 7.10E+01 | 2.58E+02 | 1.85E+02 | 1.77E+02 | 4.75E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | HSES | 1.39E+02 | 3.25E+02 | 1.43E+02 | 1.58E+02 | 4.81E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | MadDE | 4.81E+01 | 1.97E+02 | 8.84E+01 | 9.78E+01 | 3.67E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | IMODE | 1.32E+02 | 3.90E+02 | 2.84E+02 | 2.76E+02 | 7.27E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | ALSHADE | 1.85E+01 | 4.79E+01 | 3.03E+01 | **3.18E+01** | 5.71E+00 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | EA4eig | 2.24E+02 | 7.96E+02 | 4.91E+02 | 5.04E+02 | 1.20E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | APGSKIMODE | 4.71E+01 | 2.66E+02 | 1.47E+02 | 1.43E+02 | 5.62E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | DA2MODE | 2.35E+01 | 6.64E+01 | 3.58E+01 | 3.89E+01 | 1.07E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | ABC | 3.87E+02 | 4.16E+02 | 4.03E+02 | 4.02E+02 | 7.94E+00 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | GA | 2.48E+02 | 3.27E+02 | 2.90E+02 | 2.87E+02 | 2.35E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | PSO | 4.05E+02 | 5.96E+02 | 4.81E+02 | 4.78E+02 | 4.34E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | DE | 3.03E+02 | 3.75E+02 | 3.58E+02 | 3.53E+02 | 1.74E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | SA | 2.74E+02 | 3.08E+02 | 2.89E+02 | 2.88E+02 | 9.13E+00 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | TLBO | 2.62E+02 | 3.39E+02 | 2.78E+02 | 2.91E+02 | 2.26E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | BAS | 6.95E+02 | 9.69E+02 | 8.14E+02 | 8.15E+02 | 6.82E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | FA | 2.32E+02 | 3.21E+02 | 2.64E+02 | 2.73E+02 | 1.97E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | HHO | 2.23E+02 | 6.71E+02 | 5.72E+02 | 5.52E+02 | 6.70E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | GWO | 2.47E+02 | 3.30E+02 | 2.76E+02 | 2.81E+02 | 1.59E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| F20 | MFO | 3.11E+02 | 4.73E+02 | 3.78E+02 | 3.89E+02 | 4.39E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | WOA | 3.89E+02 | 5.69E+02 | 4.80E+02 | 4.72E+02 | 5.39E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | CMAES | 2.16E+02 | 6.09E+02 | 5.17E+02 | 5.05E+02 | 6.41E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | AGSK | 2.25E+02 | 2.85E+02 | 2.69E+02 | 2.67E+02 | 1.11E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | HSES | 2.04E+02 | 2.19E+02 | 2.07E+02 | 2.08E+02 | 2.86E+00 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | MadDE | 1.23E+02 | 2.82E+02 | 1.74E+02 | **1.98E+02** | 5.65E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | IMODE | 1.00E+02 | 3.28E+02 | 2.82E+02 | 2.51E+02 | 7.81E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | ALSHADE | 2.00E+02 | 2.10E+02 | 2.04E+02 | 2.05E+02 | 1.95E+00 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |

(*continued on next page*)

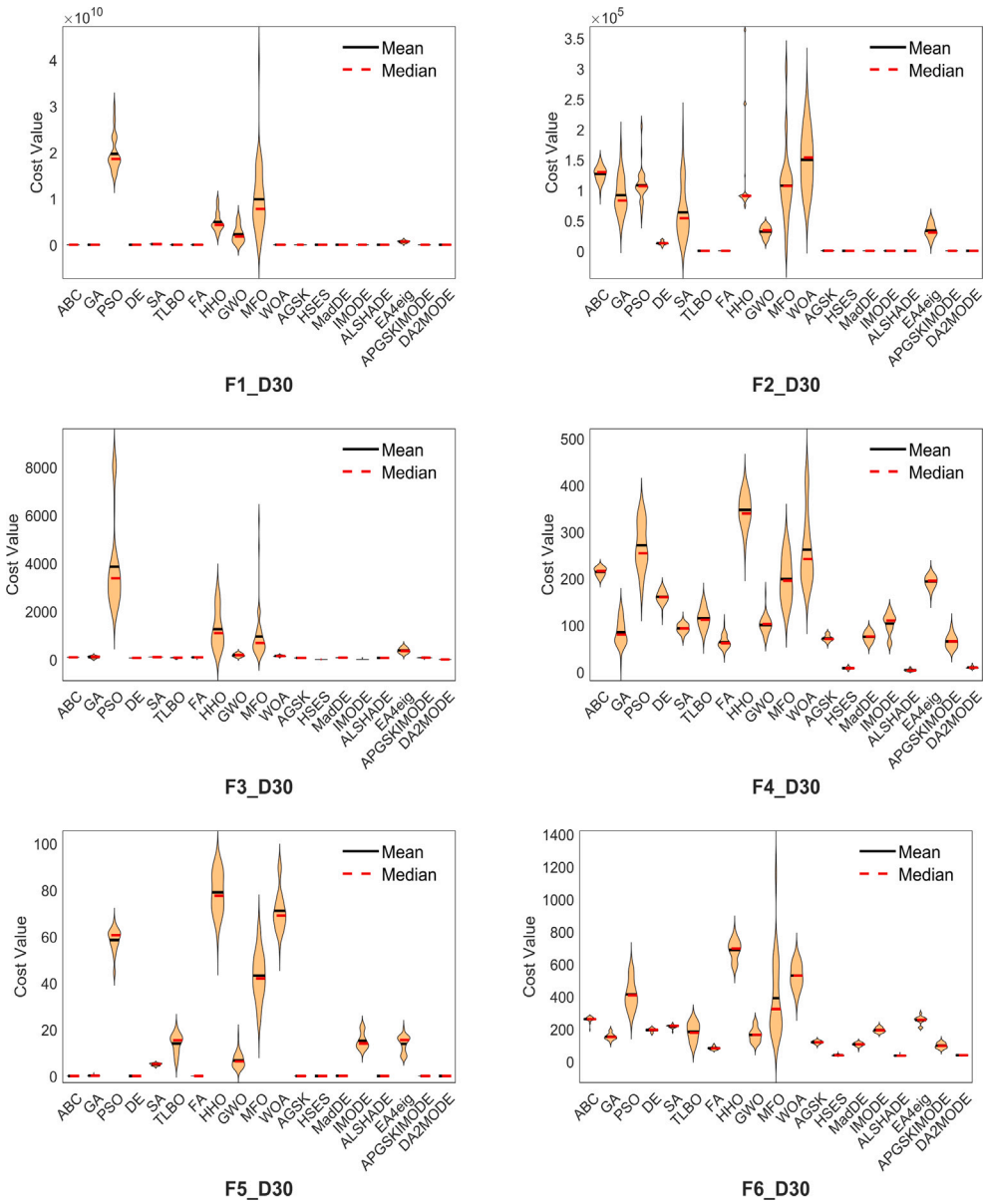



**Fig. F.9a.** Violin plots for the best fitness in 51 runs for all the algorithms in CEC2017-2018, F1-F6 (30D).

### *E.2. Part 2: Advanced DE variants*

See Tables E.12–E.14

## Appendix F. CEC2017-2018 violin plots

### *F.1. Part 1: Meta-heuristic algorithms and CEC winners*

See Figs. F.9a–F.9e, Figs. F.10a–F.10e and Figs. F.11a–F.11e.

### *F.2. Part 2: Advanced DE variants*

See Figs. F.12a–F.12e, Figs. F.13a–F.13e and Figs. F.14a–F.14e.

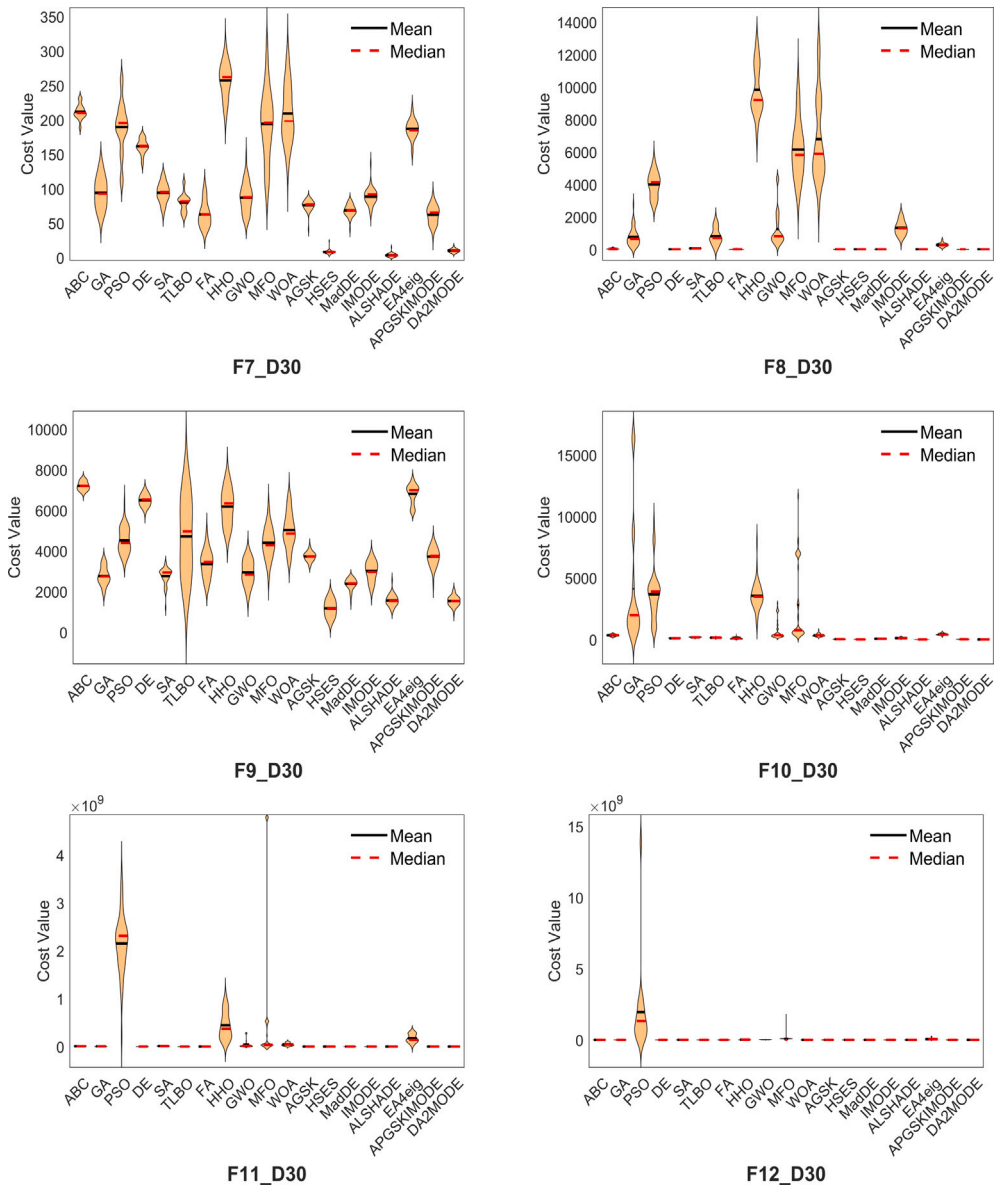



**Fig. F.9b.** Violin plots for the best fitness in 51 runs for all the algorithms in CEC2017-2018, F7-F12 (30D).

**Table E.9** (*continued*).

| Fun | Alg. | Error | | | | | Function evaluations | | | | | SR (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No. | Name | Best | Worst | Median | Mean | SD | Best | Worst | Median | Mean | SD | |
| | EA4eig | 3.56E+02 | 4.09E+02 | 3.88E+02 | 3.87E+02 | 1.33E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | APGSKIMODE | 1.12E+02 | 2.99E+02 | 2.61E+02 | 2.43E+02 | 5.05E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | DA2MODE | 2.03E+02 | 2.18E+02 | 2.08E+02 | 2.08E+02 | 2.70E+00 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | ABC | 7.76E+02 | 3.83E+03 | 2.03E+03 | 2.21E+03 | 7.52E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | GA | 1.04E+02 | 3.77E+03 | 2.69E+03 | 2.42E+03 | 1.13E+03 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | PSO | 1.99E+03 | 6.44E+03 | 5.11E+03 | 4.75E+03 | 1.17E+03 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | DE | 1.00E+02 | 6.74E+03 | 6.43E+03 | 4.46E+03 | 2.99E+03 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | SA | 1.56E+02 | 2.78E+03 | 1.65E+02 | 7.50E+02 | 1.02E+03 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | TLBO | 1.00E+02 | 6.85E+03 | 1.00E+02 | 3.74E+02 | 1.16E+03 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | BAS | 9.45E+03 | 1.08E+04 | 1.01E+04 | 1.02E+04 | 4.62E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | FA | 1.00E+02 | 3.35E+03 | 1.00E+02 | 4.13E+02 | 9.59E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | HHO | 1.24E+03 | 7.72E+03 | 6.44E+03 | 5.95E+03 | 1.29E+03 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | GWO | 2.67E+02 | 7.31E+03 | 2.86E+03 | 2.88E+03 | 2.25E+03 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| F21 | MFO | 1.02E+03 | 6.32E+03 | 4.79E+03 | 4.29E+03 | 1.33E+03 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | WOA | 2.95E+02 | 6.38E+03 | 4.80E+03 | 4.30E+03 | 1.86E+03 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | CMAES | 7.30E+03 | 8.24E+03 | 7.78E+03 | 7.80E+03 | 2.30E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | AGSK | 1.00E+02 | 1.00E+02 | 1.00E+02 | 1.00E+02 | 4.35E−12 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | HSES | 1.00E+02 | 1.00E+02 | 1.00E+02 | 1.00E+02 | 9.88E−10 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | MadDE | 1.00E+02 | 1.00E+02 | 1.00E+02 | 1.00E+02 | 4.95E−05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | IMODE | 1.00E+02 | 1.03E+02 | 1.00E+02 | 1.01E+02 | 1.38E+00 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | ALSHADE | 1.00E+02 | 1.00E+02 | 1.00E+02 | **1.00E+02** | 1.24E−13 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | EA4eig | 1.29E+02 | 4.03E+02 | 2.55E+02 | 2.44E+02 | 6.31E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | APGSKIMODE | 1.00E+02 | 1.00E+02 | 1.00E+02 | 1.00E+02 | 9.49E−09 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | DA2MODE | 1.00E+02 | 1.00E+02 | 1.00E+02 | 1.00E+02 | 2.05E−13 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | ABC | 5.38E+02 | 5.63E+02 | 5.49E+02 | 5.50E+02 | 7.84E+00 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | GA | 3.93E+02 | 5.48E+02 | 4.67E+02 | 4.68E+02 | 2.83E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | PSO | 9.59E+02 | 1.52E+03 | 1.21E+03 | 1.19E+03 | 1.45E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | DE | 4.90E+02 | 5.30E+02 | 5.10E+02 | 5.12E+02 | 1.09E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | SA | 4.27E+02 | 4.58E+02 | 4.36E+02 | 4.40E+02 | 8.98E+00 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | TLBO | 4.20E+02 | 5.98E+02 | 4.66E+02 | 4.75E+02 | 4.55E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | BAS | 1.30E+03 | 2.32E+03 | 1.59E+03 | 1.66E+03 | 2.59E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | FA | 3.84E+02 | 4.79E+02 | 4.34E+02 | 4.34E+02 | 2.28E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | HHO | 7.23E+02 | 1.44E+03 | 8.85E+02 | 9.01E+02 | 1.29E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | GWO | 4.11E+02 | 5.46E+02 | 4.39E+02 | 4.53E+02 | 3.88E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| F22 | MFO | 4.78E+02 | 6.27E+02 | 5.71E+02 | 5.55E+02 | 4.51E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | WOA | 5.93E+02 | 9.59E+02 | 7.36E+02 | 7.36E+02 | 9.13E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | CMAES | 6.59E+02 | 8.13E+02 | 7.27E+02 | 7.28E+02 | 3.77E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | AGSK | 3.97E+02 | 4.24E+02 | 4.12E+02 | 4.12E+02 | 5.84E+00 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | HSES | 3.24E+02 | 3.69E+02 | 3.50E+02 | 3.52E+02 | 9.01E+00 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | MadDE | 3.86E+02 | 4.32E+02 | 4.11E+02 | 4.11E+02 | 9.40E+00 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | IMODE | 4.74E+02 | 5.39E+02 | 5.08E+02 | 5.06E+02 | 1.85E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | ALSHADE | 3.45E+02 | 3.61E+02 | 3.51E+02 | **3.51E+02** | 3.58E+00 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | EA4eig | 5.61E+02 | 6.41E+02 | 5.83E+02 | 5.92E+02 | 2.22E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | APGSKIMODE | 3.16E+02 | 4.39E+02 | 4.12E+02 | 4.10E+02 | 1.96E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | DA2MODE | 3.49E+02 | 3.65E+02 | 3.57E+02 | 3.57E+02 | 3.33E+00 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | ABC | 5.97E+02 | 6.30E+02 | 6.14E+02 | 6.15E+02 | 9.12E+00 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | GA | 5.08E+02 | 7.15E+02 | 5.96E+02 | 5.96E+02 | 5.56E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | PSO | 1.02E+03 | 1.64E+03 | 1.34E+03 | 1.29E+03 | 1.72E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | DE | 5.67E+02 | 6.04E+02 | 5.89E+02 | 5.86E+02 | 1.16E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | SA | 4.93E+02 | 5.18E+02 | 5.06E+02 | 5.05E+02 | 7.05E+00 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | TLBO | 4.97E+02 | 6.47E+02 | 5.37E+02 | 5.45E+02 | 4.00E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | BAS | 1.49E+03 | 2.62E+03 | 1.80E+03 | 1.89E+03 | 2.93E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | FA | 4.61E+02 | 5.65E+02 | 4.91E+02 | 4.89E+02 | 2.24E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | HHO | 8.22E+02 | 1.34E+03 | 1.03E+03 | 1.03E+03 | 1.44E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | GWO | 4.81E+02 | 6.57E+02 | 5.14E+02 | 5.18E+02 | 4.05E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| F23 | MFO | 5.16E+02 | 6.37E+02 | 5.94E+02 | 5.91E+02 | 3.16E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | WOA | 6.22E+02 | 9.66E+02 | 8.31E+02 | 8.13E+02 | 8.32E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | CMAES | 7.07E+02 | 7.87E+02 | 7.66E+02 | 7.60E+02 | 2.11E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | AGSK | 4.65E+02 | 4.81E+02 | 4.72E+02 | 4.72E+02 | 4.35E+00 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | HSES | 4.12E+02 | 4.31E+02 | 4.20E+02 | **4.20E+02** | 4.54E+00 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | MadDE | 4.61E+02 | 4.99E+02 | 4.80E+02 | 4.80E+02 | 9.55E+00 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | IMODE | 4.81E+02 | 5.94E+02 | 5.54E+02 | 5.46E+02 | 3.75E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | ALSHADE | 4.24E+02 | 4.37E+02 | 4.29E+02 | 4.29E+02 | 2.64E+00 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | EA4eig | 5.81E+02 | 6.72E+02 | 6.45E+02 | 6.43E+02 | 2.08E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | APGSKIMODE | 4.27E+02 | 5.12E+02 | 4.85E+02 | 4.84E+02 | 1.54E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | DA2MODE | 4.27E+02 | 4.37E+02 | 4.32E+02 | 4.32E+02 | 2.05E+00 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | ABC | 3.87E+02 | 3.87E+02 | 3.87E+02 | 3.87E+02 | 8.96E−02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | GA | 3.88E+02 | 4.45E+02 | 3.98E+02 | 4.04E+02 | 1.43E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | PSO | 6.45E+02 | 1.57E+03 | 1.10E+03 | 1.05E+03 | 1.98E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | DE | 3.87E+02 | 3.88E+02 | 3.87E+02 | 3.87E+02 | 2.16E−01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | SA | 3.95E+02 | 3.98E+02 | 3.97E+02 | 3.97E+02 | 7.76E−01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | TLBO | 3.84E+02 | 4.53E+02 | 3.90E+02 | 4.07E+02 | 2.51E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | BAS | 7.60E+03 | 2.94E+04 | 1.48E+04 | 1.53E+04 | 5.02E+03 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | FA | 3.83E+02 | 3.87E+02 | 3.87E+02 | 3.86E+02 | 1.72E+00 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | HHO | 6.06E+02 | 8.27E+02 | 6.84E+02 | 6.87E+02 | 5.42E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | GWO | 4.25E+02 | 6.17E+02 | 4.80E+02 | 4.83E+02 | 4.86E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| F24 | MFO | 4.13E+02 | 2.16E+03 | 8.02E+02 | 8.50E+02 | 4.08E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | WOA | 3.96E+02 | 5.09E+02 | 4.43E+02 | 4.48E+02 | 3.28E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | CMAES | 3.90E+02 | 2.04E+03 | 4.17E+02 | 4.61E+02 | 2.36E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | AGSK | 3.87E+02 | 3.87E+02 | 3.87E+02 | 3.87E+02 | 2.67E−02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | HSES | 3.87E+02 | 3.87E+02 | 3.87E+02 | 3.87E+02 | 2.49E−02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | MadDE | 3.83E+02 | 3.87E+02 | 3.87E+02 | 3.86E+02 | 1.10E+00 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | IMODE | 3.84E+02 | 4.41E+02 | 3.87E+02 | 3.98E+02 | 1.94E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | ALSHADE | 3.87E+02 | 3.87E+02 | 3.87E+02 | 3.87E+02 | 2.14E−02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | EA4eig | 4.39E+02 | 5.43E+02 | 4.85E+02 | 4.84E+02 | 2.35E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | APGSKIMODE | 3.87E+02 | 3.87E+02 | 3.87E+02 | 3.87E+02 | 8.45E−02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | DA2MODE | 3.75E+02 | 3.96E+02 | 3.78E+02 | **3.78E+02** | 2.58E+00 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | ABC | 2.90E+03 | 3.25E+03 | 3.06E+03 | 3.06E+03 | 1.12E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | GA | 2.09E+02 | 4.20E+03 | 2.44E+03 | 2.35E+03 | 1.02E+03 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | PSO | 4.39E+03 | 8.77E+03 | 6.36E+03 | 6.23E+03 | 8.75E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | DE | 2.43E+03 | 2.73E+03 | 2.56E+03 | 2.56E+03 | 7.96E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | SA | 3.98E+02 | 2.10E+03 | 1.81E+03 | 1.64E+03 | 5.21E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | TLBO | 2.00E+02 | 5.03E+03 | 2.92E+03 | 2.55E+03 | 1.52E+03 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | BAS | 1.02E+04 | 1.74E+04 | 1.34E+04 | 1.35E+04 | 1.64E+03 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | FA | 3.00E+02 | 2.56E+03 | 1.77E+03 | 1.76E+03 | 4.30E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | HHO | 5.39E+03 | 8.11E+03 | 6.17E+03 | 6.31E+03 | 5.60E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | GWO | 1.36E+03 | 3.02E+03 | 2.10E+03 | 2.02E+03 | 3.41E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| F25 | MFO | 2.54E+03 | 4.75E+03 | 3.25E+03 | 3.38E+03 | 4.76E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | WOA | 2.39E+02 | 7.44E+03 | 5.25E+03 | 5.30E+03 | 1.32E+03 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | CMAES | 4.60E+03 | 6.40E+03 | 5.56E+03 | 5.58E+03 | 4.21E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | AGSK | 3.00E+02 | 1.92E+03 | 1.67E+03 | 1.54E+03 | 4.11E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | HSES | 5.68E+02 | 1.16E+03 | 9.15E+02 | 9.10E+02 | 9.96E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | MadDE | 2.00E+02 | 3.00E+02 | 3.00E+02 | 2.71E+02 | 4.60E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | IMODE | 2.00E+02 | 3.00E+02 | 3.00E+02 | **2.69E+02** | 4.69E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | ALSHADE | 8.51E+02 | 1.11E+03 | 9.76E+02 | 9.80E+02 | 6.11E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | EA4eig | 1.01E+03 | 3.81E+03 | 3.35E+03 | 3.21E+03 | 6.70E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |

(*continued on next page*)

**Table E.9** (*continued*).

| Fun | Alg. | Error | | | | | Function evaluations | | | | | SR (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No. | Name | Best | Worst | Median | Mean | SD | Best | Worst | Median | Mean | SD | |
| | APGSKIMODE | 2.18E+02 | 1.62E+03 | 3.00E+02 | 4.65E+02 | 4.18E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | DA2MODE | 2.00E+02 | 1.19E+03 | 3.00E+02 | 3.90E+02 | 2.62E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | ABC | 5.02E+02 | 5.26E+02 | 5.13E+02 | 5.14E+02 | 5.80E+00 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | GA | 5.08E+02 | 6.01E+02 | 5.33E+02 | 5.43E+02 | 2.47E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | PSO | 1.09E+03 | 2.21E+03 | 1.62E+03 | 1.60E+03 | 2.63E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | DE | 4.96E+02 | 5.18E+02 | 5.04E+02 | 5.05E+02 | 4.96E+00 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | SA | 4.82E+02 | 5.16E+02 | 5.07E+02 | 5.03E+02 | 1.09E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | TLBO | 5.24E+02 | 6.55E+02 | 5.52E+02 | 5.54E+02 | 2.13E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | BAS | 2.24E+03 | 4.59E+03 | 3.02E+03 | 3.12E+03 | 6.26E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | FA | 4.98E+02 | 5.51E+02 | 5.15E+02 | 5.18E+02 | 1.36E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | HHO | 6.75E+02 | 1.97E+03 | 9.47E+02 | 1.10E+03 | 3.52E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | GWO | 5.13E+02 | 5.75E+02 | 5.49E+02 | 5.45E+02 | 1.30E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| F26 | MFO | 5.18E+02 | 6.64E+02 | 5.53E+02 | 5.58E+02 | 2.78E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | WOA | 5.38E+02 | 7.73E+02 | 6.41E+02 | 6.41E+02 | 6.46E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | CMAES | 6.02E+02 | 7.82E+02 | 6.79E+02 | 6.83E+02 | 3.12E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | AGSK | 4.76E+02 | 5.11E+02 | 4.98E+02 | **4.97E+02** | 7.05E+00 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | HSES | 5.02E+02 | 5.48E+02 | 5.19E+02 | 5.21E+02 | 1.07E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | MadDE | 5.03E+02 | 5.23E+02 | 5.17E+02 | 5.16E+02 | 4.48E+00 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | IMODE | 5.61E+02 | 5.93E+02 | 5.79E+02 | 5.79E+02 | 9.65E+00 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | ALSHADE | 4.91E+02 | 5.16E+02 | 5.05E+02 | 5.05E+02 | 5.73E+00 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | EA4eig | 5.00E+02 | 7.82E+02 | 6.17E+02 | 6.22E+02 | 5.76E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | APGSKIMODE | 4.95E+02 | 5.20E+02 | 5.10E+02 | 5.09E+02 | 4.80E+00 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | DA2MODE | 5.00E+02 | 5.00E+02 | 5.00E+02 | 5.00E+02 | 1.73E−04 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | ABC | 4.00E+02 | 4.25E+02 | 4.08E+02 | 4.08E+02 | 4.90E+00 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | GA | 4.11E+02 | 4.85E+02 | 4.31E+02 | 4.42E+02 | 2.23E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | PSO | 1.08E+03 | 3.05E+03 | 1.82E+03 | 1.83E+03 | 4.20E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | DE | 3.00E+02 | 4.67E+02 | 3.00E+02 | 3.37E+02 | 6.26E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | SA | 3.92E+02 | 4.34E+02 | 4.27E+02 | 4.25E+02 | 1.11E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | TLBO | 3.00E+02 | 4.60E+02 | 4.02E+02 | 3.88E+02 | 3.66E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | BAS | 8.67E+03 | 1.51E+04 | 1.20E+04 | 1.16E+04 | 1.78E+03 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | FA | 3.00E+02 | 4.83E+02 | 4.10E+02 | 4.19E+02 | 3.55E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | HHO | 5.91E+02 | 1.71E+03 | 1.03E+03 | 1.00E+03 | 2.40E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | GWO | 5.01E+02 | 7.93E+02 | 5.85E+02 | 6.14E+02 | 7.92E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| F27 | MFO | 4.84E+02 | 3.92E+03 | 1.06E+03 | 1.55E+03 | 1.09E+03 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | WOA | 4.41E+02 | 6.03E+02 | 5.07E+02 | 5.09E+02 | 3.03E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | CMAES | 1.68E+03 | 4.24E+03 | 4.11E+03 | 3.66E+03 | 6.65E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | AGSK | 3.00E+02 | 4.52E+02 | 3.00E+02 | 3.14E+02 | 3.89E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | HSES | 3.00E+02 | 4.14E+02 | 3.00E+02 | 3.25E+02 | 4.47E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | MadDE | 3.91E+02 | 4.07E+02 | 3.99E+02 | 3.99E+02 | 4.69E+00 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | IMODE | 3.00E+02 | 3.00E+02 | 3.00E+02 | **3.00E+02** | 2.42E−06 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | ALSHADE | 3.00E+02 | 4.54E+02 | 3.00E+02 | 3.45E+02 | 5.69E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | EA4eig | 5.09E+02 | 7.81E+02 | 6.13E+02 | 6.35E+02 | 7.66E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | APGSKIMODE | 3.00E+02 | 4.09E+02 | 3.00E+02 | 3.10E+02 | 2.69E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | DA2MODE | 3.00E+02 | 4.53E+02 | 3.00E+02 | 3.51E+02 | 6.28E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | ABC | 1.01E+03 | 1.51E+03 | 1.34E+03 | 1.36E+03 | 1.02E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | GA | 4.77E+02 | 1.23E+03 | 8.45E+02 | 8.67E+02 | 1.97E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | PSO | 1.40E+03 | 4.16E+03 | 2.42E+03 | 2.66E+03 | 6.98E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | DE | 5.74E+02 | 1.12E+03 | 8.36E+02 | 8.26E+02 | 1.33E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | SA | 5.38E+02 | 6.47E+02 | 5.74E+02 | 5.76E+02 | 2.40E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | TLBO | 5.04E+02 | 1.30E+03 | 8.91E+02 | 8.69E+02 | 1.88E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | BAS | 8.58E+03 | 5.24E+05 | 3.86E+04 | 9.47E+04 | 1.32E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | FA | 5.35E+02 | 1.33E+03 | 8.45E+02 | 8.22E+02 | 2.18E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | HHO | 1.70E+03 | 5.53E+03 | 2.87E+03 | 2.99E+03 | 7.22E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | GWO | 5.61E+02 | 1.24E+03 | 8.54E+02 | 8.80E+02 | 1.79E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| F28 | MFO | 7.54E+02 | 1.91E+03 | 1.31E+03 | 1.28E+03 | 3.50E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | WOA | 1.08E+03 | 2.82E+03 | 2.05E+03 | 1.99E+03 | 3.99E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | CMAES | 1.85E+03 | 3.23E+03 | 2.80E+03 | 2.77E+03 | 2.61E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | AGSK | 3.97E+02 | 6.41E+02 | 5.60E+02 | 5.63E+02 | 4.06E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | HSES | 4.18E+02 | 8.24E+02 | 4.50E+02 | 4.78E+02 | 8.37E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | MadDE | 4.80E+02 | 6.09E+02 | 5.43E+02 | 5.39E+02 | 2.73E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | IMODE | 6.26E+02 | 1.00E+03 | 8.07E+02 | 8.01E+02 | 1.43E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | ALSHADE | 4.19E+02 | 4.86E+02 | 4.41E+02 | 4.44E+02 | 1.43E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | EA4eig | 8.09E+02 | 1.42E+03 | 1.07E+03 | 1.10E+03 | 1.57E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | APGSKIMODE | 4.79E+02 | 6.63E+02 | 5.60E+02 | 5.62E+02 | 3.82E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | DA2MODE | 2.33E+02 | 3.98E+02 | 3.63E+02 | **3.37E+02** | 5.47E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | ABC | 9.72E+03 | 4.10E+04 | 1.94E+04 | 1.86E+04 | 5.78E+03 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | GA | 8.10E+03 | 6.47E+04 | 2.52E+04 | 2.92E+04 | 1.70E+04 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | PSO | 1.97E+06 | 9.08E+07 | 1.99E+07 | 2.57E+07 | 2.26E+07 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | DE | 4.26E+03 | 1.18E+04 | 7.82E+03 | 7.70E+03 | 1.91E+03 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | SA | 1.03E+05 | 1.21E+06 | 3.13E+05 | 4.87E+05 | 3.72E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | TLBO | 2.09E+03 | 1.05E+04 | 3.97E+03 | 4.61E+03 | 2.28E+03 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | BAS | 1.53E+09 | 1.00E+10 | 4.51E+09 | 4.86E+09 | 2.12E+09 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | FA | 2.18E+03 | 1.25E+04 | 3.28E+03 | 4.15E+03 | 2.35E+03 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | HHO | 9.73E+06 | 1.88E+08 | 3.90E+07 | 7.31E+07 | 6.15E+07 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | GWO | 5.62E+05 | 1.87E+07 | 5.24E+06 | 7.10E+06 | 5.04E+06 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| F29 | MFO | 1.39E+04 | 5.13E+07 | 9.35E+05 | 6.07E+06 | 1.51E+07 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | WOA | 5.43E+05 | 3.26E+07 | 8.21E+06 | 9.95E+06 | 7.53E+06 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | CMAES | 2.93E+06 | 1.50E+09 | 4.60E+08 | 4.99E+08 | 4.03E+08 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | AGSK | 1.97E+03 | 2.55E+03 | 2.13E+03 | 2.17E+03 | 1.24E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | HSES | 1.98E+03 | 2.17E+03 | 2.05E+03 | 2.05E+03 | 4.08E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | MadDE | 2.66E+03 | 7.33E+03 | 4.39E+03 | 4.64E+03 | 8.82E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | IMODE | 2.75E+03 | 4.00E+03 | 3.09E+03 | 3.21E+03 | 3.56E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | ALSHADE | 1.94E+03 | 2.09E+03 | 1.97E+03 | 1.97E+03 | 3.84E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | EA4eig | 1.79E+05 | 2.40E+07 | 1.10E+07 | 1.24E+07 | 6.25E+06 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | APGSKIMODE | 1.98E+03 | 2.58E+03 | 2.09E+03 | 2.10E+03 | 9.97E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | DA2MODE | 2.04E+02 | 2.12E+02 | 2.08E+02 | **2.08E+02** | 1.76E+00 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |

**Table E.10**
The results metrics for the error and function evaluation metrics for 21 algorithms, CEC2017–2018 (F1-F3, 50 Dim).

| Fun | Alg. | Error | | | | | Function evaluations | | | | | SR (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No. | Name | Best | Worst | Median | Mean | SD | Best | Worst | Median | Mean | SD | |
| | ABC | 4.03E+00 | 1.14E+04 | 2.00E+03 | 2.86E+03 | 2.81E+03 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | GA | 4.89E+05 | 1.85E+06 | 1.07E+06 | 1.06E+06 | 3.64E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | PSO | 3.39E+10 | 6.89E+10 | 5.60E+10 | 5.48E+10 | 8.16E+09 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | DE | 3.37E+00 | 1.25E+04 | 9.77E+02 | 2.99E+03 | 3.64E+03 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | SA | 2.04E+07 | 3.56E+07 | 3.01E+07 | 2.91E+07 | 3.87E+06 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | TLBO | 4.58E+01 | 2.11E+04 | 3.21E+03 | 4.51E+03 | 5.79E+03 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | BAS | 2.34E+11 | 3.13E+11 | 2.58E+11 | 2.61E+11 | 2.05E+10 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | FA | 6.47E−01 | 1.88E+04 | 1.31E+03 | 3.29E+03 | 4.50E+03 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | HHO | 3.74E+09 | 1.34E+10 | 9.02E+09 | 8.72E+09 | 2.42E+09 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | GWO | 2.43E+09 | 1.16E+10 | 7.23E+09 | 7.20E+09 | 2.63E+09 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| F1 | MFO | 1.13E+10 | 6.88E+10 | 4.10E+10 | 3.85E+10 | 1.88E+10 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | WOA | 2.83E+06 | 4.87E+07 | 7.75E+06 | 1.18E+07 | 1.00E+07 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | CMAES | 3.34E−02 | 7.05E+10 | 5.84E+03 | 1.12E+10 | 2.31E+10 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | AGSK | 1.77E−01 | 3.48E+03 | 6.55E+01 | 3.47E+02 | 6.82E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | HSES | 0.00E+00 | 5.08E−07 | 0.00E+00 | 1.14E−08 | 7.13E−08 | 8.07E+04 | 5.00E+05 | 8.28E+04 | 1.15E+05 | 1.13E+05 | 92.16 |
| | MadDE | 2.82E+04 | 1.91E+05 | 5.05E+04 | 5.64E+04 | 2.77E+04 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | IMODE | 1.16E−02 | 1.66E−02 | 1.64E−02 | 1.52E−02 | 2.01E−03 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | ALSHADE | 0.00E+00 | 0.00E+00 | 0.00E+00 | **0.00E+00** | 0.00E+00 | 3.63E+05 | 3.91E+05 | 3.80E+05 | 3.81E+05 | 4.94E+03 | 100.00 |
| | EA4eig | 2.27E+08 | 6.48E+09 | 2.40E+09 | 2.65E+09 | 1.41E+09 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | APGSKIMODE | 3.40E+01 | 2.18E+03 | 7.28E+02 | 7.51E+02 | 4.61E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | DA2MODE | 0.00E+00 | 0.00E+00 | 0.00E+00 | **0.00E+00** | 0.00E+00 | 3.29E+05 | 3.84E+05 | 3.58E+05 | 3.58E+05 | 9.65E+03 | 100.00 |
| | ABC | 1.64E+05 | 3.05E+05 | 2.67E+05 | 2.63E+05 | 2.77E+04 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | GA | 5.12E+04 | 1.91E+05 | 9.92E+04 | 1.02E+05 | 3.23E+04 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | PSO | 1.63E+05 | 3.14E+05 | 2.43E+05 | 2.43E+05 | 4.54E+04 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | DE | 4.68E+04 | 1.02E+05 | 8.78E+04 | 8.26E+04 | 1.66E+04 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | SA | 1.72E+05 | 3.48E+05 | 2.57E+05 | 2.56E+05 | 4.69E+04 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | TLBO | 7.03E+00 | 2.14E+03 | 1.01E+02 | 3.00E+02 | 4.38E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | BAS | 2.94E+05 | 3.94E+12 | 5.16E+09 | 2.56E+11 | 8.03E+11 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | FA | 9.74E+02 | 7.19E+03 | 4.32E+03 | 4.11E+03 | 1.35E+03 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | HHO | 1.50E+05 | 3.76E+05 | 2.08E+05 | 2.15E+05 | 5.22E+04 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | GWO | 5.15E+04 | 1.14E+05 | 8.31E+04 | 8.05E+04 | 1.24E+04 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| F2 | MFO | 5.69E+02 | 4.13E+05 | 2.27E+05 | 2.30E+05 | 1.16E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | WOA | 3.96E+04 | 2.18E+05 | 8.38E+04 | 8.71E+04 | 4.06E+04 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | CMAES | 2.69E+05 | 4.94E+05 | 3.69E+05 | 3.67E+05 | 5.22E+04 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | AGSK | 1.81E+04 | 5.69E+04 | 3.29E+04 | 3.49E+04 | 8.31E+03 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | HSES | 0.00E+00 | 1.72E−08 | 0.00E+00 | 5.71E−10 | 2.90E−09 | 1.00E+05 | 5.00E+05 | 1.03E+05 | 1.19E+05 | 7.77E+04 | 96.08 |
| | MadDE | 3.21E+04 | 1.47E+05 | 1.17E+05 | 1.08E+05 | 3.03E+04 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | IMODE | 8.41E−07 | 9.95E−07 | 9.81E−07 | 9.53E−07 | 4.95E−08 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | ALSHADE | 0.00E+00 | 0.00E+00 | 0.00E+00 | **0.00E+00** | 0.00E+00 | 3.50E+05 | 3.90E+05 | 3.68E+05 | 3.69E+05 | 9.65E+03 | 100.00 |
| | EA4eig | 5.92E+04 | 1.59E+05 | 1.17E+05 | 1.15E+05 | 2.47E+04 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | APGSKIMODE | 1.77E+00 | 7.34E+01 | 1.09E+01 | 1.56E+01 | 1.51E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | DA2MODE | 0.00E+00 | 0.00E+00 | 0.00E+00 | **0.00E+00** | 0.00E+00 | 2.96E+05 | 3.49E+05 | 3.23E+05 | 3.22E+05 | 1.21E+04 | 100.00 |
| | ABC | 1.04E+02 | 2.09E+02 | 1.25E+02 | 1.31E+02 | 2.04E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | GA | 5.64E+01 | 2.52E+02 | 1.60E+02 | 1.63E+02 | 5.24E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | PSO | 7.96E+03 | 1.86E+04 | 1.22E+04 | 1.27E+04 | 2.82E+03 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | DE | 8.05E+00 | 1.33E+02 | 2.85E+01 | 6.18E+01 | 4.85E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | SA | 3.38E+01 | 1.54E+02 | 1.01E+02 | 8.73E+01 | 4.31E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | TLBO | 1.75E−01 | 2.12E+02 | 1.03E+02 | 1.15E+02 | 4.91E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | BAS | 5.71E+04 | 1.65E+05 | 8.64E+04 | 8.62E+04 | 2.07E+04 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | FA | 2.17E+01 | 1.79E+02 | 9.91E+01 | 8.67E+01 | 5.41E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | HHO | 9.06E+02 | 2.98E+03 | 1.76E+03 | 1.92E+03 | 5.56E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | GWO | 2.58E+02 | 1.69E+03 | 6.52E+02 | 7.09E+02 | 3.03E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| F3 | MFO | 1.04E+03 | 1.92E+04 | 5.08E+03 | 5.87E+03 | 3.88E+03 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | WOA | 1.93E+02 | 4.13E+02 | 2.78E+02 | 2.89E+02 | 5.69E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | CMAES | 3.48E+03 | 1.08E+04 | 7.34E+03 | 7.44E+03 | 1.60E+03 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | AGSK | 2.85E+01 | 2.02E+02 | 1.26E+02 | 1.07E+02 | 5.35E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | HSES | 0.00E+00 | 1.14E+02 | 2.85E+01 | 3.91E+01 | 4.47E+01 | 1.05E+05 | 5.00E+05 | 5.00E+05 | 3.81E+05 | 1.66E+05 | 35.29 |
| | MadDE | 1.08E+02 | 1.86E+02 | 1.57E+02 | 1.56E+02 | 1.86E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | IMODE | 0.00E+00 | 1.14E+02 | 0.00E+00 | 3.34E+01 | 4.78E+01 | 4.34E+05 | 5.00E+05 | 4.90E+05 | 4.76E+05 | 2.55E+04 | 58.82 |
| | ALSHADE | 8.17E+00 | 1.43E+02 | 5.13E+01 | 7.03E+01 | 4.87E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | EA4eig | 2.36E+02 | 1.55E+03 | 6.05E+02 | 7.42E+02 | 3.27E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | APGSKIMODE | 3.01E+01 | 2.15E+02 | 1.31E+02 | 1.17E+02 | 3.94E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | DA2MODE | 2.22E−07 | 7.85E+01 | 2.50E+01 | **2.50E+01** | 8.76E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | ABC | 4.25E+02 | 4.76E+02 | 4.49E+02 | 4.50E+02 | 1.40E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | GA | 1.13E+02 | 2.28E+02 | 1.62E+02 | 1.64E+02 | 2.92E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | PSO | 3.66E+02 | 5.96E+02 | 5.06E+02 | 4.88E+02 | 5.47E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | DE | 3.19E+02 | 3.78E+02 | 3.53E+02 | 3.51E+02 | 1.43E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | SA | 7.56E+01 | 1.14E+02 | 1.04E+02 | 1.00E+02 | 1.04E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | TLBO | 1.63E+02 | 2.72E+02 | 2.30E+02 | 2.24E+02 | 2.69E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | BAS | 1.05E+03 | 1.33E+03 | 1.22E+03 | 1.22E+03 | 6.99E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | FA | 8.06E+01 | 2.19E+02 | 1.54E+02 | 1.55E+02 | 3.20E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | HHO | 4.36E+02 | 5.93E+02 | 5.42E+02 | 5.32E+02 | 4.03E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | GWO | 1.64E+02 | 2.94E+02 | 2.20E+02 | 2.19E+02 | 3.69E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| F4 | MFO | 2.85E+02 | 7.00E+02 | 4.91E+02 | 4.87E+02 | 1.05E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | WOA | 2.66E+02 | 6.92E+02 | 4.12E+02 | 4.18E+02 | 8.65E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | CMAES | 2.89E+01 | 5.40E+02 | 4.97E+01 | 6.03E+01 | 6.94E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | AGSK | 1.82E+02 | 2.29E+02 | 2.07E+02 | 2.07E+02 | 9.82E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | HSES | 1.09E+01 | 3.38E+01 | 1.99E+01 | 2.00E+01 | 5.41E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | MadDE | 1.99E+02 | 2.78E+02 | 2.39E+02 | 2.38E+02 | 1.68E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | IMODE | 1.75E+02 | 3.31E+02 | 2.58E+02 | 2.64E+02 | 3.75E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | ALSHADE | 2.98E+00 | 1.49E+01 | 7.96E+00 | **7.90E+00** | 2.49E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | EA4eig | 3.41E+02 | 4.17E+02 | 3.97E+02 | 3.90E+02 | 1.95E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | APGSKIMODE | 1.32E+02 | 2.36E+02 | 1.96E+02 | 1.92E+02 | 2.69E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | DA2MODE | 1.77E+01 | 4.00E+01 | 2.82E+01 | 2.83E+01 | 5.05E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | ABC | 6.93E−01 | 2.00E+00 | 1.22E+00 | 1.30E+00 | 3.61E−01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | GA | 8.26E−02 | 5.81E−01 | 1.83E−01 | 2.11E−01 | 1.00E−01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | PSO | 6.29E+01 | 8.61E+01 | 7.04E+01 | 7.17E+01 | 6.69E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | DE | 0.00E+00 | 0.00E+00 | 0.00E+00 | **0.00E+00** | 0.00E+00 | 1.14E+05 | 1.23E+05 | 1.17E+05 | 1.18E+05 | 2.47E+03 | 100.00 |
| | SA | 1.71E+00 | 3.07E+00 | 2.29E+00 | 2.30E+00 | 3.16E−01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | TLBO | 1.82E+01 | 4.08E+01 | 3.19E+01 | 3.18E+01 | 6.19E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | BAS | 1.34E+02 | 1.63E+02 | 1.53E+02 | 1.52E+02 | 7.99E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | FA | 1.74E−05 | 1.89E+00 | 3.36E−02 | 9.70E−02 | 2.68E−01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | HHO | 7.81E+01 | 9.89E+01 | 8.98E+01 | 8.96E+01 | 6.13E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | GWO | 9.95E+00 | 2.41E+01 | 1.40E+01 | 1.55E+01 | 3.93E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| F5 | MFO | 4.18E+01 | 8.57E+01 | 5.83E+01 | 5.81E+01 | 1.10E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | WOA | 6.29E+01 | 1.02E+02 | 7.76E+01 | 7.82E+01 | 8.82E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | CMAES | 2.25E−06 | 7.99E+01 | 7.76E−03 | 3.40E+01 | 3.55E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | AGSK | 9.06E−04 | 1.61E−02 | 2.91E−03 | 4.02E−03 | 2.91E−03 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | HSES | 0.00E+00 | 2.44E−04 | 2.26E−07 | 1.91E−05 | 5.39E−05 | 6.85E+04 | 5.00E+05 | 5.00E+05 | 4.49E+05 | 1.40E+05 | 11.76 |
| | MadDE | 1.95E+00 | 4.05E+00 | 2.72E+00 | 2.83E+00 | 5.58E−01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | IMODE | 3.55E+01 | 4.80E+01 | 4.16E+01 | 4.11E+01 | 2.91E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | ALSHADE | 0.00E+00 | 8.36E−03 | 4.79E−08 | 1.11E−03 | 1.90E−03 | 3.09E+05 | 5.00E+05 | 5.00E+05 | 4.53E+05 | 7.80E+04 | 29.41 |
| | EA4eig | 1.43E+01 | 3.05E+01 | 2.14E+01 | 2.21E+01 | 3.93E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |

(*continued on next page*)

**Table E.10** (*continued*).

| Fun | Alg. | Error | | | | | Function evaluations | | | | | SR (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No. | Name | Best | Worst | Median | Mean | SD | Best | Worst | Median | Mean | SD | |
| | APGSKIMODE | 1.49E−03 | 1.21E−02 | 3.56E−03 | 3.75E−03 | 1.50E−03 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | DA2MODE | 1.92E−07 | 2.96E−02 | 2.50E−05 | 1.65E−03 | 5.55E−03 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | ABC | 5.04E+02 | 6.01E+02 | 5.43E+02 | 5.49E+02 | 2.40E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | GA | 2.10E+02 | 3.92E+02 | 2.61E+02 | 2.76E+02 | 4.74E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | PSO | 7.63E+02 | 1.28E+03 | 9.66E+02 | 9.43E+02 | 1.46E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | DE | 3.75E+02 | 4.30E+02 | 4.08E+02 | 4.09E+02 | 1.29E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | SA | 2.27E+02 | 3.61E+02 | 3.12E+02 | 3.06E+02 | 2.50E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | TLBO | 3.11E+02 | 6.48E+02 | 4.69E+02 | 4.91E+02 | 8.84E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | BAS | 4.78E+03 | 6.11E+03 | 5.40E+03 | 5.44E+03 | 3.22E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | FA | 1.41E+02 | 2.45E+02 | 2.01E+02 | 2.01E+02 | 2.52E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | HHO | 1.19E+03 | 1.41E+03 | 1.31E+03 | 1.30E+03 | 4.94E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | GWO | 2.63E+02 | 5.17E+02 | 3.62E+02 | 3.60E+02 | 5.50E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| F6 | MFO | 6.45E+02 | 2.09E+03 | 1.27E+03 | 1.23E+03 | 3.57E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | WOA | 7.48E+02 | 1.17E+03 | 1.00E+03 | 1.01E+03 | 1.05E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | CMAES | 8.31E+01 | 3.76E+02 | 1.01E+02 | 1.15E+02 | 6.41E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | AGSK | 2.55E+02 | 3.16E+02 | 2.88E+02 | 2.89E+02 | 1.59E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | HSES | 5.88E+01 | 9.15E+01 | 7.16E+01 | 7.11E+01 | 7.95E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | MadDE | 2.96E+02 | 3.77E+02 | 3.31E+02 | 3.31E+02 | 1.84E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | IMODE | 4.93E+02 | 6.39E+02 | 6.01E+02 | 5.92E+02 | 3.50E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | ALSHADE | 5.62E+01 | 6.76E+01 | 6.24E+01 | **6.23E+01** | 2.52E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | EA4eig | 4.76E+02 | 5.86E+02 | 5.19E+02 | 5.25E+02 | 3.52E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | APGSKIMODE | 1.66E+02 | 2.79E+02 | 2.53E+02 | 2.48E+02 | 2.49E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | DA2MODE | 6.66E+01 | 7.91E+01 | 7.08E+01 | 7.15E+01 | 2.93E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | ABC | 4.24E+02 | 4.71E+02 | 4.53E+02 | 4.53E+02 | 1.61E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | GA | 1.40E+02 | 2.63E+02 | 1.88E+02 | 1.95E+02 | 3.01E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | PSO | 3.80E+02 | 5.78E+02 | 4.84E+02 | 4.81E+02 | 4.94E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | DE | 3.18E+02 | 3.80E+02 | 3.54E+02 | 3.55E+02 | 9.91E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | SA | 6.49E+01 | 1.35E+02 | 9.75E+01 | 9.80E+01 | 1.70E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | TLBO | 1.62E+02 | 3.35E+02 | 2.24E+02 | 2.27E+02 | 3.96E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | BAS | 1.06E+03 | 1.32E+03 | 1.22E+03 | 1.22E+03 | 7.21E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | FA | 9.15E+01 | 2.28E+02 | 1.50E+02 | 1.51E+02 | 3.00E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | HHO | 4.12E+02 | 6.19E+02 | 5.19E+02 | 5.12E+02 | 5.01E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | GWO | 1.57E+02 | 4.33E+02 | 2.04E+02 | 2.20E+02 | 6.53E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| F7 | MFO | 3.69E+02 | 7.08E+02 | 4.74E+02 | 5.00E+02 | 9.43E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | WOA | 2.74E+02 | 6.61E+02 | 4.22E+02 | 4.27E+02 | 8.79E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | CMAES | 3.08E+01 | 6.39E+02 | 5.47E+01 | 2.13E+02 | 2.43E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | AGSK | 1.77E+02 | 2.32E+02 | 2.13E+02 | 2.10E+02 | 1.32E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | HSES | 7.96E+00 | 3.28E+01 | 2.09E+01 | 2.10E+01 | 5.60E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | MadDE | 2.03E+02 | 2.75E+02 | 2.49E+02 | 2.46E+02 | 1.50E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | IMODE | 2.03E+02 | 3.19E+02 | 2.63E+02 | 2.63E+02 | 3.02E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | ALSHADE | 1.99E+00 | 1.99E+01 | 7.55E+00 | **8.02E+00** | 3.33E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | EA4eig | 3.58E+02 | 4.28E+02 | 3.85E+02 | 3.88E+02 | 1.52E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | APGSKIMODE | 1.22E+02 | 2.38E+02 | 2.03E+02 | 1.96E+02 | 2.57E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | DA2MODE | 1.76E+01 | 3.92E+01 | 2.91E+01 | 2.87E+01 | 5.12E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | ABC | 2.30E+03 | 4.13E+03 | 2.83E+03 | 3.00E+03 | 5.53E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | GA | 5.90E+02 | 6.27E+03 | 1.96E+03 | 2.56E+03 | 1.61E+03 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | PSO | 1.16E+04 | 2.19E+04 | 1.61E+04 | 1.60E+04 | 2.59E+03 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | DE | 0.00E+00 | 0.00E+00 | 0.00E+00 | **0.00E+00** | 0.00E+00 | 7.83E+04 | 8.91E+04 | 8.58E+04 | 8.49E+04 | 3.67E+03 | 100.00 |
| | SA | 1.15E+01 | 3.58E+01 | 1.76E+01 | 1.84E+01 | 5.12E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | TLBO | 1.50E+03 | 8.87E+03 | 4.41E+03 | 4.90E+03 | 2.05E+03 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | BAS | 4.79E+04 | 9.12E+04 | 7.02E+04 | 6.81E+04 | 1.01E+04 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | FA | 2.81E+01 | 1.53E+03 | 3.79E+02 | 3.98E+02 | 2.95E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | HHO | 2.71E+04 | 4.43E+04 | 3.50E+04 | 3.47E+04 | 3.26E+03 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | GWO | 1.30E+03 | 1.57E+04 | 5.02E+03 | 5.72E+03 | 3.31E+03 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| F8 | MFO | 1.03E+04 | 2.81E+04 | 1.73E+04 | 1.88E+04 | 5.52E+03 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | WOA | 1.17E+04 | 3.77E+04 | 1.68E+04 | 1.94E+04 | 6.02E+03 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | CMAES | 0.00E+00 | 2.28E+04 | 0.00E+00 | 2.90E+03 | 7.35E+03 | 3.59E+04 | 5.00E+05 | 3.79E+04 | 1.92E+05 | 2.20E+05 | 66.67 |
| | AGSK | 8.95E−02 | 4.45E+00 | 9.98E−01 | 1.28E+00 | 9.15E−01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | HSES | 0.00E+00 | 9.46E−08 | 0.00E+00 | 2.94E−09 | 1.42E−08 | 4.49E+04 | 5.00E+05 | 4.71E+04 | 7.37E+04 | 1.08E+05 | 94.12 |
| | MadDE | 1.95E+03 | 6.73E+03 | 4.40E+03 | 4.33E+03 | 9.21E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | IMODE | 6.42E+03 | 1.15E+04 | 8.46E+03 | 8.69E+03 | 1.61E+03 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | ALSHADE | 0.00E+00 | 0.00E+00 | 0.00E+00 | **0.00E+00** | 0.00E+00 | 2.00E+05 | 2.14E+05 | 2.08E+05 | 2.08E+05 | 3.17E+03 | 100.00 |
| | EA4eig | 9.52E+02 | 2.97E+03 | 1.90E+03 | 1.89E+03 | 6.07E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | APGSKIMODE | 4.44E+00 | 2.13E+02 | 3.07E+01 | 4.62E+01 | 4.32E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | DA2MODE | 0.00E+00 | 5.44E−01 | 0.00E+00 | 6.37E−02 | 1.31E−01 | 1.80E+05 | 5.00E+05 | 1.89E+05 | 2.92E+05 | 1.49E+05 | 66.67 |
| | ABC | 1.24E+04 | 1.39E+04 | 1.34E+04 | 1.34E+04 | 3.33E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | GA | 3.49E+03 | 6.08E+03 | 5.27E+03 | 5.12E+03 | 5.28E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | PSO | 6.21E+03 | 1.07E+04 | 8.96E+03 | 8.84E+03 | 8.78E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | DE | 1.23E+04 | 1.32E+04 | 1.29E+04 | 1.28E+04 | 3.31E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | SA | 2.14E+03 | 3.75E+03 | 2.92E+03 | 2.88E+03 | 3.77E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | TLBO | 3.79E+03 | 1.38E+04 | 6.83E+03 | 8.75E+03 | 3.39E+03 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | BAS | 1.54E+04 | 1.77E+04 | 1.69E+04 | 1.69E+04 | 5.63E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | FA | 4.29E+03 | 7.28E+03 | 5.73E+03 | 5.72E+03 | 8.19E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | HHO | 9.66E+03 | 1.37E+04 | 1.16E+04 | 1.18E+04 | 1.05E+03 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | GWO | 4.09E+03 | 1.20E+04 | 5.39E+03 | 5.63E+03 | 1.12E+03 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| F9 | MFO | 5.34E+03 | 1.13E+04 | 7.82E+03 | 7.99E+03 | 1.34E+03 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | WOA | 5.30E+03 | 1.22E+04 | 8.56E+03 | 8.78E+03 | 1.93E+03 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | CMAES | 1.17E+04 | 1.36E+04 | 1.27E+04 | 1.27E+04 | 5.07E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | AGSK | 7.83E+03 | 9.37E+03 | 8.59E+03 | 8.56E+03 | 3.41E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | HSES | 8.65E+02 | 3.86E+03 | 2.03E+03 | **2.00E+03** | 7.30E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | MadDE | 4.76E+03 | 6.86E+03 | 5.87E+03 | 5.91E+03 | 4.81E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | IMODE | 4.19E+03 | 6.87E+03 | 5.92E+03 | 5.72E+03 | 6.99E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | ALSHADE | 2.49E+03 | 4.30E+03 | 3.47E+03 | 3.43E+03 | 4.39E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | EA4eig | 1.12E+04 | 1.34E+04 | 1.29E+04 | 1.29E+04 | 3.78E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | APGSKIMODE | 6.15E+03 | 8.43E+03 | 7.59E+03 | 7.52E+03 | 5.00E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | DA2MODE | 2.23E+03 | 3.74E+03 | 3.29E+03 | 3.21E+03 | 3.37E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |

(*continued on next page*)

**Table E.10** (*continued*).

| Fun | Alg. | Error | | | | | Function evaluations | | | | | SR (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No. | Name | Best | Worst | Median | Mean | SD | Best | Worst | Median | Mean | SD | |
| | ABC | 1.75E+03 | 3.33E+03 | 2.53E+03 | 2.57E+03 | 3.63E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | GA | 2.98E+02 | 1.67E+04 | 1.43E+03 | 3.42E+03 | 3.77E+03 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | PSO | 6.87E+03 | 2.89E+04 | 1.65E+04 | 1.71E+04 | 7.20E+03 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | DE | 1.37E+02 | 2.23E+02 | 1.61E+02 | 1.60E+02 | 1.68E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | SA | 1.48E+02 | 2.86E+02 | 2.15E+02 | 2.23E+02 | 4.07E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | TLBO | 1.11E+02 | 4.76E+02 | 2.02E+02 | 2.12E+02 | 6.86E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | BAS | 4.32E+04 | 1.72E+07 | 2.05E+05 | 1.46E+06 | 3.25E+06 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | FA | 7.10E+01 | 3.33E+02 | 2.18E+02 | 2.00E+02 | 7.44E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | HHO | 2.66E+03 | 9.16E+03 | 3.85E+03 | 4.71E+03 | 1.68E+03 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | GWO | 3.91E+02 | 1.05E+04 | 3.09E+03 | 3.85E+03 | 2.80E+03 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| F10 | MFO | 9.12E+02 | 6.19E+04 | 8.02E+03 | 1.59E+04 | 1.73E+04 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | WOA | 2.62E+02 | 9.51E+02 | 4.66E+02 | 4.98E+02 | 1.42E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | CMAES | 3.70E+04 | 1.05E+05 | 6.51E+04 | 6.77E+04 | 1.50E+04 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | AGSK | 5.86E+01 | 7.54E+01 | 6.40E+01 | 6.45E+01 | 4.21E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | HSES | 3.02E+01 | 8.09E+01 | 4.71E+01 | 4.92E+01 | 1.03E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | MadDE | 2.42E+02 | 3.63E+02 | 3.16E+02 | 3.15E+02 | 2.52E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | IMODE | 1.29E+02 | 3.16E+02 | 1.91E+02 | 1.97E+02 | 4.98E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | ALSHADE | 3.02E+01 | 6.30E+01 | 4.41E+01 | 4.41E+01 | 6.97E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | EA4eig | 9.96E+02 | 2.41E+03 | 1.52E+03 | 1.51E+03 | 3.77E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | APGSKIMODE | 4.99E+01 | 1.17E+02 | 7.69E+01 | 7.68E+01 | 1.54E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | DA2MODE | 1.34E+01 | 6.47E+01 | 3.03E+01 | **3.02E+01** | 1.00E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | ABC | 1.86E+08 | 2.84E+08 | 2.45E+08 | 2.41E+08 | 2.39E+07 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | GA | 3.05E+06 | 2.14E+07 | 1.15E+07 | 1.24E+07 | 5.92E+06 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | PSO | 1.14E+10 | 3.98E+10 | 2.40E+10 | 2.53E+10 | 7.35E+09 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | DE | 1.17E+06 | 4.56E+07 | 8.11E+06 | 1.21E+07 | 1.40E+07 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | SA | 1.06E+07 | 3.89E+07 | 2.93E+07 | 2.80E+07 | 8.23E+06 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | TLBO | 1.41E+04 | 3.04E+06 | 1.16E+05 | 2.11E+05 | 4.19E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | BAS | 9.72E+10 | 2.00E+11 | 1.52E+11 | 1.57E+11 | 2.70E+10 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | FA | 1.81E+05 | 1.89E+06 | 1.26E+06 | 1.22E+06 | 5.68E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | HHO | 6.13E+08 | 5.17E+09 | 1.66E+09 | 1.85E+09 | 1.02E+09 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | GWO | 1.09E+07 | 7.69E+09 | 3.78E+08 | 9.56E+08 | 1.51E+09 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| F11 | MFO | 5.40E+08 | 2.69E+10 | 7.59E+09 | 7.54E+09 | 5.70E+09 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | WOA | 3.52E+07 | 4.04E+08 | 1.18E+08 | 1.55E+08 | 9.59E+07 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | CMAES | 1.34E+10 | 3.52E+10 | 1.82E+10 | 1.98E+10 | 4.86E+09 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | AGSK | 1.62E+04 | 4.34E+05 | 1.22E+05 | 1.57E+05 | 1.13E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | HSES | 1.57E+03 | 4.09E+03 | 2.66E+03 | 2.62E+03 | 5.65E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | MadDE | 2.21E+06 | 4.11E+06 | 3.18E+06 | 3.12E+06 | 4.27E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | IMODE | 1.43E+03 | 2.79E+03 | 2.02E+03 | **2.01E+03** | 3.26E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | ALSHADE | 1.41E+03 | 4.79E+03 | 2.24E+03 | 2.47E+03 | 6.78E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | EA4eig | 2.81E+08 | 2.10E+09 | 9.74E+08 | 1.05E+09 | 5.27E+08 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | APGSKIMODE | 4.29E+04 | 6.96E+05 | 2.13E+05 | 2.51E+05 | 1.51E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | DA2MODE | 1.05E+03 | 3.30E+03 | 1.97E+03 | 2.01E+03 | 5.31E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | ABC | 3.54E+02 | 1.29E+04 | 1.91E+03 | 3.25E+03 | 3.57E+03 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | GA | 5.32E+04 | 1.26E+06 | 2.77E+05 | 3.08E+05 | 2.47E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | PSO | 1.86E+09 | 2.68E+10 | 6.59E+09 | 8.70E+09 | 6.36E+09 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | DE | 3.08E+02 | 2.39E+04 | 8.62E+03 | 9.78E+03 | 7.41E+03 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | SA | 8.47E+05 | 1.92E+06 | 1.37E+06 | 1.36E+06 | 2.29E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | TLBO | 1.12E+03 | 2.12E+04 | 4.89E+03 | 6.39E+03 | 5.15E+03 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | BAS | 5.32E+10 | 1.30E+11 | 8.76E+10 | 8.45E+10 | 2.27E+10 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | FA | 9.35E+02 | 3.97E+04 | 7.97E+03 | 1.36E+04 | 1.27E+04 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | HHO | 3.06E+07 | 3.69E+08 | 9.64E+07 | 1.04E+08 | 6.65E+07 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | GWO | 2.02E+04 | 3.11E+08 | 3.24E+07 | 8.15E+07 | 9.86E+07 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| F12 | MFO | 1.55E+05 | 8.70E+09 | 2.46E+08 | 1.45E+09 | 2.61E+09 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | WOA | 5.19E+04 | 4.17E+05 | 1.61E+05 | 1.83E+05 | 7.50E+04 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | CMAES | 4.37E+09 | 1.78E+10 | 1.02E+10 | 1.07E+10 | 2.86E+09 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | AGSK | 1.56E+02 | 2.30E+03 | 4.27E+02 | 5.68E+02 | 4.05E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | HSES | 2.89E+01 | 3.28E+02 | 9.82E+01 | 1.06E+02 | 5.42E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | MadDE | 6.14E+03 | 1.83E+04 | 1.13E+04 | 1.17E+04 | 2.91E+03 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | IMODE | 2.17E+02 | 1.03E+03 | 4.89E+02 | 5.43E+02 | 2.11E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | ALSHADE | 1.70E+01 | 1.29E+02 | 5.34E+01 | **6.35E+01** | 3.30E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | EA4eig | 2.61E+07 | 9.68E+08 | 3.84E+08 | 4.21E+08 | 2.34E+08 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | APGSKIMODE | 3.26E+02 | 1.45E+03 | 6.41E+02 | 7.04E+02 | 2.22E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | DA2MODE | 2.03E+01 | 1.29E+02 | 5.28E+01 | 7.22E+01 | 3.55E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | ABC | 3.68E+05 | 1.13E+06 | 5.81E+05 | 6.27E+05 | 1.77E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | GA | 8.25E+05 | 1.16E+07 | 5.11E+06 | 5.54E+06 | 2.72E+06 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | PSO | 1.63E+05 | 6.03E+07 | 2.91E+07 | 3.11E+07 | 1.78E+07 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | DE | 1.95E+03 | 3.32E+04 | 1.06E+04 | 1.21E+04 | 7.70E+03 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | SA | 4.26E+03 | 1.77E+05 | 3.05E+04 | 5.39E+04 | 5.25E+04 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | TLBO | 5.95E+03 | 9.04E+04 | 1.91E+04 | 2.97E+04 | 2.06E+04 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | BAS | 1.19E+08 | 1.15E+09 | 4.75E+08 | 5.26E+08 | 3.21E+08 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | FA | 4.89E+03 | 9.27E+04 | 2.69E+04 | 3.65E+04 | 2.43E+04 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | HHO | 7.76E+05 | 5.27E+07 | 4.01E+06 | 8.99E+06 | 1.20E+07 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | GWO | 1.08E+04 | 3.50E+06 | 3.06E+05 | 4.73E+05 | 6.13E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| F13 | MFO | 7.37E+03 | 1.13E+07 | 5.36E+05 | 1.08E+06 | 2.18E+06 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | WOA | 9.41E+04 | 4.51E+06 | 5.30E+05 | 9.53E+05 | 1.17E+06 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | CMAES | 7.68E+06 | 5.73E+07 | 2.17E+07 | 2.19E+07 | 1.05E+07 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | AGSK | 4.83E+01 | 9.81E+01 | 7.33E+01 | 7.43E+01 | 9.08E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | HSES | 1.19E+02 | 2.88E+02 | 1.91E+02 | 1.90E+02 | 4.02E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | MadDE | 2.08E+04 | 2.67E+05 | 1.16E+05 | 1.22E+05 | 4.97E+04 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | IMODE | 1.70E+02 | 2.98E+02 | 2.19E+02 | 2.28E+02 | 4.79E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | ALSHADE | 2.01E+01 | 3.57E+01 | 2.65E+01 | **2.69E+01** | 3.00E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | EA4eig | 2.50E+05 | 1.65E+06 | 6.43E+05 | 6.59E+05 | 3.53E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | APGSKIMODE | 4.86E+01 | 1.14E+02 | 7.58E+01 | 7.84E+01 | 1.57E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | DA2MODE | 1.64E+01 | 3.36E+01 | 2.80E+01 | 2.78E+01 | 2.50E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | ABC | 1.72E+02 | 1.82E+04 | 5.91E+03 | 5.96E+03 | 4.67E+03 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | GA | 1.88E+04 | 3.45E+05 | 9.53E+04 | 1.22E+05 | 7.90E+04 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | PSO | 9.32E+04 | 1.65E+09 | 1.60E+08 | 2.88E+08 | 3.36E+08 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | DE | 8.78E+02 | 1.80E+04 | 2.22E+03 | 4.74E+03 | 4.72E+03 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | SA | 1.11E+05 | 3.40E+05 | 1.94E+05 | 1.97E+05 | 6.14E+04 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | TLBO | 4.62E+02 | 2.03E+04 | 7.07E+03 | 8.89E+03 | 7.39E+03 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | BAS | 1.10E+10 | 6.00E+10 | 3.32E+10 | 3.38E+10 | 1.04E+10 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | FA | 1.78E+02 | 1.80E+04 | 7.15E+03 | 8.35E+03 | 5.80E+03 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | HHO | 7.56E+05 | 4.27E+08 | 3.84E+06 | 3.26E+07 | 1.01E+08 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | GWO | 9.11E+03 | 6.14E+08 | 5.67E+04 | 1.98E+07 | 8.66E+07 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| F14 | MFO | 1.18E+04 | 8.89E+08 | 1.02E+05 | 6.48E+07 | 2.17E+08 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | WOA | 1.46E+04 | 1.63E+05 | 5.86E+04 | 6.63E+04 | 3.97E+04 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | CMAES | 9.72E+08 | 3.93E+09 | 1.68E+09 | 1.80E+09 | 6.21E+08 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | AGSK | 2.90E+01 | 1.34E+02 | 7.29E+01 | 7.17E+01 | 1.86E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | HSES | 1.17E+01 | 7.79E+01 | 3.51E+01 | 3.82E+01 | 1.39E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | MadDE | 1.15E+04 | 1.65E+04 | 1.45E+04 | 1.44E+04 | 1.21E+03 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | IMODE | 1.08E+02 | 4.32E+02 | 2.09E+02 | 2.21E+02 | 6.49E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | ALSHADE | 2.33E+01 | 5.30E+01 | 2.89E+01 | 3.17E+01 | 7.32E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | EA4eig | 2.66E+06 | 1.76E+08 | 3.97E+07 | 5.90E+07 | 5.03E+07 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | APGSKIMODE | 5.23E+01 | 2.36E+02 | 1.03E+02 | 1.08E+02 | 3.49E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | DA2MODE | 1.43E+01 | 6.41E+01 | 2.63E+01 | **2.92E+01** | 8.89E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |

(*continued on next page*)

**Table E.10** (*continued*).

| Fun | Alg. | Error | | | | | Function evaluations | | | | | SR (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No. | Name | Best | Worst | Median | Mean | SD | Best | Worst | Median | Mean | SD | |
| | ABC | 2.66E+03 | 3.54E+03 | 3.29E+03 | 3.27E+03 | 2.17E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | GA | 1.15E+03 | 2.82E+03 | 2.06E+03 | 1.96E+03 | 4.96E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | PSO | 2.18E+03 | 5.34E+03 | 3.62E+03 | 3.81E+03 | 7.87E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | DE | 2.25E+03 | 3.12E+03 | 2.68E+03 | 2.67E+03 | 2.27E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | SA | 1.39E+02 | 6.57E+02 | 4.03E+02 | 3.98E+02 | 1.42E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | TLBO | 6.32E+02 | 2.06E+03 | 1.37E+03 | 1.42E+03 | 3.88E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | BAS | 1.12E+04 | 2.16E+04 | 1.52E+04 | 1.60E+04 | 3.68E+03 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | FA | 1.10E+03 | 2.78E+03 | 1.63E+03 | 1.74E+03 | 4.19E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | HHO | 2.44E+03 | 6.09E+03 | 4.14E+03 | 4.26E+03 | 9.43E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | GWO | 7.09E+02 | 2.10E+03 | 1.28E+03 | 1.30E+03 | 3.17E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| F15 | MFO | 1.47E+03 | 4.01E+03 | 2.82E+03 | 2.87E+03 | 5.93E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | WOA | 1.64E+03 | 4.45E+03 | 3.04E+03 | 2.92E+03 | 8.49E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | CMAES | 4.23E+03 | 6.12E+03 | 5.39E+03 | 5.30E+03 | 4.35E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | AGSK | 8.54E+02 | 1.37E+03 | 1.11E+03 | 1.12E+03 | 1.04E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | HSES | 2.45E+02 | 1.04E+03 | 5.41E+02 | 5.33E+02 | 2.20E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | MadDE | 6.80E+02 | 1.22E+03 | 9.36E+02 | 9.47E+02 | 1.23E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | IMODE | 5.61E+02 | 2.31E+03 | 1.46E+03 | 1.43E+03 | 4.51E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | ALSHADE | 1.33E+02 | 8.24E+02 | 3.57E+02 | 3.92E+02 | 1.71E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | EA4eig | 2.15E+03 | 3.90E+03 | 3.20E+03 | 3.13E+03 | 5.13E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | APGSKIMODE | 6.42E+02 | 1.67E+03 | 1.26E+03 | 1.23E+03 | 2.50E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | DA2MODE | 1.47E+02 | 5.66E+02 | 3.80E+02 | **3.53E+02** | 1.00E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | ABC | 1.60E+03 | 2.23E+03 | 1.97E+03 | 1.95E+03 | 1.77E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | GA | 8.67E+02 | 2.25E+03 | 1.41E+03 | 1.46E+03 | 3.65E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | PSO | 1.45E+03 | 3.31E+03 | 2.21E+03 | 2.26E+03 | 4.04E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | DE | 8.14E+02 | 1.58E+03 | 1.14E+03 | 1.17E+03 | 2.00E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | SA | 1.54E+02 | 6.37E+02 | 3.27E+02 | 3.39E+02 | 1.12E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | TLBO | 6.52E+02 | 1.59E+03 | 1.24E+03 | 1.18E+03 | 2.85E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | BAS | 4.99E+04 | 7.97E+06 | 3.20E+06 | 3.64E+06 | 3.05E+06 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | FA | 3.54E+02 | 1.79E+03 | 1.21E+03 | 1.17E+03 | 3.37E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | HHO | 1.64E+03 | 3.26E+03 | 2.40E+03 | 2.31E+03 | 3.94E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | GWO | 4.44E+02 | 1.88E+03 | 1.11E+03 | 1.06E+03 | 3.08E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| F16 | MFO | 1.36E+03 | 5.94E+03 | 2.20E+03 | 2.49E+03 | 1.02E+03 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | WOA | 1.58E+03 | 3.04E+03 | 2.40E+03 | 2.29E+03 | 4.08E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | CMAES | 1.06E+02 | 1.57E+03 | 7.04E+02 | 7.52E+02 | 4.16E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | AGSK | 5.86E+02 | 9.63E+02 | 7.89E+02 | 7.82E+02 | 8.65E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | HSES | 1.66E+02 | 7.95E+02 | 3.85E+02 | 3.51E+02 | 1.52E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | MadDE | 6.28E+02 | 9.92E+02 | 7.83E+02 | 7.95E+02 | 8.64E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | IMODE | 1.05E+03 | 1.80E+03 | 1.39E+03 | 1.39E+03 | 2.16E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | ALSHADE | 7.84E+01 | 4.74E+02 | 2.37E+02 | **2.57E+02** | 9.07E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | EA4eig | 1.47E+03 | 2.46E+03 | 2.06E+03 | 2.02E+03 | 2.21E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | APGSKIMODE | 2.85E+02 | 1.15E+03 | 8.48E+02 | 8.39E+02 | 2.11E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | DA2MODE | 2.54E+02 | 5.40E+02 | 3.77E+02 | 3.73E+02 | 8.77E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | ABC | 5.36E+06 | 1.93E+07 | 1.07E+07 | 1.09E+07 | 3.37E+06 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | GA | 1.55E+06 | 2.49E+07 | 6.34E+06 | 8.25E+06 | 6.40E+06 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | PSO | 3.91E+06 | 9.99E+07 | 2.52E+07 | 3.37E+07 | 2.51E+07 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | DE | 1.05E+06 | 6.97E+06 | 2.48E+06 | 2.71E+06 | 1.21E+06 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | SA | 1.52E+05 | 6.09E+05 | 3.19E+05 | 3.60E+05 | 1.44E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | TLBO | 8.29E+04 | 2.65E+06 | 4.04E+05 | 5.57E+05 | 6.10E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | BAS | 3.44E+08 | 3.38E+09 | 1.11E+09 | 1.23E+09 | 6.10E+08 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | FA | 3.43E+04 | 4.61E+05 | 1.64E+05 | 1.90E+05 | 1.09E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | HHO | 4.22E+06 | 1.08E+08 | 3.48E+07 | 3.65E+07 | 2.07E+07 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | GWO | 6.69E+05 | 4.36E+07 | 1.75E+06 | 4.15E+06 | 8.21E+06 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| F17 | MFO | 9.96E+04 | 1.91E+08 | 1.47E+06 | 1.97E+07 | 5.15E+07 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | WOA | 6.14E+05 | 1.90E+07 | 6.94E+06 | 7.43E+06 | 4.72E+06 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | CMAES | 3.39E+07 | 2.26E+08 | 8.64E+07 | 1.03E+08 | 5.69E+07 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | AGSK | 4.61E+02 | 1.04E+04 | 3.09E+03 | 3.41E+03 | 1.95E+03 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | HSES | 7.91E+01 | 5.44E+02 | 2.32E+02 | 2.56E+02 | 9.90E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | MadDE | 8.69E+04 | 1.65E+06 | 7.61E+05 | 8.08E+05 | 3.26E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | IMODE | 1.30E+02 | 3.54E+02 | 1.98E+02 | 2.11E+02 | 5.99E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | ALSHADE | 2.34E+01 | 6.53E+01 | 3.29E+01 | 3.56E+01 | 9.48E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | EA4eig | 1.10E+06 | 1.18E+07 | 5.22E+06 | 6.07E+06 | 2.78E+06 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | APGSKIMODE | 7.16E+01 | 1.33E+04 | 4.00E+02 | 1.17E+03 | 2.17E+03 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | DA2MODE | 2.31E+01 | 3.81E+01 | 2.89E+01 | **2.90E+01** | 3.57E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | ABC | 7.33E+03 | 2.86E+04 | 1.47E+04 | 1.68E+04 | 6.31E+03 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | GA | 3.53E+03 | 5.39E+04 | 2.40E+04 | 2.65E+04 | 1.64E+04 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | PSO | 3.67E+05 | 1.36E+09 | 1.44E+07 | 1.18E+08 | 2.84E+08 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | DE | 1.74E+02 | 2.41E+04 | 1.06E+03 | 4.98E+03 | 6.32E+03 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | SA | 8.27E+04 | 1.21E+06 | 4.69E+05 | 5.42E+05 | 2.89E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | TLBO | 3.90E+02 | 4.26E+04 | 1.79E+04 | 1.79E+04 | 1.01E+04 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | BAS | 4.69E+09 | 2.35E+10 | 1.49E+10 | 1.43E+10 | 4.85E+09 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | FA | 5.06E+02 | 4.22E+04 | 1.27E+04 | 1.61E+04 | 1.05E+04 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | HHO | 8.79E+05 | 5.04E+07 | 2.82E+06 | 5.35E+06 | 7.45E+06 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | GWO | 6.39E+04 | 9.96E+07 | 6.88E+05 | 5.04E+06 | 1.54E+07 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| F18 | MFO | 5.25E+02 | 1.65E+09 | 4.86E+06 | 7.71E+07 | 2.93E+08 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | WOA | 3.30E+04 | 6.51E+06 | 1.42E+06 | 1.52E+06 | 1.49E+06 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | CMAES | 2.80E+08 | 2.42E+09 | 1.26E+09 | 1.33E+09 | 5.57E+08 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | AGSK | 2.11E+01 | 5.01E+01 | 4.11E+01 | 4.03E+01 | 5.99E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | HSES | 2.16E+01 | 7.66E+01 | 3.97E+01 | 4.10E+01 | 1.27E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | MadDE | 1.50E+04 | 1.91E+04 | 1.70E+04 | 1.69E+04 | 1.10E+03 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | IMODE | 7.58E+01 | 5.60E+02 | 1.59E+02 | 1.81E+02 | 8.05E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | ALSHADE | 1.24E+01 | 2.79E+01 | 1.98E+01 | 1.99E+01 | 3.81E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | EA4eig | 5.68E+05 | 9.11E+07 | 2.05E+07 | 3.19E+07 | 2.92E+07 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | APGSKIMODE | 2.39E+01 | 6.18E+01 | 3.73E+01 | 3.96E+01 | 8.25E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | DA2MODE | 1.36E+01 | 2.54E+01 | 1.84E+01 | **1.88E+01** | 3.12E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | ABC | 1.33E+03 | 2.02E+03 | 1.90E+03 | 1.80E+03 | 2.01E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | GA | 4.16E+02 | 1.72E+03 | 1.46E+03 | 1.29E+03 | 3.56E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | PSO | 6.34E+02 | 2.20E+03 | 1.71E+03 | 1.58E+03 | 4.05E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | DE | 5.99E+02 | 1.49E+03 | 1.15E+03 | 1.12E+03 | 1.73E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | SA | 1.87E+02 | 4.38E+02 | 3.34E+02 | 3.26E+02 | 7.24E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | TLBO | 2.08E+02 | 1.17E+03 | 6.34E+02 | 6.46E+02 | 1.95E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | BAS | 2.39E+03 | 3.97E+03 | 3.11E+03 | 3.19E+03 | 3.74E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | FA | 4.52E+02 | 1.41E+03 | 8.56E+02 | 8.50E+02 | 2.17E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | HHO | 7.20E+02 | 2.21E+03 | 1.76E+03 | 1.59E+03 | 4.48E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | GWO | 4.65E+02 | 1.13E+03 | 6.94E+02 | 7.92E+02 | 2.28E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| F19 | MFO | 6.04E+02 | 2.29E+03 | 1.67E+03 | 1.59E+03 | 4.69E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | WOA | 1.11E+03 | 2.07E+03 | 1.68E+03 | 1.63E+03 | 3.47E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | CMAES | 9.50E+02 | 2.40E+03 | 1.64E+03 | 1.63E+03 | 3.39E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | AGSK | 4.09E+02 | 7.97E+02 | 6.62E+02 | 6.55E+02 | 8.10E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | HSES | 3.95E+01 | 4.35E+02 | 6.60E+01 | **1.27E+02** | 1.17E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | MadDE | 3.02E+02 | 7.68E+02 | 5.48E+02 | 5.36E+02 | 1.03E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | IMODE | 3.71E+02 | 1.45E+03 | 8.98E+02 | 8.67E+02 | 1.91E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | ALSHADE | 5.32E+01 | 3.43E+02 | 1.05E+02 | 1.36E+02 | 8.84E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | EA4eig | 9.95E+02 | 1.91E+03 | 1.55E+03 | 1.54E+03 | 2.12E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | APGSKIMODE | 3.03E+02 | 1.04E+03 | 7.24E+02 | 7.32E+02 | 1.83E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | DA2MODE | 8.65E+01 | 2.73E+02 | 1.29E+02 | 1.41E+02 | 4.08E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |

(*continued on next page*)

**Table E.10** (*continued*).

| Fun | Alg. | Error | | | | | Function evaluations | | | | | SR (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No. | Name | Best | Worst | Median | Mean | SD | Best | Worst | Median | Mean | SD | |
| | ABC | 6.05E+02 | 6.67E+02 | 6.40E+02 | 6.40E+02 | 1.77E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | GA | 3.52E+02 | 4.55E+02 | 3.99E+02 | 4.01E+02 | 2.88E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | PSO | 6.47E+02 | 9.47E+02 | 8.18E+02 | 8.10E+02 | 8.09E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | DE | 4.95E+02 | 5.88E+02 | 5.45E+02 | 5.47E+02 | 2.18E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | SA | 2.71E+02 | 3.10E+02 | 2.87E+02 | 2.91E+02 | 1.13E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | TLBO | 3.60E+02 | 5.28E+02 | 4.29E+02 | 4.44E+02 | 4.58E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | BAS | 1.28E+03 | 1.64E+03 | 1.48E+03 | 1.47E+03 | 9.91E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | FA | 2.88E+02 | 4.52E+02 | 3.48E+02 | 3.51E+02 | 3.55E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | HHO | 7.24E+02 | 1.18E+03 | 9.05E+02 | 9.05E+02 | 1.08E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | GWO | 3.41E+02 | 6.21E+02 | 4.04E+02 | 4.14E+02 | 5.07E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| F20 | MFO | 5.19E+02 | 8.24E+02 | 6.88E+02 | 6.73E+02 | 7.89E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | WOA | 6.36E+02 | 1.04E+03 | 7.63E+02 | 7.99E+02 | 1.30E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | CMAES | 2.30E+02 | 8.48E+02 | 3.04E+02 | 5.18E+02 | 2.72E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | AGSK | 3.79E+02 | 4.33E+02 | 4.09E+02 | 4.10E+02 | 1.17E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | HSES | 2.13E+02 | 2.36E+02 | 2.21E+02 | 2.22E+02 | 5.28E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | MadDE | 3.82E+02 | 4.39E+02 | 4.09E+02 | 4.10E+02 | 1.66E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | IMODE | 4.23E+02 | 5.92E+02 | 4.73E+02 | 4.87E+02 | 5.23E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | ALSHADE | 2.04E+02 | 2.15E+02 | 2.09E+02 | **2.09E+02** | 2.64E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | EA4eig | 5.40E+02 | 6.17E+02 | 5.86E+02 | 5.84E+02 | 1.75E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | APGSKIMODE | 3.28E+02 | 4.51E+02 | 3.97E+02 | 3.92E+02 | 2.82E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | DA2MODE | 2.11E+02 | 2.24E+02 | 2.17E+02 | 2.18E+02 | 2.99E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | ABC | 1.06E+04 | 1.41E+04 | 1.37E+04 | 1.32E+04 | 1.19E+03 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | GA | 3.38E+03 | 7.38E+03 | 5.46E+03 | 5.60E+03 | 8.74E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | PSO | 8.41E+03 | 1.20E+04 | 1.01E+04 | 1.01E+04 | 8.90E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | DE | 1.22E+04 | 1.36E+04 | 1.31E+04 | 1.30E+04 | 3.41E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | SA | 1.43E+02 | 4.05E+03 | 2.85E+03 | 2.47E+03 | 1.39E+03 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | TLBO | 1.00E+02 | 1.35E+04 | 1.03E+04 | 8.10E+03 | 5.19E+03 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | BAS | 1.58E+04 | 1.86E+04 | 1.76E+04 | 1.75E+04 | 8.83E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | FA | 1.00E+02 | 7.81E+03 | 6.63E+03 | 6.30E+03 | 1.49E+03 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | HHO | 9.74E+03 | 1.44E+04 | 1.23E+04 | 1.25E+04 | 1.11E+03 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | GWO | 5.09E+03 | 1.29E+04 | 6.39E+03 | 6.26E+03 | 1.15E+03 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| F21 | MFO | 5.24E+03 | 1.13E+04 | 8.77E+03 | 8.87E+03 | 1.15E+03 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | WOA | 7.45E+03 | 1.22E+04 | 1.02E+04 | 9.97E+03 | 1.09E+03 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | CMAES | 1.19E+04 | 1.46E+04 | 1.39E+04 | 1.38E+04 | 4.90E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | AGSK | 1.00E+02 | 9.62E+03 | 8.36E+03 | 4.97E+03 | 4.47E+03 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | HSES | 1.00E+02 | 2.25E+03 | 1.00E+02 | 1.42E+02 | 3.00E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | MadDE | 1.29E+02 | 2.71E+02 | 1.45E+02 | 1.49E+02 | 2.37E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | IMODE | 1.00E+02 | 7.16E+03 | 5.22E+03 | 4.20E+03 | 2.36E+03 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | ALSHADE | 1.00E+02 | 5.82E+03 | 3.53E+03 | 2.56E+03 | 1.96E+03 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | EA4eig | 5.00E+02 | 1.41E+04 | 1.29E+04 | 1.17E+04 | 4.08E+03 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | APGSKIMODE | 1.00E+02 | 8.98E+03 | 1.12E+02 | 4.72E+02 | 1.65E+03 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | DA2MODE | 1.00E+02 | 1.04E+02 | 1.00E+02 | **1.00E+02** | 6.48E−01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | ABC | 8.24E+02 | 8.89E+02 | 8.64E+02 | 8.61E+02 | 1.58E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | GA | 5.55E+02 | 8.71E+02 | 6.44E+02 | 6.72E+02 | 9.38E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | PSO | 1.61E+03 | 2.61E+03 | 2.03E+03 | 2.09E+03 | 1.85E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | DE | 7.33E+02 | 7.88E+02 | 7.72E+02 | 7.69E+02 | 1.39E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | SA | 4.80E+02 | 5.37E+02 | 5.08E+02 | 5.06E+02 | 1.43E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | TLBO | 6.76E+02 | 1.01E+03 | 7.85E+02 | 8.07E+02 | 8.05E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | BAS | 2.11E+03 | 4.02E+03 | 2.94E+03 | 3.05E+03 | 4.51E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | FA | 5.28E+02 | 7.20E+02 | 5.93E+02 | 6.00E+02 | 4.21E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | HHO | 1.14E+03 | 2.24E+03 | 1.59E+03 | 1.63E+03 | 2.81E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | GWO | 5.92E+02 | 7.90E+02 | 6.66E+02 | 6.68E+02 | 4.96E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| F22 | MFO | 7.55E+02 | 1.14E+03 | 8.89E+02 | 9.03E+02 | 6.96E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | WOA | 9.95E+02 | 1.64E+03 | 1.21E+03 | 1.23E+03 | 1.55E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | CMAES | 1.03E+03 | 1.21E+03 | 1.11E+03 | 1.12E+03 | 4.00E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | AGSK | 5.89E+02 | 6.37E+02 | 6.16E+02 | 6.16E+02 | 1.07E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | HSES | 4.15E+02 | 4.79E+02 | 4.43E+02 | 4.44E+02 | 1.31E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | MadDE | 6.12E+02 | 7.02E+02 | 6.62E+02 | 6.62E+02 | 2.00E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | IMODE | 8.63E+02 | 1.03E+03 | 9.48E+02 | 9.51E+02 | 3.46E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | ALSHADE | 4.26E+02 | 4.51E+02 | 4.38E+02 | **4.39E+02** | 6.08E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | EA4eig | 8.80E+02 | 1.01E+03 | 9.40E+02 | 9.31E+02 | 3.67E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | APGSKIMODE | 4.99E+02 | 6.68E+02 | 6.19E+02 | 6.14E+02 | 3.61E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | DA2MODE | 4.32E+02 | 4.58E+02 | 4.43E+02 | 4.43E+02 | 5.45E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | ABC | 8.80E+02 | 9.31E+02 | 9.04E+02 | 9.04E+02 | 1.47E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | GA | 6.68E+02 | 1.08E+03 | 8.79E+02 | 8.96E+02 | 9.38E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | PSO | 2.06E+03 | 2.80E+03 | 2.51E+03 | 2.43E+03 | 2.48E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | DE | 8.20E+02 | 8.69E+02 | 8.52E+02 | 8.50E+02 | 1.13E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | SA | 5.49E+02 | 5.90E+02 | 5.73E+02 | 5.71E+02 | 8.90E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | TLBO | 6.75E+02 | 9.76E+02 | 8.26E+02 | 8.26E+02 | 6.84E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | BAS | 2.45E+03 | 4.42E+03 | 3.64E+03 | 3.59E+03 | 4.88E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | FA | 5.75E+02 | 7.30E+02 | 6.42E+02 | 6.51E+02 | 4.41E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | HHO | 1.41E+03 | 2.18E+03 | 1.86E+03 | 1.84E+03 | 1.93E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | GWO | 6.47E+02 | 1.00E+03 | 7.25E+02 | 7.40E+02 | 7.69E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| F23 | MFO | 7.14E+02 | 9.63E+02 | 8.39E+02 | 8.41E+02 | 6.67E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | WOA | 1.02E+03 | 1.67E+03 | 1.32E+03 | 1.32E+03 | 1.77E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | CMAES | 1.03E+03 | 1.16E+03 | 1.10E+03 | 1.10E+03 | 3.65E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | AGSK | 6.25E+02 | 6.70E+02 | 6.45E+02 | 6.47E+02 | 8.70E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | HSES | 4.82E+02 | 5.26E+02 | 5.01E+02 | **5.01E+02** | 9.91E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | MadDE | 7.09E+02 | 7.80E+02 | 7.43E+02 | 7.46E+02 | 1.91E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | IMODE | 7.65E+02 | 1.08E+03 | 1.04E+03 | 1.03E+03 | 4.57E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | ALSHADE | 5.08E+02 | 5.20E+02 | 5.13E+02 | 5.13E+02 | 2.84E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | EA4eig | 9.18E+02 | 1.11E+03 | 9.87E+02 | 9.85E+02 | 3.49E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | APGSKIMODE | 5.67E+02 | 7.36E+02 | 6.66E+02 | 6.60E+02 | 3.57E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | DA2MODE | 5.15E+02 | 5.32E+02 | 5.22E+02 | 5.23E+02 | 3.30E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | ABC | 5.10E+02 | 5.63E+02 | 5.20E+02 | 5.23E+02 | 1.09E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | GA | 5.03E+02 | 6.52E+02 | 5.84E+02 | 5.86E+02 | 3.18E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | PSO | 4.09E+03 | 9.36E+03 | 5.45E+03 | 5.53E+03 | 8.92E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | DE | 4.80E+02 | 5.63E+02 | 4.80E+02 | 4.93E+02 | 3.04E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | SA | 4.83E+02 | 4.96E+02 | 4.85E+02 | 4.85E+02 | 1.72E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | TLBO | 5.18E+02 | 6.10E+02 | 5.70E+02 | 5.67E+02 | 2.51E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | BAS | 4.85E+04 | 8.36E+04 | 6.04E+04 | 6.19E+04 | 8.90E+03 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | FA | 4.61E+02 | 5.85E+02 | 5.29E+02 | 5.32E+02 | 3.60E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | HHO | 1.06E+03 | 2.72E+03 | 1.75E+03 | 1.69E+03 | 3.53E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | GWO | 8.68E+02 | 1.72E+03 | 1.11E+03 | 1.12E+03 | 1.80E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| F24 | MFO | 6.50E+02 | 1.02E+04 | 2.12E+03 | 2.94E+03 | 2.17E+03 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | WOA | 5.88E+02 | 7.38E+02 | 6.38E+02 | 6.48E+02 | 3.62E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | CMAES | 5.75E+02 | 4.04E+03 | 7.43E+02 | 9.77E+02 | 6.23E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | AGSK | 4.79E+02 | 4.92E+02 | 4.80E+02 | 4.83E+02 | 4.97E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | HSES | 4.60E+02 | 5.65E+02 | 5.63E+02 | 5.49E+02 | 2.26E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | MadDE | 6.11E+02 | 6.32E+02 | 6.16E+02 | 6.16E+02 | 3.62E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | IMODE | 4.60E+02 | 5.89E+02 | 5.60E+02 | 5.42E+02 | 3.95E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | ALSHADE | 4.80E+02 | 4.92E+02 | 4.80E+02 | 4.81E+02 | 2.76E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | EA4eig | 9.01E+02 | 1.58E+03 | 1.06E+03 | 1.12E+03 | 1.71E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | APGSKIMODE | 5.28E+02 | 5.83E+02 | 5.64E+02 | 5.51E+02 | 2.20E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | DA2MODE | 4.31E+02 | 4.65E+02 | 4.31E+02 | **4.32E+02** | 4.78E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |

(*continued on next page*)

**Table E.10** (*continued*).

| Fun | Alg. | Error | | | | | Function evaluations | | | | | SR (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No. | Name | Best | Worst | Median | Mean | SD | Best | Worst | Median | Mean | SD | |
| | ABC | 4.91E+03 | 5.76E+03 | 5.54E+03 | 5.47E+03 | 2.37E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | GA | 3.03E+03 | 6.08E+03 | 3.57E+03 | 3.69E+03 | 4.88E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | PSO | 9.45E+03 | 1.34E+04 | 1.11E+04 | 1.14E+04 | 9.58E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | DE | 4.23E+03 | 4.92E+03 | 4.59E+03 | 4.56E+03 | 1.71E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | SA | 1.72E+03 | 2.60E+03 | 2.00E+03 | 2.00E+03 | 1.81E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | TLBO | 3.00E+02 | 9.27E+03 | 6.88E+03 | 5.79E+03 | 3.02E+03 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | BAS | 1.77E+04 | 4.19E+04 | 3.02E+04 | 2.98E+04 | 4.42E+03 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | FA | 2.33E+03 | 4.03E+03 | 2.96E+03 | 3.07E+03 | 4.31E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | HHO | 7.93E+03 | 1.26E+04 | 1.08E+04 | 1.08E+04 | 9.51E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | GWO | 2.46E+03 | 5.79E+03 | 3.71E+03 | 3.65E+03 | 5.79E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| F25 | MFO | 4.35E+03 | 7.67E+03 | 5.78E+03 | 5.98E+03 | 8.01E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | WOA | 6.99E+03 | 1.40E+04 | 1.01E+04 | 1.03E+04 | 1.72E+03 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | CMAES | 7.37E+03 | 1.00E+04 | 8.39E+03 | 8.57E+03 | 6.16E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | AGSK | 2.76E+03 | 3.25E+03 | 3.00E+03 | 2.99E+03 | 1.07E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | HSES | 8.62E+02 | 1.27E+03 | 1.16E+03 | 1.13E+03 | 9.51E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | MadDE | 3.19E+02 | 3.87E+02 | 3.43E+02 | 3.43E+02 | 1.38E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | IMODE | 3.00E+02 | 6.01E+03 | 3.00E+02 | 2.22E+03 | 2.44E+03 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | ALSHADE | 1.10E+03 | 1.38E+03 | 1.24E+03 | 1.24E+03 | 6.75E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | EA4eig | 5.44E+03 | 7.25E+03 | 5.99E+03 | 6.04E+03 | 4.47E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | APGSKIMODE | 2.20E+03 | 3.53E+03 | 2.88E+03 | 2.89E+03 | 2.76E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | DA2MODE | 3.00E+02 | 3.00E+02 | 3.00E+02 | **3.00E+02** | 3.31E−13 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | ABC | 6.87E+02 | 7.87E+02 | 7.18E+02 | 7.21E+02 | 2.30E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | GA | 5.91E+02 | 1.04E+03 | 8.15E+02 | 8.19E+02 | 1.17E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | PSO | 3.16E+03 | 5.63E+03 | 3.64E+03 | 3.86E+03 | 6.77E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | DE | 5.16E+02 | 6.58E+02 | 5.51E+02 | 5.56E+02 | 2.61E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | SA | 4.74E+02 | 5.24E+02 | 5.04E+02 | 5.03E+02 | 1.19E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | TLBO | 7.71E+02 | 1.54E+03 | 9.98E+02 | 1.01E+03 | 1.62E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | BAS | 4.89E+03 | 7.93E+03 | 5.80E+03 | 6.10E+03 | 9.31E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | FA | 5.60E+02 | 8.64E+02 | 6.59E+02 | 6.81E+02 | 6.37E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | HHO | 1.59E+03 | 3.96E+03 | 2.68E+03 | 2.60E+03 | 5.79E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | GWO | 6.84E+02 | 1.05E+03 | 8.72E+02 | 8.70E+02 | 1.12E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| F26 | MFO | 6.73E+02 | 1.15E+03 | 1.01E+03 | 9.79E+02 | 1.15E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | WOA | 8.59E+02 | 2.57E+03 | 1.46E+03 | 1.53E+03 | 3.76E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | CMAES | 9.40E+02 | 1.23E+03 | 1.11E+03 | 1.12E+03 | 5.70E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | AGSK | 4.96E+02 | 6.93E+02 | 5.49E+02 | 5.50E+02 | 4.36E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | HSES | 5.44E+02 | 6.59E+02 | 6.07E+02 | 6.09E+02 | 2.58E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | MadDE | 6.74E+02 | 8.12E+02 | 7.56E+02 | 7.55E+02 | 2.47E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | IMODE | 8.82E+02 | 1.46E+03 | 1.26E+03 | 1.24E+03 | 1.52E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | ALSHADE | 5.11E+02 | 5.93E+02 | 5.33E+02 | 5.37E+02 | 1.73E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | EA4eig | 9.68E+02 | 1.79E+03 | 1.20E+03 | 1.21E+03 | 1.87E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | APGSKIMODE | 5.02E+02 | 6.03E+02 | 5.35E+02 | 5.39E+02 | 2.30E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | DA2MODE | 5.00E+02 | 5.00E+02 | 5.00E+02 | **5.00E+02** | 2.31E−04 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | ABC | 4.60E+02 | 4.65E+02 | 4.61E+02 | 4.61E+02 | 1.34E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | GA | 4.85E+02 | 6.56E+02 | 5.40E+02 | 5.52E+02 | 3.76E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | PSO | 3.91E+03 | 9.37E+03 | 5.29E+03 | 5.46E+03 | 8.67E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | DE | 4.59E+02 | 5.14E+02 | 5.08E+02 | 4.92E+02 | 2.39E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | SA | 4.62E+02 | 4.65E+02 | 4.64E+02 | 4.64E+02 | 9.28E−01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | TLBO | 4.72E+02 | 5.88E+02 | 5.06E+02 | 5.09E+02 | 2.67E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | BAS | 1.90E+04 | 3.09E+04 | 2.41E+04 | 2.45E+04 | 3.44E+03 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | FA | 4.59E+02 | 5.17E+02 | 5.01E+02 | 4.94E+02 | 2.01E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | HHO | 1.69E+03 | 3.17E+03 | 2.29E+03 | 2.29E+03 | 3.48E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | GWO | 8.66E+02 | 1.98E+03 | 1.34E+03 | 1.36E+03 | 3.22E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| F27 | MFO | 7.47E+02 | 7.27E+03 | 5.38E+03 | 5.11E+03 | 1.61E+03 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | WOA | 5.45E+02 | 7.81E+02 | 6.42E+02 | 6.40E+02 | 5.82E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | CMAES | 6.16E+03 | 7.36E+03 | 6.59E+03 | 6.59E+03 | 2.26E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | AGSK | 4.59E+02 | 5.08E+02 | 4.59E+02 | 4.60E+02 | 6.84E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | HSES | 4.70E+02 | 5.08E+02 | 5.08E+02 | 5.04E+02 | 9.60E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | MadDE | 5.73E+02 | 6.13E+02 | 5.94E+02 | 5.93E+02 | 8.25E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | IMODE | 4.59E+02 | 5.08E+02 | 4.97E+02 | 4.87E+02 | 2.08E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | ALSHADE | 4.59E+02 | 5.08E+02 | 4.59E+02 | 4.73E+02 | 2.25E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | EA4eig | 7.83E+02 | 1.83E+03 | 1.22E+03 | 1.25E+03 | 2.56E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | APGSKIMODE | 4.63E+02 | 5.17E+02 | 5.09E+02 | 5.09E+02 | 8.47E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | DA2MODE | 4.44E+02 | 4.63E+02 | 4.44E+02 | **4.44E+02** | 3.71E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | ABC | 1.83E+03 | 2.51E+03 | 2.19E+03 | 2.16E+03 | 1.79E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | GA | 9.31E+02 | 1.80E+03 | 1.45E+03 | 1.43E+03 | 2.25E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | PSO | 3.41E+03 | 1.39E+04 | 6.57E+03 | 7.12E+03 | 2.32E+03 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | DE | 1.16E+03 | 1.91E+03 | 1.54E+03 | 1.56E+03 | 1.96E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | SA | 4.32E+02 | 7.60E+02 | 5.48E+02 | 5.50E+02 | 7.69E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | TLBO | 1.17E+03 | 2.40E+03 | 1.92E+03 | 1.82E+03 | 3.33E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | BAS | 2.88E+05 | 1.35E+07 | 4.43E+06 | 3.75E+06 | 3.17E+06 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | FA | 6.86E+02 | 2.02E+03 | 1.14E+03 | 1.21E+03 | 3.25E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | HHO | 3.76E+03 | 1.00E+04 | 5.59E+03 | 6.04E+03 | 1.72E+03 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | GWO | 8.91E+02 | 2.32E+03 | 1.39E+03 | 1.53E+03 | 3.85E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| F28 | MFO | 1.61E+03 | 2.91E+03 | 2.50E+03 | 2.44E+03 | 3.27E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | WOA | 3.27E+03 | 5.60E+03 | 4.20E+03 | 4.26E+03 | 5.95E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | CMAES | 5.84E+03 | 1.63E+04 | 8.90E+03 | 9.42E+03 | 2.21E+03 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | AGSK | 6.59E+02 | 9.60E+02 | 8.21E+02 | 8.26E+02 | 5.96E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | HSES | 3.55E+02 | 8.46E+02 | 4.08E+02 | 5.23E+02 | 1.68E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | MadDE | 6.89E+02 | 1.22E+03 | 9.05E+02 | 9.14E+02 | 9.57E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | IMODE | 1.32E+03 | 2.71E+03 | 1.84E+03 | 1.89E+03 | 3.36E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | ALSHADE | 3.39E+02 | 4.55E+02 | 3.71E+02 | 3.78E+02 | 2.60E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | EA4eig | 1.68E+03 | 3.84E+03 | 2.64E+03 | 2.62E+03 | 5.55E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | APGSKIMODE | 5.17E+02 | 1.04E+03 | 7.95E+02 | 7.65E+02 | 1.27E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | DA2MODE | 2.56E+02 | 4.22E+02 | 2.79E+02 | **2.87E+02** | 3.37E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | ABC | 7.28E+05 | 1.22E+06 | 8.40E+05 | 8.78E+05 | 1.37E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | GA | 7.96E+05 | 1.96E+06 | 1.00E+06 | 1.07E+06 | 2.07E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | PSO | 1.48E+08 | 1.48E+09 | 3.92E+08 | 5.08E+08 | 3.12E+08 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | DE | 6.33E+05 | 2.75E+06 | 1.03E+06 | 1.29E+06 | 5.34E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | SA | 8.40E+06 | 1.49E+07 | 1.15E+07 | 1.11E+07 | 1.51E+06 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | TLBO | 7.37E+05 | 1.87E+06 | 1.01E+06 | 9.99E+05 | 2.52E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | BAS | 6.77E+09 | 3.08E+10 | 1.84E+10 | 2.11E+10 | 7.03E+09 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | FA | 6.31E+05 | 2.68E+06 | 9.76E+05 | 1.01E+06 | 3.16E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | HHO | 7.84E+07 | 3.45E+08 | 1.51E+08 | 1.89E+08 | 7.28E+07 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | GWO | 3.94E+07 | 1.80E+08 | 8.42E+07 | 8.50E+07 | 3.06E+07 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| F29 | MFO | 4.82E+06 | 1.64E+09 | 4.07E+07 | 2.31E+08 | 3.66E+08 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | WOA | 4.57E+07 | 1.46E+08 | 9.16E+07 | 9.04E+07 | 2.66E+07 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | CMAES | 1.00E+09 | 4.42E+09 | 1.95E+09 | 2.17E+09 | 9.01E+08 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | AGSK | 5.79E+05 | 6.65E+05 | 5.98E+05 | 6.04E+05 | 2.61E+04 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | HSES | 5.87E+05 | 7.27E+05 | 6.23E+05 | 6.34E+05 | 3.78E+04 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | MadDE | 2.29E+06 | 4.85E+06 | 3.52E+06 | 3.48E+06 | 5.13E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | IMODE | 5.80E+05 | 6.57E+05 | 5.90E+05 | 5.97E+05 | 2.26E+04 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | ALSHADE | 5.79E+05 | 8.93E+05 | 6.40E+05 | 6.49E+05 | 7.31E+04 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | EA4eig | 1.03E+08 | 3.82E+08 | 1.86E+08 | 2.04E+08 | 6.56E+07 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | APGSKIMODE | 5.96E+05 | 8.98E+05 | 7.08E+05 | 7.15E+05 | 7.22E+04 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | DA2MODE | 2.13E+02 | 2.31E+02 | 2.19E+02 | **2.19E+02** | 3.28E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |

**Table E.11**
The results metrics for the error and function evaluation metrics for 21 algorithms, CEC2017–2018 (F1-F3, 100 Dim).

| Fun | Alg. | Error | | | | | Function evaluations | | | | | SR (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No. | Name | Best | Worst | Median | Mean | SD | Best | Worst | Median | Mean | SD | |
| | ABC | 1.16E+10 | 1.77E+10 | 1.54E+10 | 1.48E+10 | 2.16E+09 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | GA | 2.03E+06 | 6.94E+06 | 3.93E+06 | 4.23E+06 | 1.24E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | PSO | 1.62E+11 | 2.23E+11 | 1.81E+11 | 1.84E+11 | 1.48E+10 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | DE | 4.69E−01 | 5.06E+04 | 8.01E+03 | 1.50E+04 | 1.61E+04 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | SA | 1.71E+05 | 2.84E+05 | 2.22E+05 | 2.23E+05 | 3.64E+04 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | TLBO | 7.24E+02 | 6.14E+04 | 5.60E+03 | 8.30E+03 | 8.86E+03 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | BAS | 5.26E+11 | 6.96E+11 | 6.22E+11 | 6.19E+11 | 3.78E+10 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | FA | 2.42E+01 | 6.13E+04 | 4.91E+03 | 1.16E+04 | 1.59E+04 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | HHO | 1.10E+10 | 2.94E+10 | 1.80E+10 | 1.91E+10 | 4.60E+09 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | GWO | 2.81E+10 | 7.84E+10 | 4.77E+10 | 4.62E+10 | 9.19E+09 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| F1 | MFO | 4.14E+10 | 2.09E+11 | 1.18E+11 | 1.21E+11 | 4.03E+10 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | WOA | 1.96E+07 | 8.37E+07 | 4.58E+07 | 4.57E+07 | 1.59E+07 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | CMAES | 9.42E+01 | 1.25E+11 | 3.77E+04 | 1.97E+10 | 4.60E+10 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | AGSK | 7.74E−01 | 1.01E+04 | 7.82E+02 | 1.49E+03 | 2.01E+03 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | HSES | 0.00E+00 | 2.95E−08 | 0.00E+00 | 1.14E−09 | 4.92E−09 | 1.27E+05 | 1.00E+06 | 1.30E+05 | 1.81E+05 | 2.07E+05 | 94.12 |
| | MadDE | 4.74E+09 | 7.85E+09 | 6.29E+09 | 6.29E+09 | 5.86E+08 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | IMODE | 7.92E−02 | 1.46E−01 | 1.45E−01 | 1.36E−01 | 1.54E−02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | ALSHADE | 0.00E+00 | 1.37E−08 | 0.00E+00 | **2.68E−10** | 1.92E−09 | 9.22E+05 | 1.00E+06 | 9.51E+05 | 9.54E+05 | 1.60E+04 | 98.04 |
| | EA4eig | 5.53E+09 | 2.19E+10 | 1.35E+10 | 1.37E+10 | 3.93E+09 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | APGSKIMODE | 2.12E+03 | 5.42E+03 | 3.63E+03 | 3.79E+03 | 8.04E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | DA2MODE | 1.18E−08 | 2.21E−04 | 1.41E−06 | 8.36E−06 | 3.14E−05 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | ABC | 6.15E+05 | 7.81E+05 | 7.02E+05 | 6.96E+05 | 4.32E+04 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | GA | 1.47E+05 | 2.97E+05 | 2.02E+05 | 2.08E+05 | 3.50E+04 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | PSO | 4.01E+05 | 5.83E+05 | 4.86E+05 | 4.84E+05 | 3.90E+04 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | DE | 3.14E+05 | 4.28E+05 | 3.68E+05 | 3.64E+05 | 3.13E+04 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | SA | 5.51E+05 | 8.25E+05 | 7.04E+05 | 6.84E+05 | 6.36E+04 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | TLBO | 2.08E+04 | 6.44E+04 | 3.56E+04 | 3.80E+04 | 8.50E+03 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | BAS | 6.12E+05 | 1.65E+14 | 1.21E+11 | 8.20E+12 | 2.65E+13 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | FA | 7.59E+04 | 1.93E+05 | 1.06E+05 | 1.21E+05 | 3.20E+04 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | HHO | 3.33E+05 | 7.67E+05 | 3.65E+05 | 4.17E+05 | 1.23E+05 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | GWO | 1.80E+05 | 2.56E+05 | 2.09E+05 | 2.13E+05 | 2.08E+04 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| F2 | MFO | 9.68E+04 | 9.05E+05 | 4.76E+05 | 4.62E+05 | 2.55E+05 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | WOA | 2.51E+05 | 9.70E+05 | 6.78E+05 | 6.23E+05 | 2.21E+05 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | CMAES | 6.86E+05 | 9.27E+05 | 8.19E+05 | 8.17E+05 | 6.70E+04 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | AGSK | 1.83E+05 | 3.20E+05 | 2.46E+05 | 2.47E+05 | 3.18E+04 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | HSES | 0.00E+00 | 4.43E−08 | 0.00E+00 | **2.63E−09** | 8.22E−09 | 2.70E+05 | 1.00E+06 | 2.80E+05 | 3.63E+05 | 2.35E+05 | 88.24 |
| | MadDE | 2.96E+05 | 3.81E+05 | 3.56E+05 | 3.52E+05 | 1.68E+04 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | IMODE | 6.31E−05 | 7.31E−05 | 7.07E−05 | 6.96E−05 | 2.31E−06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | ALSHADE | 7.02E−06 | 6.08E−04 | 7.21E−05 | 1.10E−04 | 1.29E−04 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | EA4eig | 2.84E+05 | 4.62E+05 | 4.01E+05 | 3.97E+05 | 3.56E+04 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | APGSKIMODE | 2.74E+04 | 7.76E+04 | 4.72E+04 | 4.72E+04 | 1.11E+04 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | DA2MODE | 3.78E−06 | 2.05E−04 | 4.47E−05 | 5.55E−05 | 4.94E−05 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | ABC | 1.93E+03 | 2.74E+03 | 2.35E+03 | 2.35E+03 | 2.22E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | GA | 2.99E+02 | 4.85E+02 | 3.55E+02 | 3.77E+02 | 5.65E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | PSO | 3.28E+04 | 6.79E+04 | 4.76E+04 | 4.68E+04 | 7.95E+03 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | DE | 1.93E+02 | 2.26E+02 | 2.04E+02 | 2.05E+02 | 7.74E+00 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | SA | 1.97E+02 | 2.70E+02 | 2.22E+02 | 2.19E+02 | 1.75E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | TLBO | 1.88E+02 | 4.08E+02 | 2.89E+02 | 2.89E+02 | 5.56E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | BAS | 2.22E+05 | 4.09E+05 | 3.10E+05 | 3.08E+05 | 4.46E+04 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | FA | 1.95E+02 | 3.41E+02 | 2.47E+02 | 2.52E+02 | 3.94E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | HHO | 2.58E+03 | 5.31E+03 | 3.72E+03 | 3.69E+03 | 6.96E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | GWO | 2.27E+03 | 6.50E+03 | 3.52E+03 | 3.81E+03 | 9.20E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| F3 | MFO | 2.89E+03 | 7.50E+04 | 2.33E+04 | 2.58E+04 | 1.49E+04 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | WOA | 4.57E+02 | 8.80E+02 | 6.21E+02 | 6.08E+02 | 9.62E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | CMAES | 1.23E+04 | 2.83E+04 | 1.63E+04 | 1.67E+04 | 3.88E+03 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | AGSK | 1.97E+02 | 2.34E+02 | 2.20E+02 | 2.21E+02 | 7.62E+00 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | HSES | 0.00E+00 | 1.88E+02 | 1.66E−01 | **1.76E+01** | 4.73E+01 | 2.17E+05 | 1.00E+06 | 1.00E+06 | 7.36E+05 | 3.51E+05 | 37.25 |
| | MadDE | 1.02E+03 | 1.37E+03 | 1.21E+03 | 1.22E+03 | 5.45E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | IMODE | 0.00E+00 | 1.97E+02 | 3.99E+00 | 6.19E+01 | 7.66E+01 | 9.17E+05 | 1.00E+06 | 1.00E+06 | 9.96E+05 | 1.38E+04 | 17.65 |
| | ALSHADE | 1.83E+02 | 2.46E+02 | 1.97E+02 | 2.03E+02 | 1.28E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | EA4eig | 1.46E+03 | 5.41E+03 | 2.34E+03 | 2.70E+03 | 1.02E+03 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | APGSKIMODE | 2.27E+02 | 3.19E+02 | 2.83E+02 | 2.73E+02 | 2.56E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | DA2MODE | 2.51E+01 | 1.75E+02 | 1.05E+02 | 1.04E+02 | 2.62E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | ABC | 1.09E+03 | 1.17E+03 | 1.13E+03 | 1.13E+03 | 1.86E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | GA | 3.68E+02 | 6.47E+02 | 5.02E+02 | 4.95E+02 | 6.68E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | PSO | 1.12E+03 | 1.45E+03 | 1.26E+03 | 1.25E+03 | 8.09E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | DE | 8.18E+02 | 9.20E+02 | 8.76E+02 | 8.80E+02 | 1.90E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | SA | 1.54E+02 | 2.65E+02 | 2.01E+02 | 2.05E+02 | 2.64E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | TLBO | 5.51E+02 | 7.48E+02 | 6.13E+02 | 6.29E+02 | 5.44E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | BAS | 2.31E+03 | 2.87E+03 | 2.70E+03 | 2.65E+03 | 1.40E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | FA | 2.77E+02 | 5.77E+02 | 3.95E+02 | 4.24E+02 | 7.08E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | HHO | 1.19E+03 | 1.40E+03 | 1.27E+03 | 1.28E+03 | 4.91E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | GWO | 4.76E+02 | 7.60E+02 | 5.71E+02 | 5.97E+02 | 8.67E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| F4 | MFO | 1.07E+03 | 1.66E+03 | 1.29E+03 | 1.33E+03 | 1.43E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | WOA | 8.05E+02 | 1.16E+03 | 9.51E+02 | 9.55E+02 | 8.60E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | CMAES | 1.11E+02 | 1.24E+03 | 1.30E+02 | 2.41E+02 | 3.34E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | AGSK | 5.71E+02 | 6.51E+02 | 6.17E+02 | 6.18E+02 | 1.89E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | HSES | 3.88E+01 | 1.00E+02 | 7.16E+01 | 6.88E+01 | 1.61E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | MadDE | 8.60E+02 | 9.88E+02 | 9.30E+02 | 9.30E+02 | 3.01E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | IMODE | 6.72E+02 | 8.63E+02 | 7.83E+02 | 7.87E+02 | 4.58E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | ALSHADE | 1.39E+01 | 3.98E+01 | 2.39E+01 | **2.42E+01** | 4.67E+00 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | EA4eig | 8.46E+02 | 1.06E+03 | 9.57E+02 | 9.61E+02 | 5.36E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | APGSKIMODE | 5.01E+02 | 6.93E+02 | 6.46E+02 | 6.31E+02 | 4.67E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | DA2MODE | 7.05E+01 | 1.35E+02 | 9.85E+01 | 9.97E+01 | 1.44E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | ABC | 2.77E+01 | 3.70E+01 | 3.42E+01 | 3.38E+01 | 2.30E+00 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | GA | 1.22E−01 | 4.34E−01 | 2.77E−01 | 2.80E−01 | 7.91E−02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | PSO | 7.52E+01 | 9.59E+01 | 8.47E+01 | 8.52E+01 | 5.18E+00 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | DE | 0.00E+00 | 1.23E−06 | 1.17E−08 | **7.62E−08** | 1.85E−07 | 3.11E+05 | 1.00E+06 | 1.00E+06 | 6.98E+05 | 3.37E+05 | 45.10 |
| | SA | 4.58E−01 | 1.69E+00 | 7.41E−01 | 8.27E−01 | 3.78E−01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | TLBO | 3.76E+01 | 5.57E+01 | 4.65E+01 | 4.64E+01 | 4.60E+00 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | BAS | 1.41E+02 | 1.76E+02 | 1.64E+02 | 1.62E+02 | 8.44E+00 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | FA | 4.57E+00 | 3.05E+01 | 1.42E+01 | 1.62E+01 | 5.93E+00 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | HHO | 8.30E+01 | 1.01E+02 | 9.60E+01 | 9.54E+01 | 3.73E+00 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | GWO | 2.49E+01 | 3.59E+01 | 3.21E+01 | 3.14E+01 | 3.40E+00 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| F5 | MFO | 5.70E+01 | 8.61E+01 | 7.35E+01 | 7.34E+01 | 6.84E+00 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | WOA | 6.61E+01 | 9.45E+01 | 7.65E+01 | 7.95E+01 | 8.68E+00 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | CMAES | 4.73E−05 | 5.18E−04 | 1.90E−04 | 2.18E−04 | 1.45E−04 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | AGSK | 4.63E−03 | 3.51E−02 | 1.28E−02 | 1.37E−02 | 6.01E−03 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | HSES | 3.13E−07 | 1.38E−02 | 5.64E−04 | 1.79E−03 | 3.25E−03 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | MadDE | 3.52E+01 | 4.70E+01 | 4.12E+01 | 4.08E+01 | 2.62E+00 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | IMODE | 5.08E+01 | 6.39E+01 | 5.77E+01 | 5.75E+01 | 2.93E+00 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | ALSHADE | 7.95E−04 | 4.78E−02 | 7.29E−03 | 9.93E−03 | 9.00E−03 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | EA4eig | 2.58E+01 | 3.85E+01 | 3.06E+01 | 3.10E+01 | 3.08E+00 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |

(*continued on next page*)

**Table E.11** (*continued*).

| Fun | Alg. | Error | | | | | Function evaluations | | | | | SR (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No. | Name | Best | Worst | Median | Mean | SD | Best | Worst | Median | Mean | SD | |
| | APGSKIMODE | 1.01E−02 | 3.13E−02 | 1.99E−02 | 2.04E−02 | 5.70E−03 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | DA2MODE | 4.64E−03 | 5.57E−01 | 1.84E−01 | 2.00E−01 | 1.08E−01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | ABC | 1.92E+03 | 2.21E+03 | 2.07E+03 | 2.07E+03 | 6.58E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | GA | 6.60E+02 | 9.58E+02 | 7.92E+02 | 8.16E+02 | 9.28E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | PSO | 2.39E+03 | 3.30E+03 | 2.88E+03 | 2.90E+03 | 2.40E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | DE | 9.38E+02 | 1.02E+03 | 1.01E+03 | 9.96E+02 | 2.57E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | SA | 2.73E+02 | 4.04E+02 | 3.20E+02 | 3.24E+02 | 3.37E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | TLBO | 1.41E+03 | 2.11E+03 | 1.66E+03 | 1.72E+03 | 2.01E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | BAS | 1.06E+04 | 1.41E+04 | 1.27E+04 | 1.26E+04 | 7.98E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | FA | 6.13E+02 | 1.06E+03 | 8.04E+02 | 8.16E+02 | 1.28E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | HHO | 3.03E+03 | 3.32E+03 | 3.23E+03 | 3.21E+03 | 6.29E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | GWO | 8.52E+02 | 1.51E+03 | 1.18E+03 | 1.16E+03 | 1.48E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| F6 | MFO | 2.72E+03 | 5.74E+03 | 3.93E+03 | 4.13E+03 | 8.06E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | WOA | 2.35E+03 | 2.83E+03 | 2.56E+03 | 2.59E+03 | 1.58E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | CMAES | 2.12E+02 | 2.69E+02 | 2.45E+02 | 2.43E+02 | 1.78E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | AGSK | 6.43E+02 | 7.92E+02 | 7.41E+02 | 7.39E+02 | 2.79E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | HSES | 1.34E+02 | 2.37E+02 | 1.74E+02 | 1.74E+02 | 2.08E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | MadDE | 1.23E+03 | 1.47E+03 | 1.37E+03 | 1.37E+03 | 5.33E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | IMODE | 1.60E+03 | 2.33E+03 | 2.15E+03 | 2.03E+03 | 2.12E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | ALSHADE | 1.20E+02 | 1.74E+02 | 1.46E+02 | **1.44E+02** | 1.29E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | EA4eig | 1.21E+03 | 1.57E+03 | 1.36E+03 | 1.37E+03 | 1.03E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | APGSKIMODE | 6.35E+02 | 7.99E+02 | 7.51E+02 | 7.48E+02 | 3.10E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | DA2MODE | 1.56E+02 | 2.07E+02 | 1.74E+02 | 1.74E+02 | 1.05E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | ABC | 1.08E+03 | 1.16E+03 | 1.13E+03 | 1.12E+03 | 2.84E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | GA | 3.78E+02 | 6.28E+02 | 4.56E+02 | 4.67E+02 | 5.71E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | PSO | 1.18E+03 | 1.56E+03 | 1.38E+03 | 1.38E+03 | 7.83E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | DE | 8.26E+02 | 8.98E+02 | 8.74E+02 | 8.68E+02 | 1.80E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | SA | 1.82E+02 | 2.80E+02 | 2.02E+02 | 2.10E+02 | 2.66E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | TLBO | 5.81E+02 | 8.83E+02 | 6.68E+02 | 6.83E+02 | 9.05E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | BAS | 2.48E+03 | 3.06E+03 | 2.81E+03 | 2.83E+03 | 1.56E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | FA | 2.96E+02 | 5.95E+02 | 4.74E+02 | 4.64E+02 | 6.99E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | HHO | 1.33E+03 | 1.57E+03 | 1.45E+03 | 1.45E+03 | 5.72E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | GWO | 5.12E+02 | 7.59E+02 | 6.03E+02 | 6.24E+02 | 6.98E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| F7 | MFO | 1.08E+03 | 1.75E+03 | 1.38E+03 | 1.43E+03 | 1.83E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | WOA | 9.03E+02 | 1.18E+03 | 1.05E+03 | 1.05E+03 | 6.11E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | CMAES | 1.15E+02 | 1.29E+03 | 1.25E+02 | 4.39E+02 | 5.14E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | AGSK | 5.76E+02 | 6.50E+02 | 6.17E+02 | 6.17E+02 | 1.76E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | HSES | 4.28E+01 | 1.11E+02 | 7.06E+01 | 7.28E+01 | 1.75E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | MadDE | 8.49E+02 | 1.02E+03 | 9.47E+02 | 9.45E+02 | 3.62E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | IMODE | 7.53E+02 | 1.07E+03 | 8.60E+02 | 8.75E+02 | 7.49E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | ALSHADE | 9.95E+00 | 3.48E+01 | 2.19E+01 | **2.27E+01** | 5.44E+00 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | EA4eig | 8.76E+02 | 1.09E+03 | 9.78E+02 | 9.84E+02 | 4.29E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | APGSKIMODE | 5.20E+02 | 6.83E+02 | 6.39E+02 | 6.29E+02 | 4.25E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | DA2MODE | 6.37E+01 | 1.46E+02 | 8.95E+01 | 9.47E+01 | 1.84E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | ABC | 2.17E+04 | 3.71E+04 | 2.98E+04 | 2.93E+04 | 2.96E+03 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | GA | 7.22E+03 | 2.25E+04 | 1.34E+04 | 1.38E+04 | 3.64E+03 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | PSO | 3.16E+04 | 4.51E+04 | 3.84E+04 | 3.83E+04 | 3.51E+03 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | DE | 0.00E+00 | 5.44E−01 | 0.00E+00 | **6.02E−02** | 1.29E−01 | 2.09E+05 | 1.00E+06 | 2.30E+05 | 4.84E+05 | 3.68E+05 | 66.67 |
| | SA | 1.11E+01 | 7.80E+01 | 3.58E+01 | 3.48E+01 | 1.49E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | TLBO | 1.40E+04 | 5.81E+04 | 4.16E+04 | 4.00E+04 | 1.04E+04 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | BAS | 1.53E+05 | 2.19E+05 | 1.87E+05 | 1.88E+05 | 1.62E+04 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | FA | 1.83E+03 | 8.79E+03 | 5.01E+03 | 5.28E+03 | 1.93E+03 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | HHO | 6.26E+04 | 8.37E+04 | 7.13E+04 | 7.11E+04 | 5.50E+03 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | GWO | 1.12E+04 | 5.03E+04 | 2.20E+04 | 2.63E+04 | 1.19E+04 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| F8 | MFO | 3.44E+04 | 6.06E+04 | 4.75E+04 | 4.66E+04 | 5.94E+03 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | WOA | 2.21E+04 | 7.57E+04 | 3.62E+04 | 3.86E+04 | 1.37E+04 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | CMAES | 0.00E+00 | 4.79E+04 | 9.09E−01 | 1.17E+04 | 1.97E+04 | 7.14E+04 | 1.00E+06 | 1.00E+06 | 9.64E+05 | 1.82E+05 | 3.92 |
| | AGSK | 6.33E−01 | 6.16E+00 | 2.81E+00 | 2.87E+00 | 1.20E+00 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | HSES | 0.00E+00 | 1.08E+01 | 4.54E−01 | 1.07E+00 | 1.93E+00 | 7.34E+04 | 1.00E+06 | 1.00E+06 | 6.92E+05 | 4.40E+05 | 33.33 |
| | MadDE | 2.82E+04 | 3.83E+04 | 3.48E+04 | 3.47E+04 | 2.24E+03 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | IMODE | 1.81E+04 | 2.61E+04 | 2.21E+04 | 2.25E+04 | 2.38E+03 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | ALSHADE | 0.00E+00 | 9.98E−01 | 1.79E−01 | 3.14E−01 | 3.05E−01 | 4.80E+05 | 1.00E+06 | 1.00E+06 | 8.96E+05 | 2.00E+05 | 21.57 |
| | EA4eig | 7.20E+03 | 1.58E+04 | 9.82E+03 | 9.98E+03 | 1.94E+03 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | APGSKIMODE | 2.42E+01 | 1.53E+03 | 4.26E+02 | 4.69E+02 | 3.19E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | DA2MODE | 4.48E−01 | 1.15E+01 | 3.63E+00 | 4.21E+00 | 2.22E+00 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | ABC | 2.88E+04 | 3.10E+04 | 3.02E+04 | 3.01E+04 | 5.79E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | GA | 9.54E+03 | 1.54E+04 | 1.19E+04 | 1.20E+04 | 1.11E+03 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | PSO | 1.95E+04 | 2.48E+04 | 2.23E+04 | 2.23E+04 | 1.29E+03 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | DE | 2.81E+04 | 3.06E+04 | 3.01E+04 | 2.99E+04 | 5.02E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | SA | 5.05E+03 | 8.43E+03 | 6.66E+03 | **6.59E+03** | 8.35E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | TLBO | 1.15E+04 | 2.96E+04 | 1.65E+04 | 1.83E+04 | 5.42E+03 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | BAS | 3.38E+04 | 3.71E+04 | 3.51E+04 | 3.54E+04 | 9.40E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | FA | 1.15E+04 | 1.60E+04 | 1.32E+04 | 1.33E+04 | 1.01E+03 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | HHO | 2.18E+04 | 2.83E+04 | 2.52E+04 | 2.51E+04 | 1.48E+03 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | GWO | 8.44E+03 | 1.61E+04 | 1.28E+04 | 1.29E+04 | 1.71E+03 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| F9 | MFO | 1.22E+04 | 2.01E+04 | 1.73E+04 | 1.73E+04 | 2.03E+03 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | WOA | 1.39E+04 | 2.47E+04 | 2.01E+04 | 2.01E+04 | 2.62E+03 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | CMAES | 5.97E+03 | 2.95E+04 | 2.84E+04 | 2.55E+04 | 7.88E+03 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | AGSK | 2.26E+04 | 2.54E+04 | 2.45E+04 | 2.44E+04 | 6.06E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | HSES | 4.47E+03 | 1.00E+04 | 7.31E+03 | 7.10E+03 | 1.17E+03 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | MadDE | 1.81E+04 | 2.10E+04 | 1.99E+04 | 1.98E+04 | 6.98E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | IMODE | 9.45E+03 | 1.49E+04 | 1.21E+04 | 1.20E+04 | 1.39E+03 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | ALSHADE | 1.02E+04 | 1.30E+04 | 1.17E+04 | 1.17E+04 | 6.22E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | EA4eig | 2.82E+04 | 3.04E+04 | 2.98E+04 | 2.97E+04 | 5.09E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |

(*continued on next page*)

**Table E.11** (*continued*).

| Fun | Alg. | Error | | | | | Function evaluations | | | | | SR (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No. | Name | Best | Worst | Median | Mean | SD | Best | Worst | Median | Mean | SD | |
| | APGSKIMODE | 1.87E+04 | 2.13E+04 | 2.03E+04 | 2.02E+04 | 6.55E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | DA2MODE | 8.64E+03 | 1.07E+04 | 9.62E+03 | 9.65E+03 | 4.61E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | ABC | 1.21E+05 | 1.83E+05 | 1.47E+05 | 1.44E+05 | 1.31E+04 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | GA | 1.02E+04 | 6.04E+04 | 2.36E+04 | 2.61E+04 | 1.36E+04 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | PSO | 1.09E+05 | 3.78E+05 | 1.91E+05 | 1.91E+05 | 6.60E+04 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | DE | 6.94E+02 | 9.29E+02 | 7.22E+02 | 7.51E+02 | 7.38E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | SA | 1.30E+03 | 2.45E+03 | 1.73E+03 | 1.67E+03 | 2.73E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | TLBO | 9.43E+02 | 1.72E+03 | 1.28E+03 | 1.31E+03 | 2.02E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | BAS | 3.13E+05 | 7.83E+10 | 1.46E+08 | 4.90E+09 | 1.42E+10 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | FA | 9.36E+02 | 1.77E+03 | 1.38E+03 | 1.38E+03 | 2.33E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | HHO | 8.73E+04 | 4.24E+05 | 1.71E+05 | 1.80E+05 | 6.78E+04 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | GWO | 2.52E+04 | 6.79E+04 | 4.35E+04 | 4.32E+04 | 1.00E+04 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| F10 | MFO | 3.04E+03 | 3.14E+05 | 1.53E+05 | 1.54E+05 | 8.20E+04 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | WOA | 3.78E+03 | 2.41E+04 | 7.99E+03 | 9.50E+03 | 4.62E+03 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | CMAES | 4.06E+05 | 6.24E+05 | 4.72E+05 | 4.89E+05 | 6.96E+04 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | AGSK | 5.02E+02 | 7.73E+02 | 6.38E+02 | 6.37E+02 | 6.36E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | HSES | 5.16E+02 | 1.13E+03 | 8.25E+02 | 8.46E+02 | 1.28E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | MadDE | 3.07E+04 | 5.71E+04 | 4.92E+04 | 4.81E+04 | 6.05E+03 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | IMODE | 8.61E+02 | 1.61E+03 | 1.17E+03 | 1.15E+03 | 2.01E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | ALSHADE | 2.15E+02 | 7.64E+02 | 4.73E+02 | 4.63E+02 | 1.28E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | EA4eig | 1.79E+04 | 5.28E+04 | 3.27E+04 | 3.35E+04 | 1.05E+04 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | APGSKIMODE | 6.11E+02 | 1.58E+03 | 1.04E+03 | 1.07E+03 | 2.14E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | DA2MODE | 1.54E+02 | 6.50E+02 | 2.64E+02 | **2.81E+02** | 9.48E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | ABC | 2.14E+09 | 3.41E+09 | 2.76E+09 | 2.72E+09 | 2.70E+08 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | GA | 1.32E+07 | 1.25E+08 | 4.18E+07 | 4.57E+07 | 2.44E+07 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | PSO | 6.47E+10 | 1.41E+11 | 1.02E+11 | 1.01E+11 | 1.63E+10 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | DE | 6.33E+06 | 9.75E+07 | 1.89E+07 | 2.74E+07 | 2.03E+07 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | SA | 7.90E+06 | 3.20E+07 | 1.78E+07 | 1.90E+07 | 7.35E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | TLBO | 5.20E+05 | 1.54E+07 | 2.43E+06 | 2.35E+06 | 2.10E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | BAS | 2.65E+11 | 4.73E+11 | 3.85E+11 | 3.96E+11 | 6.01E+10 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | FA | 8.33E+05 | 4.60E+06 | 1.61E+06 | 1.74E+06 | 8.49E+05 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | HHO | 1.55E+09 | 5.28E+09 | 2.94E+09 | 3.13E+09 | 1.02E+09 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | GWO | 3.55E+09 | 2.66E+10 | 8.84E+09 | 1.06E+10 | 6.00E+09 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| F11 | MFO | 1.12E+10 | 1.15E+11 | 5.21E+10 | 5.10E+10 | 2.45E+10 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | WOA | 2.57E+08 | 1.17E+09 | 7.40E+08 | 6.74E+08 | 2.54E+08 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | CMAES | 4.55E+10 | 7.45E+10 | 5.14E+10 | 5.50E+10 | 7.90E+09 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | AGSK | 1.10E+05 | 1.22E+06 | 4.22E+05 | 4.26E+05 | 1.79E+05 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | HSES | 4.09E+03 | 7.32E+03 | 5.40E+03 | 5.37E+03 | 6.88E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | MadDE | 3.37E+08 | 5.34E+08 | 4.54E+08 | 4.53E+08 | 4.55E+07 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | IMODE | 3.11E+03 | 5.41E+03 | 4.29E+03 | **4.37E+03** | 6.09E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | ALSHADE | 1.16E+04 | 6.29E+04 | 3.43E+04 | 3.56E+04 | 1.30E+04 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | EA4eig | 1.12E+09 | 1.08E+10 | 4.02E+09 | 4.01E+09 | 2.08E+09 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | APGSKIMODE | 1.62E+06 | 7.20E+06 | 3.63E+06 | 3.73E+06 | 1.21E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | DA2MODE | 1.25E+04 | 1.04E+05 | 3.44E+04 | 3.78E+04 | 1.91E+04 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | ABC | 1.10E+03 | 7.64E+03 | 3.94E+03 | 3.66E+03 | 1.96E+03 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | GA | 6.03E+03 | 5.61E+04 | 1.55E+04 | 2.02E+04 | 1.11E+04 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | PSO | 1.01E+10 | 3.18E+10 | 1.84E+10 | 1.88E+10 | 4.78E+09 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | DE | 4.44E+02 | 2.91E+04 | 1.60E+03 | 4.73E+03 | 6.67E+03 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | SA | 5.79E+04 | 2.85E+05 | 1.20E+05 | 1.26E+05 | 4.66E+04 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | TLBO | 5.89E+03 | 3.45E+04 | 8.88E+03 | 1.14E+04 | 6.98E+03 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | BAS | 7.74E+10 | 1.20E+11 | 1.00E+11 | 1.00E+11 | 1.05E+10 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | FA | 3.43E+03 | 3.73E+04 | 8.97E+03 | 1.00E+04 | 6.24E+03 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | HHO | 4.73E+07 | 2.12E+08 | 9.47E+07 | 9.08E+07 | 2.91E+07 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | GWO | 7.43E+06 | 4.25E+09 | 8.35E+08 | 9.71E+08 | 9.44E+08 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| F12 | MFO | 1.09E+07 | 1.49E+10 | 4.39E+09 | 5.83E+09 | 4.30E+09 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | WOA | 3.79E+04 | 2.13E+05 | 9.82E+04 | 9.89E+04 | 3.61E+04 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | CMAES | 7.05E+09 | 1.37E+10 | 1.10E+10 | 1.07E+10 | 1.85E+09 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | AGSK | 6.58E+02 | 6.84E+03 | 1.89E+03 | 2.28E+03 | 1.42E+03 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | HSES | 6.10E+02 | 1.34E+03 | 9.08E+02 | 9.47E+02 | 1.74E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | MadDE | 5.11E+04 | 2.31E+05 | 1.37E+05 | 1.35E+05 | 3.50E+04 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | IMODE | 4.25E+02 | 9.62E+02 | 6.66E+02 | 6.66E+02 | 1.30E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | ALSHADE | 2.91E+02 | 4.01E+03 | 1.27E+03 | 1.60E+03 | 1.02E+03 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | EA4eig | 3.73E+07 | 1.60E+09 | 5.80E+08 | 7.09E+08 | 4.54E+08 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | APGSKIMODE | 1.78E+03 | 3.60E+03 | 2.75E+03 | 2.71E+03 | 4.79E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | DA2MODE | 1.41E+02 | 5.01E+02 | 2.52E+02 | **2.52E+02** | 6.94E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | ABC | 1.10E+07 | 3.79E+07 | 2.71E+07 | 2.56E+07 | 6.77E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | GA | 1.70E+06 | 2.05E+07 | 9.13E+06 | 9.48E+06 | 5.07E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | PSO | 4.23E+06 | 6.26E+07 | 1.78E+07 | 2.58E+07 | 1.76E+07 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | DE | 3.61E+06 | 2.22E+07 | 1.18E+07 | 1.17E+07 | 4.67E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | SA | 4.38E+04 | 1.98E+05 | 7.48E+04 | 8.72E+04 | 3.98E+04 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | TLBO | 1.48E+04 | 3.25E+05 | 6.26E+04 | 1.01E+05 | 9.53E+04 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | BAS | 3.76E+08 | 1.85E+09 | 1.07E+09 | 1.03E+09 | 3.56E+08 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | FA | 4.68E+04 | 1.05E+06 | 2.19E+05 | 2.27E+05 | 1.62E+05 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | HHO | 4.09E+06 | 2.22E+07 | 1.27E+07 | 1.29E+07 | 4.81E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | GWO | 9.05E+05 | 1.28E+07 | 2.31E+06 | 3.29E+06 | 2.65E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| F13 | MFO | 9.13E+04 | 5.38E+07 | 4.46E+06 | 1.09E+07 | 1.48E+07 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | WOA | 5.74E+05 | 4.06E+06 | 1.42E+06 | 1.55E+06 | 7.89E+05 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | CMAES | 4.52E+07 | 2.02E+08 | 8.18E+07 | 9.63E+07 | 3.69E+07 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | AGSK | 5.62E+02 | 4.56E+03 | 1.32E+03 | 1.54E+03 | 8.98E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | HSES | 2.26E+02 | 4.73E+02 | 3.36E+02 | 3.39E+02 | 5.74E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | MadDE | 2.22E+06 | 4.64E+06 | 3.23E+06 | 3.30E+06 | 5.73E+05 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | IMODE | 2.35E+02 | 4.79E+02 | 3.25E+02 | 3.29E+02 | 5.97E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | ALSHADE | 1.98E+02 | 3.38E+02 | 2.50E+02 | 2.57E+02 | 3.77E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | EA4eig | 4.28E+06 | 2.01E+07 | 8.62E+06 | 9.96E+06 | 4.97E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | APGSKIMODE | 1.87E+03 | 4.68E+04 | 1.35E+04 | 1.47E+04 | 9.52E+03 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | DA2MODE | 8.37E+01 | 2.57E+02 | 1.79E+02 | **1.73E+02** | 4.57E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | ABC | 5.87E+02 | 8.59E+03 | 1.10E+03 | 1.90E+03 | 2.03E+03 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | GA | 1.58E+03 | 1.66E+05 | 7.56E+03 | 1.07E+04 | 2.24E+04 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | PSO | 2.10E+09 | 1.17E+10 | 6.06E+09 | 6.07E+09 | 1.83E+09 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | DE | 4.61E+02 | 2.58E+04 | 3.86E+03 | 4.90E+03 | 4.78E+03 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | SA | 4.53E+04 | 2.04E+05 | 9.32E+04 | 1.06E+05 | 4.00E+04 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | TLBO | 5.39E+02 | 1.64E+04 | 1.90E+03 | 3.62E+03 | 4.20E+03 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | BAS | 1.65E+10 | 7.89E+10 | 5.25E+10 | 5.19E+10 | 1.27E+10 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | FA | 4.64E+02 | 1.08E+04 | 2.32E+03 | 3.35E+03 | 3.27E+03 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | HHO | 5.32E+06 | 1.17E+08 | 1.84E+07 | 2.15E+07 | 1.83E+07 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | GWO | 6.46E+05 | 9.47E+08 | 2.71E+07 | 1.64E+08 | 2.60E+08 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| F14 | MFO | 6.21E+04 | 8.70E+09 | 1.34E+09 | 1.89E+09 | 1.87E+09 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | WOA | 2.13E+04 | 8.40E+05 | 5.29E+04 | 1.30E+05 | 2.08E+05 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | CMAES | 2.40E+09 | 6.20E+09 | 5.03E+09 | 4.83E+09 | 1.15E+09 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | AGSK | 2.19E+02 | 1.09E+03 | 5.34E+02 | 5.30E+02 | 1.67E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | HSES | 1.49E+02 | 3.65E+02 | 2.42E+02 | 2.44E+02 | 4.88E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | MadDE | 1.07E+04 | 3.81E+04 | 2.20E+04 | 2.19E+04 | 5.57E+03 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | IMODE | 1.31E+02 | 3.40E+02 | 2.23E+02 | **2.23E+02** | 4.44E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | ALSHADE | 1.60E+02 | 3.30E+02 | 2.36E+02 | 2.37E+02 | 4.27E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | EA4eig | 2.17E+07 | 7.09E+08 | 2.02E+08 | 2.39E+08 | 1.42E+08 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |

(*continued on next page*)

**Table E.11** (*continued*).

| Fun | Alg. | Error | | | | | Function evaluations | | | | | SR (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No. | Name | Best | Worst | Median | Mean | SD | Best | Worst | Median | Mean | SD | |
| | APGSKIMODE | 4.94E+02 | 1.11E+03 | 6.91E+02 | 7.31E+02 | 1.46E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | DA2MODE | 1.60E+02 | 3.96E+02 | 2.81E+02 | 2.76E+02 | 6.34E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | ABC | 7.87E+03 | 9.03E+03 | 8.71E+03 | 8.68E+03 | 2.51E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | GA | 2.68E+03 | 5.67E+03 | 4.24E+03 | 4.26E+03 | 7.72E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | PSO | 1.10E+04 | 1.72E+04 | 1.34E+04 | 1.33E+04 | 1.14E+03 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | DE | 7.23E+03 | 8.36E+03 | 7.83E+03 | 7.79E+03 | 2.69E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | SA | 4.64E+02 | 2.16E+03 | 1.19E+03 | 1.19E+03 | 4.12E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | TLBO | 2.67E+03 | 5.06E+03 | 3.73E+03 | 3.77E+03 | 5.52E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | BAS | 2.57E+04 | 5.66E+04 | 4.41E+04 | 4.36E+04 | 6.61E+03 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | FA | 2.45E+03 | 5.27E+03 | 4.06E+03 | 3.79E+03 | 6.88E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | HHO | 7.72E+03 | 1.15E+04 | 9.18E+03 | 9.79E+03 | 1.18E+03 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | GWO | 3.22E+03 | 5.41E+03 | 4.16E+03 | 4.14E+03 | 6.20E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| F15 | MFO | 4.71E+03 | 9.20E+03 | 6.75E+03 | 6.71E+03 | 8.98E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | WOA | 5.67E+03 | 1.07E+04 | 7.36E+03 | 7.95E+03 | 1.31E+03 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | CMAES | 1.09E+04 | 1.27E+04 | 1.18E+04 | 1.16E+04 | 5.12E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | AGSK | 3.88E+03 | 4.84E+03 | 4.36E+03 | 4.34E+03 | 2.14E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | HSES | 2.07E+02 | 2.02E+03 | 1.07E+03 | **1.09E+03** | 4.10E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | MadDE | 4.86E+03 | 6.24E+03 | 5.66E+03 | 5.64E+03 | 3.27E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | IMODE | 3.19E+03 | 6.20E+03 | 4.18E+03 | 4.29E+03 | 5.15E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | ALSHADE | 7.82E+02 | 2.40E+03 | 1.61E+03 | 1.58E+03 | 3.65E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | EA4eig | 6.65E+03 | 9.02E+03 | 8.17E+03 | 8.06E+03 | 6.35E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | APGSKIMODE | 2.74E+03 | 5.62E+03 | 4.57E+03 | 4.45E+03 | 5.94E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | DA2MODE | 6.61E+02 | 2.10E+03 | 1.45E+03 | 1.42E+03 | 4.00E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | ABC | 4.73E+03 | 5.86E+03 | 5.59E+03 | 5.53E+03 | 2.27E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | GA | 2.28E+03 | 4.74E+03 | 3.81E+03 | 3.81E+03 | 5.61E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | PSO | 2.58E+04 | 9.11E+05 | 1.55E+05 | 2.64E+05 | 2.53E+05 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | DE | 4.41E+03 | 5.31E+03 | 4.94E+03 | 4.96E+03 | 1.81E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | SA | 5.47E+02 | 1.53E+03 | 1.01E+03 | 9.82E+02 | 1.63E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | TLBO | 2.41E+03 | 5.02E+03 | 3.48E+03 | 3.50E+03 | 6.06E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | BAS | 6.62E+06 | 3.32E+08 | 1.58E+08 | 1.55E+08 | 9.01E+07 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | FA | 1.62E+03 | 4.08E+03 | 3.01E+03 | 3.01E+03 | 6.01E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | HHO | 4.71E+03 | 1.11E+04 | 6.74E+03 | 7.28E+03 | 1.67E+03 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | GWO | 2.04E+03 | 5.61E+03 | 3.03E+03 | 3.22E+03 | 7.79E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| F16 | MFO | 4.56E+03 | 4.94E+04 | 6.83E+03 | 9.69E+03 | 8.00E+03 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | WOA | 3.95E+03 | 7.48E+03 | 5.53E+03 | 5.61E+03 | 7.14E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | CMAES | 1.80E+04 | 9.78E+04 | 2.66E+04 | 4.77E+04 | 3.23E+04 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | AGSK | 2.36E+03 | 2.98E+03 | 2.69E+03 | 2.71E+03 | 1.23E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | HSES | 3.04E+02 | 1.84E+03 | 8.44E+02 | **9.15E+02** | 4.21E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | MadDE | 2.79E+03 | 3.86E+03 | 3.53E+03 | 3.49E+03 | 2.30E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | IMODE | 2.49E+03 | 5.41E+03 | 3.92E+03 | 3.81E+03 | 6.38E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | ALSHADE | 6.79E+02 | 1.62E+03 | 1.30E+03 | 1.24E+03 | 2.31E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | EA4eig | 4.99E+03 | 6.77E+03 | 5.90E+03 | 5.96E+03 | 3.68E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | APGSKIMODE | 1.58E+03 | 3.53E+03 | 2.92E+03 | 2.86E+03 | 4.15E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | DA2MODE | 6.70E+02 | 2.09E+03 | 1.29E+03 | 1.24E+03 | 2.82E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | ABC | 3.06E+07 | 5.84E+07 | 4.67E+07 | 4.67E+07 | 8.82E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | GA | 2.72E+06 | 1.57E+07 | 8.12E+06 | 8.21E+06 | 3.81E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | PSO | 9.38E+06 | 1.25E+08 | 3.30E+07 | 4.26E+07 | 2.61E+07 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | DE | 1.70E+07 | 3.44E+07 | 2.59E+07 | 2.67E+07 | 5.15E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | SA | 1.56E+05 | 5.23E+05 | 2.73E+05 | 2.64E+05 | 7.54E+04 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | TLBO | 1.29E+05 | 6.94E+05 | 3.07E+05 | 3.04E+05 | 1.33E+05 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | BAS | 6.25E+08 | 3.18E+09 | 2.01E+09 | 1.89E+09 | 7.29E+08 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | FA | 1.33E+05 | 1.40E+06 | 4.25E+05 | 5.78E+05 | 3.94E+05 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | HHO | 2.61E+06 | 2.58E+07 | 8.80E+06 | 1.10E+07 | 4.97E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | GWO | 7.71E+05 | 8.44E+06 | 2.38E+06 | 3.23E+06 | 1.98E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| F17 | MFO | 2.74E+05 | 8.57E+07 | 3.20E+06 | 1.04E+07 | 1.82E+07 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | WOA | 4.80E+05 | 4.65E+06 | 1.51E+06 | 1.93E+06 | 1.04E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | CMAES | 3.01E+07 | 2.38E+08 | 1.27E+08 | 1.41E+08 | 3.53E+07 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | AGSK | 4.68E+04 | 1.51E+05 | 1.04E+05 | 1.03E+05 | 2.94E+04 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | HSES | 1.07E+02 | 3.67E+02 | 2.04E+02 | **2.09E+02** | 5.43E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | MadDE | 1.64E+06 | 4.20E+06 | 2.98E+06 | 2.91E+06 | 5.42E+05 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | IMODE | 1.68E+02 | 3.46E+02 | 2.33E+02 | 2.34E+02 | 4.55E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | ALSHADE | 1.14E+02 | 4.07E+02 | 2.17E+02 | 2.23E+02 | 5.81E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | EA4eig | 3.69E+06 | 2.48E+07 | 1.08E+07 | 1.08E+07 | 4.42E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | APGSKIMODE | 9.63E+04 | 2.44E+05 | 1.42E+05 | 1.46E+05 | 3.18E+04 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | DA2MODE | 1.55E+02 | 7.30E+02 | 2.76E+02 | 2.93E+02 | 1.05E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | ABC | 2.50E+02 | 1.22E+04 | 1.18E+03 | 1.80E+03 | 2.39E+03 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | GA | 2.39E+03 | 2.40E+04 | 8.43E+03 | 9.64E+03 | 5.85E+03 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | PSO | 1.76E+09 | 8.94E+09 | 4.28E+09 | 4.93E+09 | 2.36E+09 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | DE | 1.85E+02 | 1.43E+04 | 4.58E+03 | 6.22E+03 | 5.30E+03 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | SA | 4.74E+05 | 9.74E+05 | 7.56E+05 | 7.30E+05 | 1.13E+05 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | TLBO | 3.83E+02 | 6.71E+03 | 1.20E+03 | 2.20E+03 | 2.22E+03 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | BAS | 3.45E+10 | 7.06E+10 | 5.51E+10 | 5.40E+10 | 1.11E+10 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | FA | 3.07E+02 | 2.29E+04 | 6.33E+02 | 1.92E+03 | 3.50E+03 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | HHO | 1.38E+07 | 6.10E+07 | 3.26E+07 | 3.35E+07 | 1.28E+07 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | GWO | 1.93E+06 | 7.40E+08 | 5.37E+07 | 1.13E+08 | 1.77E+08 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| F18 | MFO | 1.73E+06 | 5.94E+09 | 1.24E+09 | 1.82E+09 | 1.70E+09 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | WOA | 3.19E+06 | 3.01E+07 | 1.27E+07 | 1.50E+07 | 6.85E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | CMAES | 2.94E+09 | 6.40E+09 | 5.71E+09 | 5.49E+09 | 8.26E+08 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | AGSK | 1.14E+02 | 7.38E+02 | 2.45E+02 | 2.99E+02 | 1.45E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | HSES | 6.48E+01 | 1.52E+02 | 9.97E+01 | **9.98E+01** | 1.94E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | MadDE | 1.14E+04 | 5.83E+04 | 2.45E+04 | 2.72E+04 | 9.68E+03 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | IMODE | 2.24E+02 | 1.33E+03 | 4.70E+02 | 6.19E+02 | 3.27E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | ALSHADE | 1.28E+02 | 2.14E+02 | 1.69E+02 | 1.71E+02 | 2.04E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | EA4eig | 5.91E+07 | 7.16E+08 | 2.79E+08 | 3.48E+08 | 1.76E+08 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | APGSKIMODE | 4.50E+02 | 1.28E+03 | 8.31E+02 | 8.54E+02 | 2.09E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | DA2MODE | 1.25E+02 | 2.95E+02 | 1.86E+02 | 1.87E+02 | 3.12E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | ABC | 4.85E+03 | 5.43E+03 | 5.21E+03 | 5.17E+03 | 1.49E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | GA | 1.84E+03 | 4.60E+03 | 3.37E+03 | 3.35E+03 | 6.09E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | PSO | 2.71E+03 | 5.00E+03 | 4.08E+03 | 3.96E+03 | 5.93E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | DE | 4.22E+03 | 5.08E+03 | 4.77E+03 | 4.78E+03 | 1.74E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | SA | 4.50E+02 | 1.21E+03 | 8.10E+02 | 8.27E+02 | 1.78E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | TLBO | 1.12E+03 | 3.74E+03 | 2.14E+03 | 2.19E+03 | 6.98E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | BAS | 6.69E+03 | 8.32E+03 | 7.80E+03 | 7.72E+03 | 3.60E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | FA | 1.95E+03 | 3.94E+03 | 2.50E+03 | 2.49E+03 | 4.10E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | HHO | 3.13E+03 | 5.42E+03 | 4.31E+03 | 4.38E+03 | 5.20E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | GWO | 1.25E+03 | 4.97E+03 | 2.30E+03 | 2.35E+03 | 6.42E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| F19 | MFO | 2.95E+03 | 5.62E+03 | 3.77E+03 | 3.90E+03 | 4.58E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | WOA | 3.07E+03 | 5.56E+03 | 4.38E+03 | 4.31E+03 | 5.76E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | CMAES | 3.66E+03 | 5.66E+03 | 4.98E+03 | 4.80E+03 | 6.36E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | AGSK | 2.18E+03 | 2.90E+03 | 2.66E+03 | 2.65E+03 | 1.32E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | HSES | 3.44E+02 | 1.72E+03 | 7.12E+02 | **8.25E+02** | 3.33E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | MadDE | 2.65E+03 | 3.41E+03 | 3.16E+03 | 3.13E+03 | 1.63E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | IMODE | 1.88E+03 | 3.78E+03 | 2.66E+03 | 2.69E+03 | 3.85E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | ALSHADE | 1.13E+03 | 2.11E+03 | 1.64E+03 | 1.65E+03 | 2.41E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | EA4eig | 4.14E+03 | 5.31E+03 | 4.82E+03 | 4.79E+03 | 3.09E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | APGSKIMODE | 2.09E+03 | 3.65E+03 | 3.22E+03 | 3.12E+03 | 3.61E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | DA2MODE | 1.02E+03 | 1.69E+03 | 1.32E+03 | 1.33E+03 | 1.46E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |

(*continued on next page*)

**Table E.11** (*continued*).

| Fun | Alg. | Error | | | | | Function evaluations | | | | | SR (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No. | Name | Best | Worst | Median | Mean | SD | Best | Worst | Median | Mean | SD | |
| | ABC | 1.32E+03 | 1.40E+03 | 1.38E+03 | 1.37E+03 | 2.26E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | GA | 6.06E+02 | 1.02E+03 | 7.47E+02 | 7.63E+02 | 1.02E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | PSO | 2.21E+03 | 2.88E+03 | 2.44E+03 | 2.47E+03 | 1.65E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | DE | 1.03E+03 | 1.15E+03 | 1.11E+03 | 1.11E+03 | 2.36E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | SA | 3.81E+02 | 4.80E+02 | 4.25E+02 | 4.27E+02 | 2.27E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | TLBO | 9.08E+02 | 1.26E+03 | 1.01E+03 | 1.05E+03 | 9.76E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | BAS | 2.96E+03 | 4.05E+03 | 3.48E+03 | 3.52E+03 | 2.61E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | FA | 5.75E+02 | 8.97E+02 | 7.33E+02 | 7.28E+02 | 9.24E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | HHO | 1.85E+03 | 2.80E+03 | 2.20E+03 | 2.24E+03 | 1.96E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | GWO | 6.84E+02 | 9.62E+02 | 8.67E+02 | 8.75E+02 | 6.83E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| F20 | MFO | 1.34E+03 | 1.87E+03 | 1.63E+03 | 1.63E+03 | 1.35E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | WOA | 1.27E+03 | 2.11E+03 | 1.79E+03 | 1.74E+03 | 1.87E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | CMAES | 3.24E+02 | 1.68E+03 | 1.53E+03 | 1.35E+03 | 4.42E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | AGSK | 8.03E+02 | 8.97E+02 | 8.56E+02 | 8.56E+02 | 1.93E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | HSES | 2.70E+02 | 3.72E+02 | 3.11E+02 | 3.10E+02 | 1.94E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | MadDE | 9.78E+02 | 1.14E+03 | 1.07E+03 | 1.07E+03 | 3.12E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | IMODE | 1.12E+03 | 1.61E+03 | 1.41E+03 | 1.40E+03 | 1.03E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | ALSHADE | 2.41E+02 | 2.62E+02 | 2.53E+02 | **2.53E+02** | 4.86E+00 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | EA4eig | 1.13E+03 | 1.32E+03 | 1.20E+03 | 1.22E+03 | 5.56E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | APGSKIMODE | 7.35E+02 | 9.09E+02 | 8.55E+02 | 8.49E+02 | 3.81E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | DA2MODE | 2.64E+02 | 2.99E+02 | 2.87E+02 | 2.86E+02 | 8.18E+00 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | ABC | 2.99E+04 | 3.18E+04 | 3.13E+04 | 3.12E+04 | 3.75E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | GA | 1.15E+04 | 1.58E+04 | 1.32E+04 | 1.34E+04 | 1.12E+03 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | PSO | 2.18E+04 | 2.81E+04 | 2.43E+04 | 2.42E+04 | 1.03E+03 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | DE | 2.86E+04 | 3.13E+04 | 3.03E+04 | 3.03E+04 | 6.82E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | SA | 5.36E+03 | 9.25E+03 | 7.11E+03 | 7.18E+03 | 9.94E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | TLBO | 1.24E+04 | 3.11E+04 | 2.67E+04 | 2.47E+04 | 5.61E+03 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | BAS | 3.49E+04 | 3.85E+04 | 3.68E+04 | 3.67E+04 | 9.27E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | FA | 1.07E+04 | 1.66E+04 | 1.41E+04 | 1.36E+04 | 1.61E+03 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | HHO | 2.44E+04 | 2.94E+04 | 2.68E+04 | 2.69E+04 | 1.40E+03 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | GWO | 1.23E+04 | 3.14E+04 | 1.59E+04 | 1.76E+04 | 5.72E+03 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| F21 | MFO | 1.46E+04 | 2.04E+04 | 1.78E+04 | 1.78E+04 | 1.60E+03 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | WOA | 1.77E+04 | 2.62E+04 | 2.17E+04 | 2.22E+04 | 2.34E+03 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | CMAES | 2.79E+04 | 2.91E+04 | 2.86E+04 | 2.85E+04 | 3.84E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | AGSK | 2.38E+04 | 2.66E+04 | 2.55E+04 | 2.53E+04 | 7.00E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | HSES | 1.00E+02 | 1.14E+04 | 6.04E+03 | 4.39E+03 | 4.33E+03 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | MadDE | 1.15E+04 | 2.23E+04 | 2.12E+04 | 1.97E+04 | 3.12E+03 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | IMODE | 1.19E+04 | 1.62E+04 | 1.36E+04 | 1.37E+04 | 9.78E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | ALSHADE | 1.10E+04 | 1.39E+04 | 1.24E+04 | 1.24E+04 | 6.02E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | EA4eig | 2.90E+04 | 3.20E+04 | 3.07E+04 | 3.07E+04 | 6.48E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | APGSKIMODE | 8.84E+02 | 2.27E+04 | 2.14E+04 | 2.01E+04 | 5.11E+03 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | DA2MODE | 1.00E+02 | 1.03E+02 | 1.00E+02 | **1.00E+02** | 3.51E−01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | ABC | 1.53E+03 | 1.61E+03 | 1.57E+03 | 1.57E+03 | 2.41E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | GA | 7.20E+02 | 1.04E+03 | 8.90E+02 | 9.02E+02 | 6.74E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | PSO | 3.99E+03 | 5.76E+03 | 4.89E+03 | 4.94E+03 | 4.51E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | DE | 1.25E+03 | 1.37E+03 | 1.31E+03 | 1.31E+03 | 2.67E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | SA | 6.61E+02 | 7.81E+02 | 7.12E+02 | 7.11E+02 | 2.66E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | TLBO | 1.29E+03 | 1.75E+03 | 1.50E+03 | 1.49E+03 | 1.34E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | BAS | 4.84E+03 | 7.70E+03 | 6.44E+03 | 6.33E+03 | 7.37E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | FA | 8.75E+02 | 1.16E+03 | 1.06E+03 | 1.03E+03 | 6.16E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | HHO | 2.63E+03 | 3.90E+03 | 3.12E+03 | 3.18E+03 | 3.04E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | GWO | 1.12E+03 | 1.29E+03 | 1.21E+03 | 1.20E+03 | 6.13E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| F22 | MFO | 1.32E+03 | 1.78E+03 | 1.56E+03 | 1.56E+03 | 1.16E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | WOA | 2.02E+03 | 2.94E+03 | 2.42E+03 | 2.44E+03 | 1.95E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | CMAES | 1.71E+03 | 1.98E+03 | 1.88E+03 | 1.88E+03 | 4.22E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | AGSK | 1.04E+03 | 1.12E+03 | 1.09E+03 | 1.08E+03 | 1.88E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | HSES | 6.42E+02 | 7.93E+02 | 7.09E+02 | 7.07E+02 | 3.43E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | MadDE | 1.30E+03 | 1.47E+03 | 1.38E+03 | 1.38E+03 | 3.74E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | IMODE | 1.84E+03 | 2.44E+03 | 2.17E+03 | 2.17E+03 | 1.39E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | ALSHADE | 5.55E+02 | 5.93E+02 | 5.72E+02 | **5.72E+02** | 8.61E+00 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | EA4eig | 1.62E+03 | 2.17E+03 | 1.83E+03 | 1.85E+03 | 1.11E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | APGSKIMODE | 8.21E+02 | 1.07E+03 | 1.04E+03 | 1.02E+03 | 5.36E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | DA2MODE | 5.85E+02 | 6.43E+02 | 6.16E+02 | 6.15E+02 | 1.38E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | ABC | 1.86E+03 | 1.98E+03 | 1.92E+03 | 1.93E+03 | 2.42E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | GA | 1.30E+03 | 1.64E+03 | 1.47E+03 | 1.47E+03 | 8.74E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | PSO | 6.24E+03 | 1.09E+04 | 8.17E+03 | 8.47E+03 | 8.97E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | DE | 1.67E+03 | 1.75E+03 | 1.71E+03 | 1.71E+03 | 1.88E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | SA | 9.57E+02 | 1.12E+03 | 1.04E+03 | 1.05E+03 | 3.53E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | TLBO | 1.94E+03 | 2.87E+03 | 2.34E+03 | 2.36E+03 | 2.13E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | BAS | 1.04E+04 | 1.50E+04 | 1.25E+04 | 1.25E+04 | 1.10E+03 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | FA | 1.24E+03 | 1.48E+03 | 1.38E+03 | 1.36E+03 | 6.82E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | HHO | 3.51E+03 | 7.32E+03 | 5.06E+03 | 5.15E+03 | 7.73E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | GWO | 1.55E+03 | 1.97E+03 | 1.74E+03 | 1.76E+03 | 1.23E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| F23 | MFO | 1.85E+03 | 2.40E+03 | 2.04E+03 | 2.09E+03 | 1.44E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | WOA | 2.59E+03 | 4.46E+03 | 3.36E+03 | 3.41E+03 | 4.57E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | CMAES | 2.26E+03 | 2.71E+03 | 2.45E+03 | 2.49E+03 | 1.30E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | AGSK | 1.36E+03 | 1.45E+03 | 1.42E+03 | 1.42E+03 | 2.07E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | HSES | 8.67E+02 | 1.10E+03 | 9.57E+02 | 9.59E+02 | 4.39E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | MadDE | 1.71E+03 | 1.89E+03 | 1.84E+03 | 1.83E+03 | 4.13E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | IMODE | 1.86E+03 | 3.18E+03 | 2.54E+03 | 2.52E+03 | 3.68E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | ALSHADE | 9.06E+02 | 9.45E+02 | 9.25E+02 | **9.25E+02** | 9.09E+00 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | EA4eig | 2.03E+03 | 2.90E+03 | 2.24E+03 | 2.31E+03 | 2.30E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | APGSKIMODE | 1.27E+03 | 1.52E+03 | 1.47E+03 | 1.45E+03 | 6.20E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | DA2MODE | 9.30E+02 | 9.85E+02 | 9.56E+02 | 9.58E+02 | 1.06E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | ABC | 3.77E+03 | 5.21E+03 | 4.76E+03 | 4.64E+03 | 4.00E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | GA | 7.89E+02 | 1.08E+03 | 9.10E+02 | 9.29E+02 | 7.92E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | PSO | 1.16E+04 | 1.75E+04 | 1.53E+04 | 1.47E+04 | 1.99E+03 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | DE | 6.38E+02 | 7.97E+02 | 7.62E+02 | 7.41E+02 | 4.27E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | SA | 5.77E+02 | 7.62E+02 | 6.45E+02 | **6.63E+02** | 4.82E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | TLBO | 7.01E+02 | 1.02E+03 | 8.77E+02 | 8.77E+02 | 8.73E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | BAS | 1.02E+05 | 1.81E+05 | 1.54E+05 | 1.47E+05 | 1.85E+04 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | FA | 6.29E+02 | 9.19E+02 | 7.82E+02 | 7.85E+02 | 9.05E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | HHO | 2.57E+03 | 3.47E+03 | 3.00E+03 | 3.00E+03 | 2.68E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | GWO | 2.38E+03 | 5.22E+03 | 3.81E+03 | 3.83E+03 | 7.40E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| F24 | MFO | 1.83E+03 | 2.47E+04 | 8.64E+03 | 8.50E+03 | 5.17E+03 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | WOA | 9.09E+02 | 1.29E+03 | 1.11E+03 | 1.12E+03 | 8.60E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | CMAES | 2.10E+03 | 1.31E+04 | 3.02E+03 | 4.85E+03 | 3.36E+03 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | AGSK | 6.41E+02 | 8.01E+02 | 7.07E+02 | 7.17E+02 | 4.31E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | HSES | 6.98E+02 | 8.22E+02 | 7.62E+02 | 7.60E+02 | 3.70E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | MadDE | 1.91E+03 | 2.16E+03 | 2.02E+03 | 2.02E+03 | 5.27E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | IMODE | 6.38E+02 | 8.01E+02 | 7.03E+02 | 7.14E+02 | 4.54E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | ALSHADE | 6.98E+02 | 7.78E+02 | 7.62E+02 | 7.45E+02 | 2.95E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | EA4eig | 2.19E+03 | 3.71E+03 | 2.82E+03 | 2.78E+03 | 4.03E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | APGSKIMODE | 8.05E+02 | 9.38E+02 | 8.81E+02 | 8.80E+02 | 2.72E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | DA2MODE | 6.12E+02 | 8.26E+02 | 7.12E+02 | 7.14E+02 | 4.18E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |

(*continued on next page*)

**Table E.11** (*continued*).

| Fun | Alg. | Error | | | | | Function evaluations | | | | | SR (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No. | Name | Best | Worst | Median | Mean | SD | Best | Worst | Median | Mean | SD | |
| | ABC | 1.38E+04 | 1.47E+04 | 1.44E+04 | 1.44E+04 | 2.47E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | GA | 8.64E+03 | 1.23E+04 | 9.71E+03 | 1.00E+04 | 8.77E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | PSO | 3.47E+04 | 4.81E+04 | 4.03E+04 | 4.09E+04 | 2.81E+03 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | DE | 1.14E+04 | 1.24E+04 | 1.19E+04 | 1.19E+04 | 2.56E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | SA | 4.35E+03 | 5.62E+03 | 4.96E+03 | 4.95E+03 | 3.09E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | TLBO | 1.72E+04 | 2.61E+04 | 2.39E+04 | 2.32E+04 | 2.31E+03 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | BAS | 7.73E+04 | 1.18E+05 | 9.99E+04 | 9.87E+04 | 1.17E+04 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | FA | 6.69E+03 | 1.08E+04 | 8.82E+03 | 8.76E+03 | 7.63E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | HHO | 2.49E+04 | 3.62E+04 | 3.01E+04 | 2.98E+04 | 2.09E+03 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | GWO | 9.21E+03 | 1.39E+04 | 1.20E+04 | 1.19E+04 | 9.81E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| F25 | MFO | 1.39E+04 | 2.17E+04 | 1.69E+04 | 1.69E+04 | 1.43E+03 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | WOA | 2.11E+04 | 3.30E+04 | 2.84E+04 | 2.85E+04 | 2.85E+03 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | CMAES | 1.80E+04 | 2.13E+04 | 1.98E+04 | 1.98E+04 | 9.09E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | AGSK | 8.50E+03 | 9.37E+03 | 8.85E+03 | 8.87E+03 | 1.67E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | HSES | 3.07E+03 | 4.13E+03 | 3.63E+03 | 3.58E+03 | 2.27E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | MadDE | 1.65E+04 | 2.01E+04 | 1.91E+04 | 1.91E+04 | 6.39E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | IMODE | 3.00E+02 | 1.61E+04 | 1.33E+04 | 1.17E+04 | 4.47E+03 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | ALSHADE | 3.23E+03 | 3.74E+03 | 3.45E+03 | 3.46E+03 | 1.19E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | EA4eig | 1.42E+04 | 1.84E+04 | 1.55E+04 | 1.57E+04 | 1.00E+03 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | APGSKIMODE | 7.35E+03 | 9.48E+03 | 9.08E+03 | 8.92E+03 | 4.89E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | DA2MODE | 3.00E+02 | 4.49E+03 | 4.07E+03 | **3.16E+03** | 1.69E+03 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | ABC | 1.02E+03 | 1.25E+03 | 1.12E+03 | 1.14E+03 | 6.67E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | GA | 8.70E+02 | 1.13E+03 | 9.77E+02 | 9.75E+02 | 7.02E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | PSO | 6.13E+03 | 1.18E+04 | 9.44E+03 | 9.27E+03 | 1.50E+03 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | DE | 5.96E+02 | 7.02E+02 | 6.27E+02 | 6.34E+02 | 2.20E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | SA | 5.31E+02 | 5.84E+02 | 5.53E+02 | 5.57E+02 | 1.44E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | TLBO | 1.23E+03 | 2.21E+03 | 1.80E+03 | 1.76E+03 | 2.38E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | BAS | 1.15E+04 | 2.02E+04 | 1.58E+04 | 1.58E+04 | 1.81E+03 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | FA | 7.12E+02 | 9.34E+02 | 8.27E+02 | 8.34E+02 | 5.91E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | HHO | 2.33E+03 | 5.68E+03 | 4.08E+03 | 3.92E+03 | 7.41E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | GWO | 9.98E+02 | 1.56E+03 | 1.28E+03 | 1.27E+03 | 1.71E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| F26 | MFO | 9.89E+02 | 1.84E+03 | 1.36E+03 | 1.34E+03 | 2.17E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | WOA | 1.46E+03 | 3.99E+03 | 2.07E+03 | 2.29E+03 | 6.16E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | CMAES | 1.45E+03 | 1.89E+03 | 1.71E+03 | 1.69E+03 | 9.13E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | AGSK | 6.02E+02 | 7.04E+02 | 6.48E+02 | 6.48E+02 | 2.39E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | HSES | 6.57E+02 | 7.64E+02 | 7.10E+02 | 7.12E+02 | 2.42E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | MadDE | 1.33E+03 | 1.50E+03 | 1.42E+03 | 1.42E+03 | 3.75E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | IMODE | 1.19E+03 | 2.02E+03 | 1.50E+03 | 1.57E+03 | 2.16E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | ALSHADE | 6.11E+02 | 6.93E+02 | 6.36E+02 | 6.42E+02 | 1.87E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | EA4eig | 1.63E+03 | 2.96E+03 | 2.41E+03 | 2.30E+03 | 3.84E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | APGSKIMODE | 5.82E+02 | 6.91E+02 | 6.38E+02 | 6.39E+02 | 2.27E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | DA2MODE | 5.00E+02 | 5.00E+02 | 5.00E+02 | **5.00E+02** | 1.19E−04 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | ABC | 1.82E+03 | 2.87E+03 | 2.21E+03 | 2.21E+03 | 2.30E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | GA | 6.45E+02 | 8.10E+02 | 7.49E+02 | 7.39E+02 | 3.43E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | PSO | 1.69E+04 | 2.47E+04 | 2.14E+04 | 2.14E+04 | 2.18E+03 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | DE | 5.20E+02 | 1.43E+03 | 5.22E+02 | 5.52E+02 | 1.27E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | SA | 4.78E+02 | 5.78E+02 | 5.09E+02 | 5.16E+02 | 2.75E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | TLBO | 5.65E+02 | 7.15E+02 | 6.31E+02 | 6.31E+02 | 3.39E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | BAS | 5.71E+04 | 9.19E+04 | 7.24E+04 | 7.42E+04 | 9.37E+03 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | FA | 5.15E+02 | 6.77E+02 | 5.94E+02 | 5.93E+02 | 3.59E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | HHO | 3.53E+03 | 6.05E+03 | 5.01E+03 | 4.89E+03 | 6.78E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | GWO | 3.67E+03 | 7.60E+03 | 5.69E+03 | 5.60E+03 | 1.21E+03 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| F27 | MFO | 1.23E+04 | 2.42E+04 | 1.76E+04 | 1.79E+04 | 2.74E+03 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | WOA | 7.90E+02 | 1.09E+03 | 8.93E+02 | 9.03E+02 | 6.33E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | CMAES | 1.55E+04 | 1.76E+04 | 1.59E+04 | 1.61E+04 | 4.90E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | AGSK | 4.79E+02 | 5.79E+02 | 5.36E+02 | 5.36E+02 | 2.25E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | HSES | 3.00E+02 | 5.90E+02 | 5.35E+02 | 5.18E+02 | 8.01E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | MadDE | 2.78E+03 | 3.43E+03 | 3.08E+03 | 3.07E+03 | 1.24E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | IMODE | 3.00E+02 | 5.93E+02 | 5.19E+02 | **4.44E+02** | 1.12E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | ALSHADE | 4.78E+02 | 6.27E+02 | 5.22E+02 | 5.26E+02 | 2.32E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | EA4eig | 2.87E+03 | 7.42E+03 | 5.00E+03 | 4.72E+03 | 1.26E+03 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | APGSKIMODE | 6.17E+02 | 7.15E+02 | 6.49E+02 | 6.56E+02 | 2.38E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | DA2MODE | 4.87E+02 | 5.19E+02 | 4.95E+02 | 4.96E+02 | 1.00E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | ABC | 5.97E+03 | 7.08E+03 | 6.71E+03 | 6.67E+03 | 2.93E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | GA | 2.43E+03 | 4.78E+03 | 3.74E+03 | 3.73E+03 | 5.87E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | PSO | 1.25E+04 | 1.16E+05 | 2.72E+04 | 3.86E+04 | 2.86E+04 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | DE | 4.57E+03 | 5.84E+03 | 5.29E+03 | 5.31E+03 | 3.24E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | SA | 9.31E+02 | 2.09E+03 | 1.51E+03 | 1.51E+03 | 3.04E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | TLBO | 3.79E+03 | 6.58E+03 | 4.75E+03 | 4.76E+03 | 6.21E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | BAS | 5.35E+05 | 1.12E+08 | 2.73E+07 | 3.04E+07 | 2.61E+07 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | FA | 2.35E+03 | 5.07E+03 | 3.67E+03 | 3.67E+03 | 5.73E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | HHO | 7.69E+03 | 1.45E+04 | 1.07E+04 | 1.09E+04 | 1.48E+03 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | GWO | 3.69E+03 | 6.61E+03 | 5.10E+03 | 5.12E+03 | 6.52E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| F28 | MFO | 5.00E+03 | 1.45E+05 | 7.96E+03 | 1.47E+04 | 2.79E+04 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | WOA | 9.13E+03 | 1.62E+04 | 1.06E+04 | 1.10E+04 | 1.40E+03 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | CMAES | 2.02E+03 | 3.94E+04 | 1.67E+04 | 1.62E+04 | 1.43E+04 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | AGSK | 2.96E+03 | 3.58E+03 | 3.33E+03 | 3.30E+03 | 1.42E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | HSES | 1.07E+03 | 2.21E+03 | 1.51E+03 | 1.56E+03 | 2.60E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | MadDE | 5.06E+03 | 6.05E+03 | 5.66E+03 | 5.65E+03 | 2.34E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | IMODE | 3.56E+03 | 6.62E+03 | 4.71E+03 | 4.69E+03 | 6.26E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | ALSHADE | 9.24E+02 | 1.87E+03 | 1.39E+03 | 1.39E+03 | 2.38E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | EA4eig | 7.36E+03 | 8.83E+03 | 8.01E+03 | 7.95E+03 | 4.52E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | APGSKIMODE | 2.53E+03 | 4.23E+03 | 3.57E+03 | 3.51E+03 | 3.95E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | DA2MODE | 7.67E+02 | 1.61E+03 | 1.15E+03 | **1.16E+03** | 2.05E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | ABC | 1.53E+05 | 5.78E+05 | 3.25E+05 | 3.16E+05 | 9.94E+04 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | GA | 5.98E+04 | 4.00E+05 | 1.90E+05 | 1.96E+05 | 8.64E+04 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | PSO | 9.86E+09 | 2.33E+10 | 1.74E+10 | 1.68E+10 | 3.55E+09 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | DE | 2.63E+03 | 1.59E+04 | 3.89E+03 | 6.45E+03 | 4.54E+03 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | SA | 1.25E+06 | 5.39E+06 | 3.18E+06 | 3.18E+06 | 1.17E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | TLBO | 4.53E+03 | 3.74E+05 | 2.10E+04 | 5.59E+04 | 1.05E+05 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | BAS | 5.69E+10 | 1.03E+11 | 9.54E+10 | 8.50E+10 | 1.60E+10 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | FA | 3.16E+03 | 1.88E+04 | 7.47E+03 | 9.51E+03 | 5.36E+03 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | HHO | 1.31E+08 | 7.46E+08 | 3.34E+08 | 3.62E+08 | 1.67E+08 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | GWO | 4.66E+07 | 3.67E+09 | 3.68E+08 | 6.33E+08 | 6.56E+08 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| F29 | MFO | 2.05E+08 | 5.71E+09 | 2.04E+09 | 2.60E+09 | 1.63E+09 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | WOA | 7.22E+07 | 4.80E+08 | 1.78E+08 | 1.92E+08 | 8.50E+07 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | CMAES | 9.59E+09 | 1.27E+10 | 1.11E+10 | 1.10E+10 | 1.02E+09 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | AGSK | 2.40E+03 | 5.29E+03 | 2.93E+03 | 3.09E+03 | 6.24E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | HSES | 4.43E+03 | 6.55E+03 | 5.68E+03 | 5.67E+03 | 4.93E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | MadDE | 5.93E+06 | 1.78E+07 | 1.08E+07 | 1.08E+07 | 2.40E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | IMODE | 6.19E+03 | 4.39E+05 | 8.69E+03 | 2.01E+04 | 6.01E+04 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | ALSHADE | 2.16E+03 | 2.79E+03 | 2.42E+03 | 2.43E+03 | 1.50E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | EA4eig | 1.13E+08 | 1.96E+09 | 8.61E+08 | 9.37E+08 | 4.49E+08 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | APGSKIMODE | 7.10E+03 | 1.95E+04 | 1.05E+04 | 1.08E+04 | 2.44E+03 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | DA2MODE | 3.65E+02 | 9.81E+02 | 5.65E+02 | **5.99E+02** | 1.38E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |

**Table E.12**
The results metrics for the error and function evaluation metrics for 14 DE variants, CEC2017–2018 (F1-F5, 30 Dim).

| Fun | Alg. | Error | | | | | Function evaluations | | | | | SR (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No. | Name | Best | Worst | Median | Mean | SD | Best | Worst | Median | Mean | SD | |
| F1 | MDE | 0.00E+00 | 4.98E+03 | 1.33E−03 | 2.68E+02 | 1.01E+03 | 2.70E+05 | 3.00E+05 | 3.00E+05 | 2.98E+05 | 7.17E+03 | 15.69 |
| | WDE | 2.11E+04 | 5.56E+04 | 3.55E+04 | 3.61E+04 | 1.04E+04 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | EODE | 3.18E−06 | 4.17E−02 | 7.05E−04 | 1.08E−02 | 1.62E−02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | MTDE | 0.00E+00 | 0.00E+00 | 0.00E+00 | **0.00E+00** | 0.00E+00 | 1.72E+05 | 2.26E+05 | 1.89E+05 | 1.93E+05 | 1.99E+04 | 100.00 |
| | mDEW | 0.00E+00 | 1.03E−08 | 0.00E+00 | 1.61E−09 | 3.78E−09 | 1.46E+05 | 3.00E+05 | 2.06E+05 | 2.15E+05 | 4.07E+04 | 84.31 |
| | BSD | 5.84E−06 | 3.92E−01 | 4.48E−03 | 9.09E−02 | 1.44E−01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | QRDE | 8.56E+01 | 1.77E+04 | 4.88E+03 | 6.83E+03 | 5.40E+03 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | BDE | 0.00E+00 | 1.99E−06 | 9.98E−08 | 3.79E−07 | 7.06E−07 | 2.79E+05 | 3.00E+05 | 3.00E+05 | 2.97E+05 | 7.17E+03 | 19.61 |
| | dFDBLSHADE | 1.70E−01 | 9.22E+03 | 1.56E+03 | 3.16E+03 | 3.15E+03 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | BeSD | 1.18E−01 | 1.81E+00 | 5.11E−01 | 7.50E−01 | 6.12E−01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | JADEGMO | 2.81E+01 | 2.08E+04 | 1.03E+03 | 4.74E+03 | 7.28E+03 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | JADE | 0.00E+00 | 5.91E+09 | 0.00E+00 | 1.51E+09 | 2.18E+09 | 5.19E+04 | 3.00E+05 | 7.76E+04 | 1.66E+05 | 1.13E+05 | 58.82 |
| | meanDE | 0.00E+00 | 5.22E+03 | 0.00E+00 | 4.41E+02 | 1.25E+03 | 2.26E+05 | 3.00E+05 | 2.43E+05 | 2.57E+05 | 3.22E+04 | 64.71 |
| | DA2MODE | 0.00E+00 | 0.00E+00 | 0.00E+00 | **0.00E+00** | 0.00E+00 | 1.38E+05 | 1.57E+05 | 1.51E+05 | 1.51E+05 | 4.21E+03 | 100.00 |
| F2 | MDE | 4.17E+03 | 2.77E+04 | 1.02E+04 | 9.86E+03 | 3.87E+03 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | WDE | 1.14E+04 | 1.69E+04 | 1.37E+04 | 1.40E+04 | 1.72E+03 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | EODE | 3.68E−03 | 1.60E+00 | 2.71E−02 | 3.41E−01 | 5.94E−01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | MTDE | 0.00E+00 | 0.00E+00 | 0.00E+00 | **0.00E+00** | 0.00E+00 | 1.75E+05 | 1.95E+05 | 1.85E+05 | 1.87E+05 | 7.47E+03 | 100.00 |
| | mDEW | 8.16E−01 | 3.66E+02 | 2.88E+01 | 5.43E+01 | 6.93E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | BSD | 1.20E+03 | 6.11E+03 | 3.73E+03 | 3.98E+03 | 1.58E+03 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | QRDE | 6.93E+03 | 5.76E+05 | 1.47E+04 | 3.60E+04 | 1.10E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | BDE | 4.32E−01 | 2.29E+01 | 2.41E+00 | 6.80E+00 | 8.05E+00 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | dFDBLSHADE | 1.21E+01 | 4.72E+02 | 1.33E+02 | 1.31E+02 | 1.35E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | BeSD | 7.35E−01 | 7.90E+00 | 1.89E+00 | 2.92E+00 | 2.38E+00 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | JADEGMO | 1.39E+03 | 3.20E+05 | 5.38E+03 | 7.45E+04 | 1.13E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | JADE | 0.00E+00 | 5.07E+04 | 0.00E+00 | 7.25E+03 | 1.48E+04 | 9.55E+04 | 3.00E+05 | 1.23E+05 | 1.67E+05 | 8.31E+04 | 72.55 |
| | meanDE | 0.00E+00 | 2.38E−08 | 0.00E+00 | 3.73E−09 | 8.73E−09 | 2.41E+05 | 3.00E+05 | 2.67E+05 | 2.70E+05 | 1.96E+04 | 84.31 |
| | DA2MODE | 0.00E+00 | 0.00E+00 | 0.00E+00 | **0.00E+00** | 0.00E+00 | 1.22E+05 | 1.38E+05 | 1.29E+05 | 1.29E+05 | 3.37E+03 | 100.00 |
| F3 | MDE | 5.86E+01 | 1.15E+02 | 7.54E+01 | 8.21E+01 | 1.63E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | WDE | 1.12E+01 | 7.38E+01 | 7.06E+01 | 6.45E+01 | 1.82E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | EODE | 1.54E−01 | 1.36E+02 | 7.28E+01 | 6.70E+01 | 4.37E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | MTDE | 4.85E+01 | 8.47E+01 | 8.44E+01 | 7.86E+01 | 1.31E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | mDEW | 9.46E−01 | 7.51E+01 | 4.98E+01 | 4.25E+01 | 2.82E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | BSD | 6.66E+01 | 1.18E+02 | 1.13E+02 | 1.01E+02 | 1.96E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | QRDE | 5.86E+01 | 9.03E+01 | 8.80E+01 | 8.39E+01 | 1.11E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | BDE | 2.84E−02 | 7.22E+01 | 4.01E+00 | 2.28E+01 | 3.15E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | dFDBLSHADE | 3.52E+01 | 1.19E+02 | 9.04E+01 | 9.40E+01 | 1.87E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | BeSD | 1.48E−01 | 9.43E+01 | 6.80E+01 | 5.06E+01 | 3.80E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | JADEGMO | 6.80E+01 | 1.90E+02 | 9.03E+01 | 1.03E+02 | 3.11E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | JADE | 3.62E−04 | 4.13E+02 | 6.41E+01 | 1.59E+02 | 1.57E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | meanDE | 6.25E−03 | 1.09E+02 | 7.00E+01 | 5.66E+01 | 3.84E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | DA2MODE | 5.17E−06 | 4.12E+00 | 9.58E−02 | **1.31E+00** | 1.84E+00 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| F4 | MDE | 2.19E+01 | 6.57E+01 | 3.18E+01 | 3.30E+01 | 1.04E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | WDE | 6.00E+01 | 9.88E+01 | 8.70E+01 | 8.50E+01 | 1.25E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | EODE | 3.38E+01 | 6.17E+01 | 5.37E+01 | 5.08E+01 | 9.56E+00 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | MTDE | 2.89E+01 | 7.16E+01 | 5.57E+01 | 5.32E+01 | 1.56E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | mDEW | 4.98E+01 | 9.25E+01 | 6.77E+01 | 6.51E+01 | 1.24E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | BSD | 5.44E+01 | 9.55E+01 | 8.36E+01 | 8.05E+01 | 1.17E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | QRDE | 3.29E+01 | 8.25E+01 | 5.66E+01 | 5.82E+01 | 1.61E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | BDE | 2.59E+01 | 6.37E+01 | 4.88E+01 | 4.80E+01 | 9.38E+00 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | dFDBLSHADE | 1.20E+01 | 1.90E+01 | 1.61E+01 | 1.59E+01 | 2.26E+00 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | BeSD | 6.22E+01 | 7.88E+01 | 6.57E+01 | 6.95E+01 | 6.50E+00 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | JADEGMO | 5.91E+01 | 1.27E+02 | 1.06E+02 | 9.93E+01 | 2.31E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | JADE | 6.07E+01 | 1.27E+02 | 9.01E+01 | 9.83E+01 | 2.15E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | meanDE | 1.79E+01 | 3.98E+01 | 2.39E+01 | 2.59E+01 | 7.43E+00 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | DA2MODE | 5.12E+00 | 1.72E+01 | 8.94E+00 | **9.40E+00** | 2.31E+00 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| F5 | MDE | 0.00E+00 | 8.04E−03 | 0.00E+00 | 5.32E−04 | 1.90E−03 | 5.88E+04 | 3.00E+05 | 2.02E+05 | 1.84E+05 | 1.05E+05 | 58.82 |
| | WDE | 2.35E+00 | 4.07E+00 | 3.01E+00 | 2.98E+00 | 4.29E−01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | EODE | 4.40E−05 | 2.32E−02 | 1.80E−04 | 7.31E−04 | 3.23E−03 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | MTDE | 4.48E−05 | 2.96E−02 | 4.73E−03 | 5.17E−03 | 6.71E−03 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | mDEW | 0.00E+00 | 1.37E−07 | 0.00E+00 | 2.95E−08 | 5.69E−08 | 1.41E+05 | 3.00E+05 | 1.61E+05 | 1.85E+05 | 6.18E+04 | 78.43 |
| | BSD | 3.32E−05 | 3.16E−03 | 5.50E−04 | 1.09E−03 | 1.00E−03 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | QRDE | 0.00E+00 | 1.15E−02 | 0.00E+00 | 1.13E−03 | 3.46E−03 | 5.80E+04 | 3.00E+05 | 6.30E+04 | 1.09E+05 | 9.53E+04 | 80.39 |
| | BDE | 0.00E+00 | 0.00E+00 | 0.00E+00 | **0.00E+00** | 0.00E+00 | 1.67E+05 | 1.78E+05 | 1.72E+05 | 1.72E+05 | 3.20E+03 | 100.00 |
| | dFDBLSHADE | 5.08E−03 | 9.72E−01 | 3.06E−01 | 3.30E−01 | 2.64E−01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | BeSD | 6.76E−05 | 1.08E−03 | 4.41E−04 | 4.72E−04 | 3.13E−04 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | JADEGMO | 1.11E+00 | 1.21E+01 | 3.82E+00 | 5.29E+00 | 3.65E+00 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | JADE | 3.75E−03 | 5.53E+01 | 4.61E−02 | 1.58E+01 | 2.46E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | meanDE | 3.66E−03 | 2.26E+00 | 3.09E−02 | 1.44E−01 | 4.37E−01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | DA2MODE | 0.00E+00 | 2.00E−06 | 0.00E+00 | 1.10E−07 | 3.21E−07 | 1.64E+05 | 3.00E+05 | 1.72E+05 | 2.08E+05 | 5.80E+04 | 72.55 |
| F6 | MDE | 5.21E+01 | 8.72E+01 | 7.07E+01 | 6.79E+01 | 9.13E+00 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | WDE | 1.30E+02 | 1.86E+02 | 1.69E+02 | 1.65E+02 | 1.81E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | EODE | 7.02E+01 | 1.04E+02 | 9.20E+01 | 8.74E+01 | 1.24E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | MTDE | 3.92E+01 | 9.24E+01 | 7.31E+01 | 6.68E+01 | 1.93E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | mDEW | 9.82E+01 | 1.43E+02 | 1.21E+02 | 1.18E+02 | 1.12E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | BSD | 1.26E+02 | 1.59E+02 | 1.51E+02 | 1.49E+02 | 9.40E+00 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | QRDE | 6.43E+01 | 1.29E+02 | 8.83E+01 | 8.73E+01 | 1.29E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | BDE | 6.90E+01 | 1.03E+02 | 7.45E+01 | 7.74E+01 | 9.57E+00 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | dFDBLSHADE | 3.15E+01 | 6.32E+01 | 4.84E+01 | 4.94E+01 | 7.70E+00 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | BeSD | 9.22E+01 | 1.24E+02 | 1.06E+02 | 1.10E+02 | 8.99E+00 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | JADEGMO | 1.20E+02 | 1.95E+02 | 1.30E+02 | 1.40E+02 | 1.99E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | JADE | 1.01E+02 | 8.65E+02 | 1.18E+02 | 1.44E+02 | 1.07E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | meanDE | 4.86E+01 | 7.40E+01 | 6.39E+01 | 6.13E+01 | 7.88E+00 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | DA2MODE | 3.42E+01 | 4.14E+01 | 3.83E+01 | **3.83E+01** | 1.62E+00 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| F7 | MDE | 2.69E+01 | 5.67E+01 | 4.08E+01 | 4.04E+01 | 8.47E+00 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | WDE | 6.94E+01 | 1.10E+02 | 8.38E+01 | 8.79E+01 | 1.39E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | EODE | 3.58E+01 | 8.37E+01 | 5.07E+01 | 4.95E+01 | 1.19E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | MTDE | 2.98E+01 | 9.25E+01 | 6.27E+01 | 6.48E+01 | 2.11E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | mDEW | 5.37E+01 | 9.75E+01 | 8.46E+01 | 8.59E+01 | 1.17E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | BSD | 4.88E+01 | 8.96E+01 | 6.78E+01 | 6.69E+01 | 1.15E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | QRDE | 3.48E+01 | 6.13E+01 | 4.79E+01 | 4.90E+01 | 8.73E+00 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | BDE | 2.79E+01 | 6.67E+01 | 4.58E+01 | 5.03E+01 | 1.14E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | dFDBLSHADE | 1.10E+01 | 2.19E+01 | 1.83E+01 | 1.79E+01 | 3.11E+00 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | BeSD | 4.99E+01 | 7.17E+01 | 6.19E+01 | 6.18E+01 | 5.86E+00 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | JADEGMO | 5.69E+01 | 1.38E+02 | 8.65E+01 | 8.94E+01 | 2.38E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | JADE | 7.41E+01 | 1.84E+02 | 1.38E+02 | 1.25E+02 | 3.67E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | meanDE | 1.49E+01 | 3.98E+01 | 2.59E+01 | 2.73E+01 | 6.92E+00 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | DA2MODE | 4.95E+00 | 1.71E+01 | 1.01E+01 | **9.95E+00** | 2.56E+00 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |

(*continued on next page*)

**Table E.12** (*continued*).

| Fun | Alg. | Error | | | | | Function evaluations | | | | | SR (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No. | Name | Best | Worst | Median | Mean | SD | Best | Worst | Median | Mean | SD | |
| F8 | MDE | 0.00E+00 | 1.13E+01 | 6.33E−01 | 2.12E+00 | 2.91E+00 | 4.94E+04 | 3.00E+05 | 3.00E+05 | 2.90E+05 | 4.91E+04 | 3.92 |
| | WDE | 6.54E+02 | 1.85E+03 | 1.54E+03 | 1.40E+03 | 3.65E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | EODE | 0.00E+00 | 7.55E+00 | 6.33E−01 | 1.84E+00 | 2.13E+00 | 3.92E+04 | 3.00E+05 | 3.00E+05 | 2.40E+05 | 1.10E+05 | 23.53 |
| | MTDE | 2.26E+00 | 3.26E+01 | 1.03E+01 | 1.23E+01 | 8.58E+00 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | mDEW | 4.63E+00 | 9.29E+01 | 2.10E+01 | 3.42E+01 | 2.95E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | BSD | 1.93E+02 | 1.13E+03 | 6.00E+02 | 5.99E+02 | 3.45E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | QRDE | 0.00E+00 | 2.56E−05 | 0.00E+00 | 2.51E−06 | 7.70E−06 | 5.33E+04 | 3.00E+05 | 5.75E+04 | 8.21E+04 | 7.27E+04 | 90.20 |
| | BDE | 0.00E+00 | 2.45E+00 | 4.54E−01 | 1.08E+00 | 9.87E−01 | 1.32E+05 | 3.00E+05 | 3.00E+05 | 2.74E+05 | 6.16E+04 | 15.69 |
| | dFDBLSHADE | 2.63E+00 | 6.41E+01 | 2.56E+01 | 2.69E+01 | 1.51E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | BeSD | 8.95E−02 | 9.46E+00 | 4.54E−01 | 1.86E+00 | 3.32E+00 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | JADEGMO | 5.43E+01 | 1.18E+03 | 4.67E+02 | 4.41E+02 | 2.49E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | JADE | 3.54E+00 | 8.39E+03 | 4.77E+02 | 1.16E+03 | 2.43E+03 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | meanDE | 4.48E−01 | 8.54E+01 | 3.52E+00 | 1.59E+01 | 2.59E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | DA2MODE | 0.00E+00 | 0.00E+00 | 0.00E+00 | **0.00E+00** | 0.00E+00 | 9.68E+04 | 1.04E+05 | 9.95E+04 | 9.95E+04 | 1.63E+03 | 100.00 |
| F9 | MDE | 1.81E+03 | 4.02E+03 | 2.36E+03 | 2.62E+03 | 6.74E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | WDE | 1.89E+03 | 2.83E+03 | 2.49E+03 | 2.41E+03 | 3.17E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | EODE | 2.31E+03 | 4.76E+03 | 3.09E+03 | 3.45E+03 | 8.34E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | MTDE | 1.76E+03 | 3.57E+03 | 2.37E+03 | 2.45E+03 | 6.23E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | mDEW | 1.81E+03 | 2.61E+03 | 2.16E+03 | 2.16E+03 | 2.28E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | BSD | 2.02E+03 | 3.05E+03 | 2.78E+03 | 2.57E+03 | 3.66E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | QRDE | 2.46E+03 | 4.36E+03 | 3.00E+03 | 3.16E+03 | 5.43E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | BDE | 1.47E+03 | 2.42E+03 | 2.12E+03 | 2.01E+03 | 3.28E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | dFDBLSHADE | 9.78E+02 | 1.82E+03 | 1.34E+03 | **1.40E+03** | 2.14E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | BeSD | 2.95E+03 | 3.56E+03 | 3.09E+03 | 3.17E+03 | 2.22E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | JADEGMO | 3.60E+03 | 7.64E+03 | 5.31E+03 | 5.34E+03 | 6.95E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | JADE | 4.00E+03 | 6.26E+03 | 5.36E+03 | 5.32E+03 | 6.13E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | meanDE | 2.13E+03 | 3.71E+03 | 2.95E+03 | 2.89E+03 | 4.76E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | DA2MODE | 8.91E+02 | 2.07E+03 | 1.53E+03 | 1.53E+03 | 2.46E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| F10 | MDE | 1.09E+01 | 7.69E+01 | 2.30E+01 | 3.90E+01 | 2.56E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | WDE | 3.18E+01 | 1.05E+02 | 7.75E+01 | 7.31E+01 | 1.12E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | EODE | 6.26E+00 | 8.58E+01 | 1.81E+01 | 3.05E+01 | 2.60E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | MTDE | 5.97E+00 | 2.09E+01 | 1.62E+01 | 1.36E+01 | 5.95E+00 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | mDEW | 3.54E+00 | 7.31E+01 | 1.11E+01 | 2.33E+01 | 2.55E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | BSD | 4.95E+01 | 1.04E+02 | 6.31E+01 | 7.16E+01 | 1.88E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | QRDE | 1.29E+01 | 3.46E+03 | 6.90E+01 | 6.60E+02 | 1.17E+03 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | BDE | 1.39E+01 | 3.58E+01 | 2.09E+01 | 2.36E+01 | 8.69E+00 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | dFDBLSHADE | 4.58E+01 | 1.97E+02 | 1.03E+02 | 1.07E+02 | 3.20E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | BeSD | 2.79E+01 | 9.43E+01 | 4.00E+01 | 4.74E+01 | 2.15E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | JADEGMO | 8.52E+01 | 4.44E+03 | 2.30E+02 | 8.72E+02 | 1.56E+03 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | JADE | 6.47E+01 | 6.39E+02 | 1.20E+02 | 2.30E+02 | 1.92E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | meanDE | 1.90E+01 | 1.24E+02 | 7.29E+01 | 7.89E+01 | 3.59E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | DA2MODE | 4.56E−01 | 1.23E+01 | 3.99E+00 | **4.02E+00** | 2.06E+00 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| F11 | MDE | 1.07E+04 | 1.26E+05 | 3.31E+04 | 4.44E+04 | 2.83E+04 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | WDE | 1.34E+04 | 2.99E+04 | 1.91E+04 | 1.87E+04 | 4.12E+03 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | EODE | 1.25E+03 | 3.96E+04 | 1.12E+04 | 1.73E+04 | 1.32E+04 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | MTDE | 1.13E+03 | 3.02E+04 | 2.32E+03 | 8.08E+03 | 1.08E+04 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | mDEW | 6.98E+03 | 1.20E+05 | 4.38E+04 | 4.64E+04 | 3.47E+04 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | BSD | 1.66E+04 | 4.90E+04 | 3.25E+04 | 3.28E+04 | 8.75E+03 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | QRDE | 3.35E+04 | 3.87E+06 | 2.95E+05 | 8.33E+05 | 1.08E+06 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | BDE | 2.44E+03 | 4.14E+04 | 1.59E+04 | 1.90E+04 | 1.07E+04 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | dFDBLSHADE | 5.94E+03 | 8.29E+04 | 3.76E+04 | 4.16E+04 | 2.63E+04 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | BeSD | 1.10E+04 | 3.10E+04 | 2.33E+04 | 2.38E+04 | 5.60E+03 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | JADEGMO | 2.92E+04 | 6.37E+05 | 1.35E+05 | 1.85E+05 | 1.61E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | JADE | 7.90E+02 | 2.67E+08 | 5.08E+03 | 9.70E+07 | 1.18E+08 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | meanDE | 1.90E+03 | 1.32E+04 | 4.04E+03 | 5.26E+03 | 3.39E+03 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | DA2MODE | 1.23E+02 | 1.26E+03 | 5.80E+02 | **6.13E+02** | 2.43E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| F12 | MDE | 4.45E+01 | 5.73E+04 | 3.63E+03 | 1.54E+04 | 2.05E+04 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | WDE | 2.08E+02 | 2.75E+02 | 2.59E+02 | 2.49E+02 | 2.41E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | EODE | 4.69E+02 | 2.90E+04 | 2.69E+03 | 6.59E+03 | 6.41E+03 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | MTDE | 8.55E+01 | 1.49E+03 | 2.70E+02 | 6.01E+02 | 5.09E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | mDEW | 3.71E+01 | 2.25E+02 | 5.06E+01 | 7.06E+01 | 4.07E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | BSD | 2.37E+03 | 2.77E+04 | 8.67E+03 | 1.25E+04 | 9.74E+03 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | QRDE | 6.08E+02 | 4.21E+04 | 6.50E+03 | 1.38E+04 | 1.45E+04 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | BDE | 2.07E+02 | 1.49E+04 | 3.96E+03 | 6.52E+03 | 5.03E+03 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | dFDBLSHADE | 4.42E+01 | 6.09E+04 | 3.07E+03 | 7.20E+03 | 1.38E+04 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | BeSD | 8.84E+01 | 1.33E+04 | 5.98E+03 | 5.72E+03 | 4.84E+03 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | JADEGMO | 5.54E+03 | 7.12E+04 | 9.42E+03 | 2.28E+04 | 2.46E+04 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | JADE | 1.45E+02 | 1.22E+05 | 7.34E+02 | 2.79E+04 | 4.47E+04 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | meanDE | 3.62E+01 | 2.38E+04 | 1.77E+03 | 5.45E+03 | 7.11E+03 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | DA2MODE | 2.05E−01 | 3.51E+01 | 1.69E+01 | **1.60E+01** | 6.48E+00 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| F13 | MDE | 2.23E+03 | 1.38E+04 | 6.66E+03 | 7.10E+03 | 4.11E+03 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | WDE | 5.02E+01 | 7.96E+01 | 6.59E+01 | 6.61E+01 | 9.09E+00 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | EODE | 3.66E+01 | 5.75E+01 | 4.77E+01 | 4.81E+01 | 6.11E+00 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | MTDE | 2.75E+01 | 4.39E+01 | 3.13E+01 | 3.37E+01 | 5.25E+00 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | mDEW | 3.11E+01 | 4.74E+01 | 3.67E+01 | 3.75E+01 | 4.32E+00 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | BSD | 3.07E+02 | 2.59E+03 | 8.07E+02 | 1.29E+03 | 8.99E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | QRDE | 9.97E+03 | 2.21E+06 | 8.51E+04 | 2.97E+05 | 5.78E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | BDE | 1.11E+01 | 1.17E+03 | 3.29E+01 | 1.64E+02 | 3.71E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | dFDBLSHADE | 7.89E+01 | 3.45E+02 | 1.64E+02 | 1.96E+02 | 9.08E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | BeSD | 3.83E+01 | 6.38E+01 | 5.08E+01 | 5.02E+01 | 8.12E+00 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | JADEGMO | 1.34E+02 | 5.59E+05 | 2.24E+02 | 5.50E+04 | 1.68E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | JADE | 9.67E+01 | 2.56E+02 | 1.99E+02 | 1.82E+02 | 5.57E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | meanDE | 6.96E+01 | 4.61E+02 | 1.07E+02 | 1.55E+02 | 1.15E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | DA2MODE | 4.42E+00 | 2.50E+01 | 2.15E+01 | **1.90E+01** | 5.97E+00 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| F14 | MDE | 2.49E+01 | 1.78E+04 | 4.07E+03 | 5.88E+03 | 6.82E+03 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | WDE | 2.55E+01 | 6.78E+01 | 5.29E+01 | 4.90E+01 | 1.12E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | EODE | 3.57E+01 | 5.67E+03 | 9.17E+01 | 2.13E+02 | 7.81E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | MTDE | 7.25E+00 | 4.04E+01 | 3.51E+01 | 3.31E+01 | 8.38E+00 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | mDEW | 3.87E+00 | 2.91E+01 | 1.46E+01 | 1.53E+01 | 5.42E+00 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | BSD | 9.73E+01 | 2.99E+03 | 2.90E+02 | 9.46E+02 | 1.07E+03 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | QRDE | 4.97E+02 | 2.13E+04 | 7.00E+03 | 8.00E+03 | 7.30E+03 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | BDE | 1.54E+01 | 5.07E+03 | 1.29E+02 | 1.12E+03 | 1.81E+03 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | dFDBLSHADE | 1.60E+02 | 8.95E+02 | 2.46E+02 | 2.87E+02 | 1.38E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | BeSD | 2.11E+01 | 1.98E+02 | 8.19E+01 | 1.02E+02 | 6.67E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | JADEGMO | 3.69E+02 | 4.17E+04 | 7.93E+02 | 1.67E+03 | 5.72E+03 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | JADE | 8.28E+01 | 2.30E+03 | 1.60E+02 | 4.22E+02 | 6.97E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | meanDE | 2.08E+01 | 4.00E+03 | 1.68E+02 | 6.20E+02 | 1.25E+03 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | DA2MODE | 8.75E−01 | 1.02E+01 | 4.18E+00 | **5.01E+00** | 2.52E+00 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |

(*continued on next page*)

**Table E.12** (*continued*).

| Fun | Alg. | Error | | | | | Function evaluations | | | | | SR (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No. | Name | Best | Worst | Median | Mean | SD | Best | Worst | Median | Mean | SD | |
| F15 | MDE | 1.77E+02 | 8.33E+02 | 5.49E+02 | 5.34E+02 | 2.32E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | WDE | 2.81E+02 | 7.71E+02 | 5.71E+02 | 5.27E+02 | 1.72E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | EODE | 1.78E+02 | 7.16E+02 | 5.38E+02 | 4.45E+02 | 1.76E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | MTDE | 3.48E+01 | 9.84E+02 | 4.13E+02 | 4.26E+02 | 3.03E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | mDEW | 3.83E+02 | 7.92E+02 | 5.60E+02 | 6.12E+02 | 1.54E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | BSD | 4.52E+02 | 8.33E+02 | 6.06E+02 | 6.07E+02 | 1.23E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | QRDE | 3.97E+02 | 1.55E+03 | 1.12E+03 | 1.07E+03 | 2.23E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | BDE | 1.56E+02 | 9.55E+02 | 4.12E+02 | 4.89E+02 | 2.30E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | dFDBLSHADE | 6.82E+00 | 5.28E+02 | 1.55E+02 | 2.50E+02 | 1.88E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | BeSD | 3.53E+02 | 6.46E+02 | 5.68E+02 | 5.41E+02 | 8.01E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | JADEGMO | 4.46E+02 | 3.57E+03 | 7.78E+02 | 1.44E+03 | 1.14E+03 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | JADE | 1.42E+02 | 2.11E+03 | 1.21E+03 | 1.11E+03 | 5.32E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | meanDE | 4.47E+00 | 8.39E+02 | 1.43E+02 | 2.27E+02 | 2.28E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | DA2MODE | 1.30E+01 | 2.86E+02 | 4.18E+01 | **7.79E+01** | 7.44E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| F16 | MDE | 3.89E+01 | 4.31E+02 | 2.95E+02 | 2.50E+02 | 1.47E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | WDE | 5.35E+01 | 2.71E+02 | 9.68E+01 | 1.19E+02 | 6.33E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | EODE | 5.12E+01 | 3.29E+02 | 1.19E+02 | 1.35E+02 | 7.68E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | MTDE | 2.15E+01 | 3.89E+02 | 9.29E+01 | 1.49E+02 | 1.31E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | mDEW | 4.05E+01 | 2.00E+02 | 9.25E+01 | 1.19E+02 | 4.95E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | BSD | 5.68E+01 | 3.18E+02 | 1.83E+02 | 1.82E+02 | 7.47E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | QRDE | 3.24E+02 | 8.47E+02 | 6.11E+02 | 6.08E+02 | 1.69E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | BDE | 3.53E+01 | 2.62E+02 | 1.60E+02 | 1.62E+02 | 7.17E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | dFDBLSHADE | 2.26E+01 | 4.19E+01 | 3.62E+01 | **3.52E+01** | 6.24E+00 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | BeSD | 6.48E+01 | 1.09E+02 | 7.88E+01 | 8.52E+01 | 1.71E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | JADEGMO | 1.15E+02 | 4.02E+02 | 2.79E+02 | 2.69E+02 | 7.99E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | JADE | 1.12E+02 | 1.45E+03 | 2.32E+02 | 4.70E+02 | 4.60E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | meanDE | 5.71E+01 | 2.35E+02 | 9.27E+01 | 1.22E+02 | 6.43E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | DA2MODE | 2.64E+01 | 7.73E+01 | 4.25E+01 | 4.51E+01 | 1.01E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| F17 | MDE | 2.20E+04 | 2.48E+05 | 1.02E+05 | 1.07E+05 | 7.82E+04 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | WDE | 2.52E+02 | 5.09E+02 | 3.17E+02 | 3.54E+02 | 8.76E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | EODE | 1.31E+04 | 5.15E+04 | 2.99E+04 | 2.85E+04 | 1.06E+04 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | MTDE | 4.98E+01 | 1.43E+03 | 2.35E+02 | 3.64E+02 | 4.72E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | mDEW | 4.23E+02 | 1.37E+04 | 8.46E+02 | 1.68E+03 | 2.06E+03 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | BSD | 2.01E+04 | 9.60E+04 | 6.32E+04 | 5.99E+04 | 1.79E+04 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | QRDE | 3.48E+04 | 3.31E+06 | 7.32E+05 | 9.09E+05 | 8.83E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | BDE | 3.42E+03 | 3.70E+04 | 1.65E+04 | 1.72E+04 | 1.11E+04 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | dFDBLSHADE | 3.27E+03 | 2.02E+04 | 7.67E+03 | 1.02E+04 | 6.20E+03 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | BeSD | 5.26E+01 | 2.36E+02 | 7.14E+01 | 9.06E+01 | 3.86E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | JADEGMO | 1.09E+03 | 2.40E+06 | 7.49E+03 | 1.11E+05 | 4.07E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | JADE | 2.43E+02 | 1.13E+05 | 8.54E+03 | 2.20E+04 | 2.30E+04 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | meanDE | 5.98E+01 | 2.36E+04 | 1.28E+03 | 3.30E+03 | 4.83E+03 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | DA2MODE | 2.02E+01 | 2.26E+01 | 2.06E+01 | **2.11E+01** | 6.77E−01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| F18 | MDE | 5.32E+02 | 3.93E+04 | 2.01E+03 | 7.89E+03 | 1.25E+04 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | WDE | 1.79E+01 | 3.21E+01 | 2.32E+01 | 2.31E+01 | 4.53E+00 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | EODE | 1.63E+01 | 3.72E+03 | 2.34E+01 | 3.19E+02 | 1.00E+03 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | MTDE | 8.85E+00 | 3.14E+01 | 1.61E+01 | 1.62E+01 | 5.60E+00 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | mDEW | 9.50E+00 | 1.64E+01 | 1.11E+01 | 1.20E+01 | 2.23E+00 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | BSD | 3.84E+01 | 1.08E+04 | 7.33E+01 | 2.85E+03 | 4.09E+03 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | QRDE | 1.11E+02 | 8.62E+04 | 9.17E+03 | 1.39E+04 | 2.19E+04 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | BDE | 6.62E+00 | 7.32E+02 | 9.95E+01 | 1.90E+02 | 2.57E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | dFDBLSHADE | 6.43E+01 | 2.86E+03 | 1.02E+02 | 2.88E+02 | 6.51E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | BeSD | 1.43E+01 | 3.22E+01 | 2.02E+01 | 2.07E+01 | 4.02E+00 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | JADEGMO | 7.91E+01 | 7.40E+07 | 2.50E+02 | 8.70E+06 | 2.41E+07 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | JADE | 3.38E+01 | 5.14E+04 | 1.44E+02 | 5.31E+03 | 1.54E+04 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | meanDE | 2.47E+01 | 1.19E+02 | 8.57E+01 | 7.03E+01 | 3.47E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | DA2MODE | 3.34E+00 | 7.80E+00 | 5.37E+00 | **5.40E+00** | 1.06E+00 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| F19 | MDE | 1.22E+01 | 4.45E+02 | 1.77E+02 | 2.29E+02 | 1.66E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | WDE | 7.16E+01 | 2.75E+02 | 1.89E+02 | 1.71E+02 | 7.10E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | EODE | 2.90E+01 | 5.31E+02 | 1.93E+02 | 2.20E+02 | 1.55E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | MTDE | 2.96E+01 | 3.11E+02 | 5.16E+01 | 1.18E+02 | 1.04E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | mDEW | 4.54E+01 | 4.07E+02 | 8.38E+01 | 1.38E+02 | 9.84E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | BSD | 4.64E+01 | 2.80E+02 | 1.67E+02 | 1.73E+02 | 8.72E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | QRDE | 1.89E+02 | 7.12E+02 | 4.05E+02 | 4.37E+02 | 1.71E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | BDE | 1.07E+01 | 2.64E+02 | 1.57E+02 | 1.77E+02 | 7.69E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | dFDBLSHADE | 2.37E+01 | 4.67E+01 | 2.89E+01 | **2.91E+01** | 4.37E+00 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | BeSD | 7.03E+01 | 1.35E+02 | 9.69E+01 | 9.88E+01 | 1.92E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | JADEGMO | 1.04E+02 | 1.16E+03 | 2.95E+02 | 3.79E+02 | 2.70E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | JADE | 1.73E+02 | 7.99E+02 | 5.09E+02 | 5.06E+02 | 1.94E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | meanDE | 5.95E+01 | 3.12E+02 | 1.88E+02 | 1.68E+02 | 7.83E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | DA2MODE | 2.35E+01 | 6.64E+01 | 3.58E+01 | 3.89E+01 | 1.07E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| F20 | MDE | 2.24E+02 | 2.62E+02 | 2.40E+02 | 2.43E+02 | 1.25E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | WDE | 2.75E+02 | 3.07E+02 | 2.90E+02 | 2.90E+02 | 1.02E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | EODE | 2.24E+02 | 2.66E+02 | 2.40E+02 | 2.43E+02 | 1.20E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | MTDE | 2.34E+02 | 2.89E+02 | 2.43E+02 | 2.46E+02 | 1.26E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | mDEW | 1.03E+02 | 3.01E+02 | 2.84E+02 | 2.74E+02 | 4.40E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | BSD | 2.55E+02 | 2.87E+02 | 2.70E+02 | 2.70E+02 | 9.93E+00 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | QRDE | 2.35E+02 | 2.66E+02 | 2.53E+02 | 2.52E+02 | 1.03E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | BDE | 2.23E+02 | 2.85E+02 | 2.46E+02 | 2.48E+02 | 2.01E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | dFDBLSHADE | 2.11E+02 | 2.26E+02 | 2.18E+02 | 2.17E+02 | 4.26E+00 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | BeSD | 2.43E+02 | 2.72E+02 | 2.59E+02 | 2.58E+02 | 7.68E+00 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | JADEGMO | 2.72E+02 | 5.48E+02 | 3.01E+02 | 3.14E+02 | 5.28E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | JADE | 2.78E+02 | 3.74E+02 | 3.01E+02 | 3.07E+02 | 2.91E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | meanDE | 2.16E+02 | 2.42E+02 | 2.20E+02 | 2.22E+02 | 6.35E+00 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | DA2MODE | 2.03E+02 | 2.18E+02 | 2.08E+02 | **2.08E+02** | 2.70E+00 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| F21 | MDE | 1.00E+02 | 3.18E+03 | 1.00E+02 | 3.02E+02 | 7.05E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | WDE | 1.17E+02 | 1.34E+02 | 1.23E+02 | 1.23E+02 | 3.67E+00 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | EODE | 1.00E+02 | 4.77E+03 | 1.00E+02 | 5.19E+02 | 1.29E+03 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | MTDE | 1.00E+02 | 3.91E+03 | 3.10E+03 | 2.87E+03 | 1.02E+03 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | mDEW | 1.00E+02 | 1.03E+02 | 1.00E+02 | 1.01E+02 | 1.25E+00 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | BSD | 1.00E+02 | 1.06E+02 | 1.02E+02 | 1.02E+02 | 2.36E+00 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | QRDE | 1.00E+02 | 3.89E+03 | 3.14E+03 | 2.41E+03 | 1.57E+03 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | BDE | 1.00E+02 | 2.26E+03 | 1.00E+02 | 4.38E+02 | 7.92E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | dFDBLSHADE | 1.00E+02 | 1.15E+02 | 1.00E+02 | 1.02E+02 | 3.11E+00 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | BeSD | 1.00E+02 | 1.02E+02 | 1.00E+02 | 1.00E+02 | 9.03E−01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | JADEGMO | 1.03E+02 | 7.89E+03 | 4.82E+03 | 4.66E+03 | 1.93E+03 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | JADE | 1.00E+02 | 4.04E+03 | 1.03E+02 | 5.62E+02 | 8.42E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | meanDE | 1.00E+02 | 1.77E+02 | 1.05E+02 | 1.16E+02 | 2.54E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | DA2MODE | 1.00E+02 | 1.00E+02 | 1.00E+02 | **1.00E+02** | 2.05E−13 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |

(*continued on next page*)

**Table E.12** (*continued*).

| Fun | Alg. | Error | | | | | Function evaluations | | | | | SR (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No. | Name | Best | Worst | Median | Mean | SD | Best | Worst | Median | Mean | SD | |
| F22 | MDE | 3.79E+02 | 4.26E+02 | 4.03E+02 | 4.01E+02 | 1.24E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | WDE | 3.93E+02 | 4.55E+02 | 4.24E+02 | 4.23E+02 | 2.28E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | EODE | 3.84E+02 | 4.59E+02 | 3.98E+02 | 4.01E+02 | 2.04E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | MTDE | 3.93E+02 | 4.26E+02 | 4.10E+02 | 4.11E+02 | 1.06E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | mDEW | 3.78E+02 | 4.45E+02 | 4.24E+02 | 4.16E+02 | 1.75E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | BSD | 4.20E+02 | 4.82E+02 | 4.41E+02 | 4.43E+02 | 1.82E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | QRDE | 3.82E+02 | 4.36E+02 | 4.00E+02 | 4.02E+02 | 1.98E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | BDE | 3.71E+02 | 4.22E+02 | 3.91E+02 | 3.94E+02 | 1.42E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | dFDBLSHADE | 3.57E+02 | 3.74E+02 | 3.67E+02 | 3.67E+02 | 4.48E+00 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | BeSD | 3.97E+02 | 4.37E+02 | 4.07E+02 | 4.12E+02 | 1.38E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | JADEGMO | 4.49E+02 | 6.68E+02 | 4.74E+02 | 4.94E+02 | 5.27E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | JADE | 3.81E+02 | 5.08E+02 | 4.65E+02 | 4.60E+02 | 3.81E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | meanDE | 3.56E+02 | 4.22E+02 | 3.85E+02 | 3.93E+02 | 2.06E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | DA2MODE | 3.49E+02 | 3.65E+02 | 3.57E+02 | **3.57E+02** | 3.33E+00 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| F23 | MDE | 4.51E+02 | 4.88E+02 | 4.64E+02 | 4.66E+02 | 8.92E+00 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | WDE | 5.29E+02 | 5.94E+02 | 5.63E+02 | 5.68E+02 | 1.84E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | EODE | 4.40E+02 | 4.73E+02 | 4.60E+02 | 4.62E+02 | 9.24E+00 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | MTDE | 4.54E+02 | 4.94E+02 | 4.76E+02 | 4.77E+02 | 1.37E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | mDEW | 2.10E+02 | 5.98E+02 | 5.15E+02 | 5.02E+02 | 7.89E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | BSD | 4.90E+02 | 5.90E+02 | 5.43E+02 | 5.42E+02 | 2.62E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | QRDE | 4.72E+02 | 5.50E+02 | 4.99E+02 | 5.05E+02 | 2.17E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | BDE | 4.52E+02 | 5.22E+02 | 4.82E+02 | 4.83E+02 | 1.89E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | dFDBLSHADE | 4.31E+02 | 4.46E+02 | 4.37E+02 | 4.37E+02 | 5.40E+00 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | BeSD | 4.58E+02 | 4.97E+02 | 4.82E+02 | 4.81E+02 | 9.71E+00 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | JADEGMO | 4.98E+02 | 5.86E+02 | 5.41E+02 | 5.47E+02 | 2.65E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | JADE | 4.83E+02 | 7.37E+02 | 5.15E+02 | 5.51E+02 | 6.81E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | meanDE | 4.38E+02 | 4.81E+02 | 4.51E+02 | 4.51E+02 | 1.04E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | DA2MODE | 4.27E+02 | 4.37E+02 | 4.32E+02 | **4.32E+02** | 2.05E+00 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| F24 | MDE | 3.84E+02 | 4.23E+02 | 3.89E+02 | 3.92E+02 | 1.16E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | WDE | 3.85E+02 | 3.88E+02 | 3.86E+02 | 3.86E+02 | 8.26E−01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | EODE | 3.83E+02 | 3.87E+02 | 3.87E+02 | 3.86E+02 | 1.81E+00 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | MTDE | 3.87E+02 | 3.89E+02 | 3.88E+02 | 3.88E+02 | 5.36E−01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | mDEW | 3.83E+02 | 3.87E+02 | 3.87E+02 | 3.86E+02 | 1.58E+00 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | BSD | 3.90E+02 | 4.39E+02 | 4.15E+02 | 4.20E+02 | 1.40E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | QRDE | 3.87E+02 | 3.89E+02 | 3.87E+02 | 3.88E+02 | 7.24E−01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | BDE | 3.84E+02 | 3.88E+02 | 3.87E+02 | 3.86E+02 | 1.63E+00 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | dFDBLSHADE | 3.88E+02 | 3.90E+02 | 3.89E+02 | 3.89E+02 | 6.15E−01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | BeSD | 3.87E+02 | 3.88E+02 | 3.87E+02 | 3.87E+02 | 3.90E−01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | JADEGMO | 3.87E+02 | 4.18E+02 | 3.89E+02 | 3.89E+02 | 4.23E+00 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | JADE | 3.87E+02 | 1.57E+03 | 3.90E+02 | 6.45E+02 | 4.18E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | meanDE | 3.88E+02 | 4.24E+02 | 3.90E+02 | 3.95E+02 | 1.06E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | DA2MODE | 3.75E+02 | 3.96E+02 | 3.78E+02 | **3.78E+02** | 2.58E+00 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| F25 | MDE | 1.20E+03 | 1.68E+03 | 1.39E+03 | 1.39E+03 | 1.22E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | WDE | 2.73E+02 | 4.79E+02 | 2.86E+02 | 3.17E+02 | 7.21E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | EODE | 1.21E+03 | 1.78E+03 | 1.41E+03 | 1.45E+03 | 1.38E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | MTDE | 1.38E+03 | 1.92E+03 | 1.56E+03 | 1.59E+03 | 1.79E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | mDEW | 2.00E+02 | 3.00E+02 | 3.00E+02 | **2.51E+02** | 5.05E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | BSD | 2.00E+02 | 3.81E+03 | 2.00E+02 | 1.08E+03 | 1.42E+03 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | QRDE | 1.29E+03 | 2.11E+03 | 1.66E+03 | 1.73E+03 | 2.29E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | BDE | 3.00E+02 | 1.80E+03 | 1.66E+03 | 1.32E+03 | 6.03E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | dFDBLSHADE | 3.00E+02 | 1.26E+03 | 1.23E+03 | 1.12E+03 | 2.31E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | BeSD | 2.00E+02 | 1.92E+03 | 3.00E+02 | 5.09E+02 | 6.16E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | JADEGMO | 2.04E+03 | 5.20E+03 | 2.34E+03 | 2.68E+03 | 9.64E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | JADE | 2.00E+02 | 4.10E+03 | 2.25E+03 | 2.07E+03 | 9.05E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | meanDE | 2.00E+02 | 1.96E+03 | 1.36E+03 | 1.20E+03 | 5.98E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | DA2MODE | 2.00E+02 | 1.19E+03 | 3.00E+02 | 3.90E+02 | 2.62E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| F26 | MDE | 5.03E+02 | 5.22E+02 | 5.11E+02 | 5.11E+02 | 5.72E+00 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | WDE | 5.19E+02 | 5.41E+02 | 5.35E+02 | 5.32E+02 | 8.34E+00 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | EODE | 4.96E+02 | 5.19E+02 | 5.13E+02 | 5.11E+02 | 7.90E+00 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | MTDE | 5.01E+02 | 5.23E+02 | 5.13E+02 | 5.13E+02 | 6.61E+00 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | mDEW | 5.01E+02 | 5.34E+02 | 5.22E+02 | 5.24E+02 | 8.27E+00 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | BSD | 5.33E+02 | 5.69E+02 | 5.40E+02 | 5.47E+02 | 1.16E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | QRDE | 5.03E+02 | 5.29E+02 | 5.13E+02 | 5.14E+02 | 6.44E+00 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | BDE | 4.96E+02 | 5.25E+02 | 5.14E+02 | 5.11E+02 | 6.90E+00 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | dFDBLSHADE | 4.99E+02 | 5.42E+02 | 5.27E+02 | 5.21E+02 | 1.43E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | BeSD | 5.08E+02 | 5.24E+02 | 5.16E+02 | 5.15E+02 | 5.83E+00 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | JADEGMO | 5.09E+02 | 6.78E+02 | 5.26E+02 | 5.45E+02 | 4.76E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | JADE | 4.99E+02 | 6.06E+02 | 5.16E+02 | 5.35E+02 | 3.35E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | meanDE | 4.96E+02 | 5.44E+02 | 5.23E+02 | 5.21E+02 | 1.23E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | DA2MODE | 5.00E+02 | 5.00E+02 | 5.00E+02 | **5.00E+02** | 1.73E−04 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| F27 | MDE | 3.51E+02 | 4.67E+02 | 4.11E+02 | 4.20E+02 | 3.19E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | WDE | 4.10E+02 | 4.25E+02 | 4.21E+02 | 4.19E+02 | 5.20E+00 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | EODE | 3.00E+02 | 4.40E+02 | 3.00E+02 | 3.37E+02 | 5.28E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | MTDE | 3.00E+02 | 4.54E+02 | 4.05E+02 | 3.70E+02 | 5.88E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | mDEW | 3.00E+02 | 4.11E+02 | 3.83E+02 | 3.66E+02 | 4.66E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | BSD | 3.86E+02 | 4.45E+02 | 4.00E+02 | 4.07E+02 | 1.91E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | QRDE | 3.00E+02 | 4.85E+02 | 4.26E+02 | 4.18E+02 | 5.09E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | BDE | 3.00E+02 | 4.07E+02 | 3.00E+02 | **3.33E+02** | 4.94E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | dFDBLSHADE | 4.12E+02 | 4.80E+02 | 4.50E+02 | 4.38E+02 | 2.17E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | BeSD | 3.10E+02 | 3.98E+02 | 3.91E+02 | 3.69E+02 | 3.03E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | JADEGMO | 4.18E+02 | 3.69E+03 | 4.54E+02 | 6.39E+02 | 7.70E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | JADE | 3.00E+02 | 6.75E+02 | 3.00E+02 | 4.13E+02 | 1.51E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | meanDE | 3.00E+02 | 4.40E+02 | 3.98E+02 | 3.71E+02 | 5.20E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | DA2MODE | 3.00E+02 | 4.53E+02 | 3.00E+02 | 3.51E+02 | 6.28E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| F28 | MDE | 3.70E+02 | 7.79E+02 | 4.67E+02 | 5.43E+02 | 1.44E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | WDE | 5.40E+02 | 6.55E+02 | 5.99E+02 | 6.03E+02 | 4.28E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | EODE | 4.68E+02 | 9.18E+02 | 7.55E+02 | 7.70E+02 | 1.22E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | MTDE | 4.74E+02 | 7.98E+02 | 6.45E+02 | 6.33E+02 | 9.31E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | mDEW | 5.25E+02 | 8.63E+02 | 6.01E+02 | 6.41E+02 | 1.02E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | BSD | 4.96E+02 | 7.10E+02 | 5.33E+02 | 5.71E+02 | 7.19E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | QRDE | 4.64E+02 | 1.15E+03 | 5.92E+02 | 7.29E+02 | 2.68E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | BDE | 4.37E+02 | 6.54E+02 | 4.72E+02 | 4.73E+02 | 3.55E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | dFDBLSHADE | 4.37E+02 | 6.32E+02 | 4.89E+02 | 5.13E+02 | 7.37E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | BeSD | 5.20E+02 | 6.70E+02 | 5.47E+02 | 5.72E+02 | 5.19E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | JADEGMO | 6.29E+02 | 1.15E+03 | 8.18E+02 | 8.22E+02 | 1.28E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | JADE | 6.63E+02 | 1.95E+03 | 8.41E+02 | 8.91E+02 | 2.68E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | meanDE | 4.79E+02 | 7.73E+02 | 5.56E+02 | 5.86E+02 | 9.96E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | DA2MODE | 2.33E+02 | 3.98E+02 | 3.63E+02 | **3.37E+02** | 5.47E+01 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |

(*continued on next page*)

**Table E.12** (*continued*).

| Fun | Alg. | Error | | | | | Function evaluations | | | | | SR (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No. | Name | Best | Worst | Median | Mean | SD | Best | Worst | Median | Mean | SD | |
| F29 | MDE | 2.49E+03 | 6.70E+03 | 3.14E+03 | 3.41E+03 | 1.01E+03 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | WDE | 3.18E+03 | 4.55E+03 | 4.20E+03 | 3.93E+03 | 4.76E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | EODE | 2.09E+03 | 7.41E+03 | 2.20E+03 | 3.51E+03 | 1.84E+03 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | MTDE | 2.19E+03 | 3.89E+03 | 2.60E+03 | 2.78E+03 | 5.65E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | mDEW | 2.88E+03 | 4.53E+03 | 4.02E+03 | 4.05E+03 | 4.13E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | BSD | 2.48E+03 | 5.52E+03 | 4.18E+03 | 4.12E+03 | 1.05E+03 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | QRDE | 2.33E+03 | 9.13E+04 | 1.13E+04 | 1.93E+04 | 2.15E+04 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | BDE | 2.31E+03 | 9.86E+03 | 3.57E+03 | 4.47E+03 | 2.57E+03 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | dFDBLSHADE | 2.82E+03 | 1.23E+04 | 3.35E+03 | 5.94E+03 | 3.48E+03 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | BeSD | 3.38E+03 | 5.82E+03 | 3.95E+03 | 4.16E+03 | 7.16E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | JADEGMO | 4.61E+03 | 1.20E+06 | 1.66E+04 | 1.00E+05 | 2.79E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | JADE | 2.06E+03 | 1.46E+05 | 2.24E+03 | 1.16E+04 | 3.40E+04 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | meanDE | 2.50E+03 | 4.33E+03 | 3.58E+03 | 3.54E+03 | 4.92E+02 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |
| | DA2MODE | 2.04E+02 | 2.12E+02 | 2.08E+02 | **2.08E+02** | 1.76E+00 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 3.00E+05 | 0.00E+00 | 0.00 |

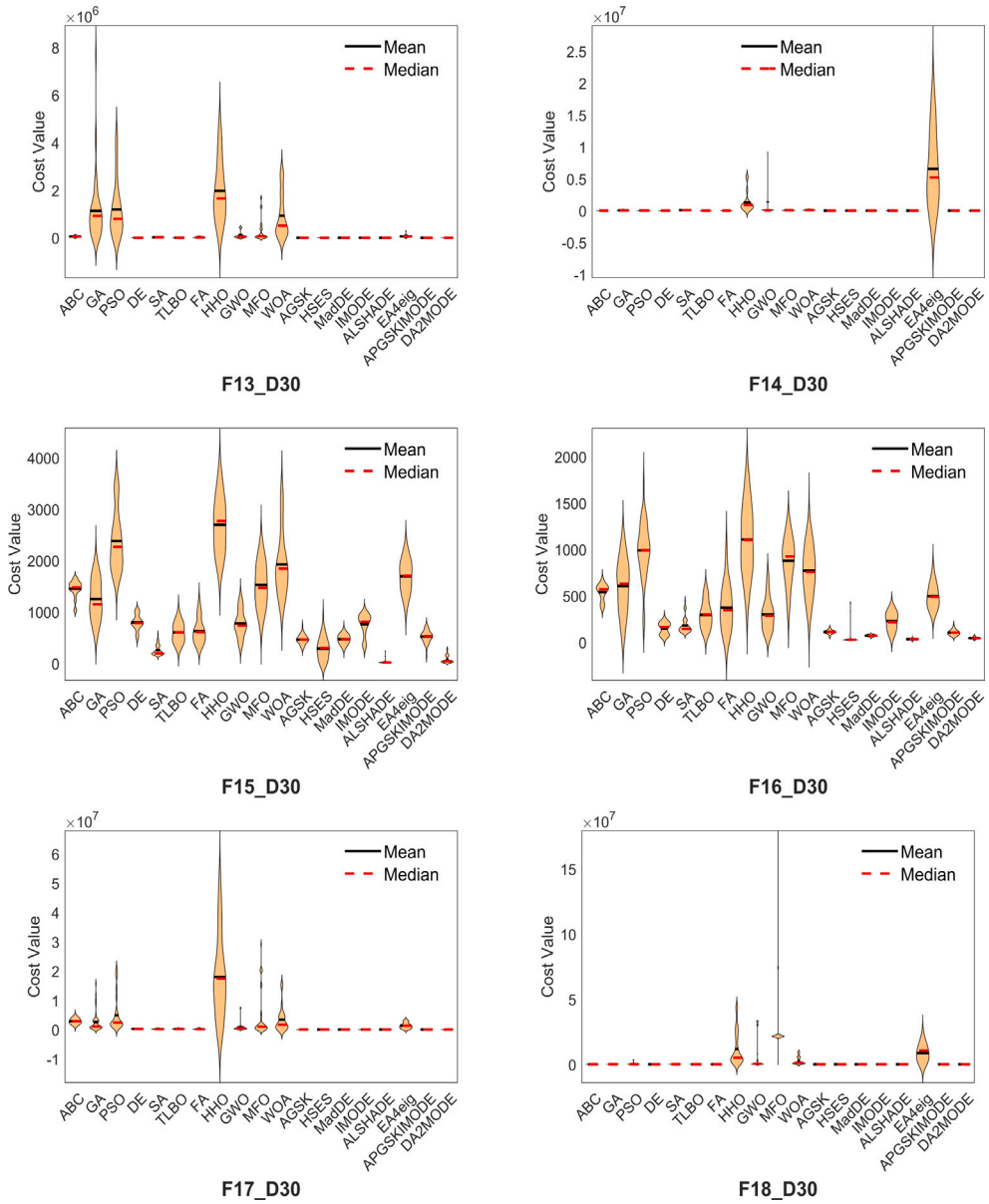



**Fig. F.9c.** Violin plots for the best fitness in 51 runs for all the algorithms in CEC2017-2018, F13-F18 (30D).

**Table E.13**
The results metrics for the error and function evaluation metrics for 14 DE variants, CEC2017–2018 (F1-F5, 50 Dim).

| Fun | Alg. | Error | | | | | Function evaluations | | | | | SR (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No. | Name | Best | Worst | Median | Mean | SD | Best | Worst | Median | Mean | SD | |
| F1 | MDE | 1.34E+01 | 4.17E+03 | 5.24E+02 | 1.23E+03 | 1.42E+03 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | WDE | 7.03E+05 | 1.28E+06 | 1.14E+06 | 1.00E+06 | 2.50E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | EODE | 2.54E+00 | 1.22E+04 | 3.11E+03 | 2.96E+03 | 3.20E+03 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | MTDE | 3.98E+02 | 1.49E+04 | 7.67E+03 | 7.05E+03 | 5.22E+03 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | mDEW | 5.36E−04 | 1.16E+04 | 3.59E+02 | 2.38E+03 | 3.24E+03 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | BSD | 9.91E−01 | 2.24E+03 | 4.33E+02 | 7.37E+02 | 7.58E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | QRDE | 4.34E+01 | 2.95E+04 | 2.62E+03 | 8.86E+03 | 1.07E+04 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | BDE | 3.39E+00 | 5.13E+03 | 3.91E+02 | 8.01E+02 | 1.32E+03 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | dFDBLSHADE | 3.05E+01 | 2.41E+04 | 1.90E+03 | 6.38E+03 | 8.64E+03 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | BeSD | 4.29E+01 | 1.15E+03 | 1.66E+02 | 4.37E+02 | 4.22E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | JADEGMO | 5.62E+04 | 8.55E+08 | 3.44E+05 | 1.01E+08 | 2.78E+08 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | JADE | 4.87E−01 | 7.69E+09 | 5.43E+01 | 1.51E+08 | 1.08E+09 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | meanDE | 1.55E+01 | 5.23E+07 | 6.45E+03 | 7.19E+06 | 1.82E+07 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | DA2MODE | 0.00E+00 | 0.00E+00 | 0.00E+00 | **0.00E+00** | 0.00E+00 | 3.29E+05 | 3.84E+05 | 3.58E+05 | 3.58E+05 | 9.65E+03 | 100.00 |
| F2 | MDE | 6.87E+04 | 1.30E+05 | 9.03E+04 | 9.03E+04 | 1.58E+04 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | WDE | 5.75E+04 | 8.45E+04 | 7.63E+04 | 7.20E+04 | 8.68E+03 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | EODE | 2.61E+02 | 3.78E+03 | 4.86E+02 | 1.35E+03 | 1.39E+03 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | MTDE | 0.00E+00 | 0.00E+00 | 0.00E+00 | **0.00E+00** | 0.00E+00 | 4.41E+05 | 4.84E+05 | 4.56E+05 | 4.58E+05 | 1.09E+04 | 100.00 |
| | mDEW | 6.69E+03 | 2.33E+04 | 8.28E+03 | 1.05E+04 | 3.88E+03 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | BSD | 2.09E+04 | 3.10E+04 | 2.54E+04 | 2.59E+04 | 3.59E+03 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | QRDE | 7.84E+04 | 1.34E+05 | 1.01E+05 | 1.06E+05 | 1.57E+04 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | BDE | 8.95E+01 | 7.57E+02 | 4.67E+02 | 4.68E+02 | 2.34E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | dFDBLSHADE | 1.76E+03 | 7.30E+03 | 2.66E+03 | 3.52E+03 | 1.90E+03 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | BeSD | 2.84E+02 | 1.70E+03 | 5.50E+02 | 6.89E+02 | 4.63E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | JADEGMO | 2.31E+04 | 6.61E+05 | 3.59E+04 | 8.01E+04 | 1.24E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | JADE | 0.00E+00 | 1.40E+05 | 0.00E+00 | 1.96E+04 | 4.28E+04 | 2.71E+05 | 5.00E+05 | 3.26E+05 | 3.45E+05 | 8.00E+04 | 80.39 |
| | meanDE | 6.86E−05 | 3.89E−01 | 1.54E−03 | 5.38E−02 | 1.25E−01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | DA2MODE | 0.00E+00 | 0.00E+00 | 0.00E+00 | **0.00E+00** | 0.00E+00 | 2.96E+05 | 3.49E+05 | 3.23E+05 | 3.22E+05 | 1.21E+04 | 100.00 |
| F3 | MDE | 2.85E+01 | 1.79E+02 | 9.77E+01 | 9.04E+01 | 4.11E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | WDE | 6.45E+01 | 1.59E+02 | 1.21E+02 | 1.26E+02 | 2.37E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | EODE | 4.02E+00 | 2.08E+02 | 9.84E+01 | 1.21E+02 | 6.60E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | MTDE | 1.93E+01 | 2.15E+02 | 1.01E+02 | 1.17E+02 | 6.19E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | mDEW | 2.96E+01 | 1.28E+02 | 7.90E+01 | 7.25E+01 | 3.35E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | BSD | 5.67E+01 | 1.45E+02 | 7.07E+01 | 7.40E+01 | 1.87E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | QRDE | 2.98E+01 | 1.74E+02 | 1.31E+02 | 1.11E+02 | 5.02E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | BDE | 1.23E+01 | 1.53E+02 | 7.53E+01 | 8.72E+01 | 4.54E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | dFDBLSHADE | 1.16E+02 | 2.03E+02 | 1.47E+02 | 1.43E+02 | 1.78E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | BeSD | 2.87E+01 | 1.44E+02 | 7.06E+01 | 8.57E+01 | 3.49E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | JADEGMO | 1.08E+02 | 2.48E+02 | 2.10E+02 | 2.02E+02 | 3.50E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | JADE | 1.90E−03 | 5.00E+03 | 1.14E+02 | 5.06E+02 | 1.06E+03 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | meanDE | 8.30E−01 | 1.51E+02 | 9.91E+01 | 1.00E+02 | 4.58E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | DA2MODE | 2.22E−07 | 7.85E+01 | 2.50E+01 | **2.50E+01** | 8.76E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| F4 | MDE | 4.28E+01 | 1.11E+02 | 7.46E+01 | 7.44E+01 | 1.67E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | WDE | 1.80E+02 | 2.20E+02 | 2.07E+02 | 2.05E+02 | 9.58E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | EODE | 1.14E+02 | 1.51E+02 | 1.30E+02 | 1.31E+02 | 1.41E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | MTDE | 5.27E+01 | 8.36E+01 | 6.47E+01 | 6.75E+01 | 1.10E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | mDEW | 1.57E+02 | 2.10E+02 | 1.84E+02 | 1.81E+02 | 1.94E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | BSD | 1.16E+02 | 1.39E+02 | 1.36E+02 | 1.34E+02 | 7.18E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | QRDE | 7.90E+01 | 1.66E+02 | 1.04E+02 | 1.12E+02 | 2.06E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | BDE | 6.67E+01 | 1.22E+02 | 1.07E+02 | 9.84E+01 | 2.07E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | dFDBLSHADE | 3.07E+01 | 5.50E+01 | 4.83E+01 | 4.40E+01 | 7.89E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | BeSD | 1.37E+02 | 1.92E+02 | 1.62E+02 | 1.59E+02 | 1.45E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | JADEGMO | 2.34E+02 | 3.28E+02 | 2.55E+02 | 2.66E+02 | 2.96E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | JADE | 1.81E+02 | 6.09E+02 | 3.13E+02 | 3.21E+02 | 1.24E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | meanDE | 5.17E+01 | 9.05E+01 | 6.87E+01 | 6.84E+01 | 9.20E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | DA2MODE | 1.77E+01 | 4.00E+01 | 2.82E+01 | **2.83E+01** | 5.05E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| F5 | MDE | 2.84E−03 | 4.37E−02 | 3.18E−02 | 2.34E−02 | 1.48E−02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | WDE | 4.77E+00 | 7.06E+00 | 5.70E+00 | 6.00E+00 | 7.46E−01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | EODE | 5.52E−03 | 1.14E+00 | 1.98E−01 | 2.09E−01 | 2.06E−01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | MTDE | 6.50E−01 | 1.89E+00 | 1.22E+00 | 1.14E+00 | 3.32E−01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | mDEW | 0.00E+00 | 1.68E−02 | 6.26E−06 | 4.98E−03 | 6.43E−03 | 2.76E+05 | 5.00E+05 | 5.00E+05 | 4.17E+05 | 1.04E+05 | 39.22 |
| | BSD | 0.00E+00 | 0.00E+00 | 0.00E+00 | **0.00E+00** | 0.00E+00 | 1.68E+05 | 1.92E+05 | 1.77E+05 | 1.80E+05 | 8.07E+03 | 100.00 |
| | QRDE | 0.00E+00 | 1.72E−01 | 0.00E+00 | 2.36E−02 | 5.96E−02 | 1.17E+05 | 5.00E+05 | 1.29E+05 | 3.00E+05 | 1.90E+05 | 52.94 |
| | BDE | 0.00E+00 | 0.00E+00 | 0.00E+00 | **0.00E+00** | 0.00E+00 | 2.62E+05 | 3.08E+05 | 2.82E+05 | 2.85E+05 | 1.35E+04 | 100.00 |
| | dFDBLSHADE | 2.28E−01 | 4.44E+00 | 1.57E+00 | 1.82E+00 | 1.21E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | BeSD | 7.57E−04 | 3.09E−03 | 1.03E−03 | 1.35E−03 | 8.12E−04 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | JADEGMO | 8.21E+00 | 3.19E+01 | 1.80E+01 | 1.75E+01 | 7.14E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | JADE | 2.02E−01 | 3.95E+01 | 2.06E+01 | 1.58E+01 | 1.47E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | meanDE | 4.75E−01 | 4.66E+00 | 1.66E+00 | 1.88E+00 | 1.06E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | DA2MODE | 1.92E−07 | 2.96E−02 | 2.50E−05 | 1.65E−03 | 5.55E−03 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| F6 | MDE | 9.89E+01 | 1.48E+02 | 1.17E+02 | 1.20E+02 | 1.55E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | WDE | 2.89E+02 | 4.05E+02 | 3.89E+02 | 3.73E+02 | 3.21E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | EODE | 1.27E+02 | 2.96E+02 | 1.62E+02 | 1.82E+02 | 5.45E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | MTDE | 1.62E+02 | 2.17E+02 | 1.83E+02 | 1.84E+02 | 1.92E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | mDEW | 2.47E+02 | 3.03E+02 | 2.69E+02 | 2.73E+02 | 1.65E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | BSD | 1.33E+02 | 2.15E+02 | 1.81E+02 | 1.77E+02 | 2.32E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | QRDE | 1.47E+02 | 2.17E+02 | 1.60E+02 | 1.71E+02 | 2.00E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | BDE | 1.27E+02 | 1.75E+02 | 1.40E+02 | 1.47E+02 | 1.86E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | dFDBLSHADE | 1.13E+02 | 1.60E+02 | 1.29E+02 | 1.36E+02 | 1.54E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | BeSD | 2.19E+02 | 3.12E+02 | 2.59E+02 | 2.61E+02 | 3.09E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | JADEGMO | 3.30E+02 | 5.51E+02 | 4.19E+02 | 4.19E+02 | 5.22E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | JADE | 3.36E+02 | 1.92E+03 | 4.49E+02 | 5.41E+02 | 3.57E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | meanDE | 1.27E+02 | 1.99E+02 | 1.39E+02 | 1.52E+02 | 2.22E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | DA2MODE | 6.66E+01 | 7.91E+01 | 7.08E+01 | **7.15E+01** | 2.93E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| F7 | MDE | 5.27E+01 | 9.35E+01 | 8.26E+01 | 7.77E+01 | 1.32E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | WDE | 1.66E+02 | 2.21E+02 | 2.08E+02 | 2.04E+02 | 1.22E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | EODE | 7.26E+01 | 2.20E+02 | 1.42E+02 | 1.49E+02 | 3.86E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | MTDE | 4.08E+01 | 9.25E+01 | 5.97E+01 | 6.15E+01 | 1.47E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | mDEW | 1.51E+02 | 2.10E+02 | 1.71E+02 | 1.77E+02 | 1.47E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | BSD | 9.58E+01 | 1.51E+02 | 1.26E+02 | 1.22E+02 | 1.47E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | QRDE | 7.59E+01 | 1.62E+02 | 1.24E+02 | 1.22E+02 | 2.36E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | BDE | 7.86E+01 | 1.47E+02 | 1.13E+02 | 1.13E+02 | 2.12E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | dFDBLSHADE | 2.96E+01 | 5.11E+01 | 4.34E+01 | 4.13E+01 | 7.00E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | BeSD | 1.41E+02 | 1.97E+02 | 1.68E+02 | 1.66E+02 | 1.71E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | JADEGMO | 2.27E+02 | 3.13E+02 | 2.68E+02 | 2.73E+02 | 2.24E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | JADE | 1.93E+02 | 6.11E+02 | 2.95E+02 | 3.18E+02 | 1.41E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | meanDE | 5.07E+01 | 1.00E+02 | 7.56E+01 | 7.53E+01 | 1.70E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | DA2MODE | 1.76E+01 | 3.92E+01 | 2.91E+01 | **2.87E+01** | 5.12E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |

(*continued on next page*)

**Table E.13** (*continued*).

| Fun | Alg. | Error | | | | | Function evaluations | | | | | SR (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No. | Name | Best | Worst | Median | Mean | SD | Best | Worst | Median | Mean | SD | |
| F8 | MDE | 1.33E+01 | 7.90E+01 | 2.11E+01 | 3.52E+01 | 2.18E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | WDE | 5.53E+03 | 7.85E+03 | 7.02E+03 | 6.74E+03 | 8.26E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | EODE | 3.08E+00 | 2.72E+01 | 8.90E+00 | 1.31E+01 | 7.94E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | MTDE | 1.23E+02 | 3.95E+02 | 2.52E+02 | 2.55E+02 | 9.15E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | mDEW | 3.63E+02 | 7.65E+03 | 5.63E+03 | 4.52E+03 | 2.27E+03 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | BSD | 1.84E+03 | 6.21E+03 | 3.14E+03 | 3.25E+03 | 1.36E+03 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | QRDE | 0.00E+00 | 1.69E+02 | 4.54E−01 | 3.21E+01 | 5.87E+01 | 1.19E+05 | 5.00E+05 | 5.00E+05 | 3.67E+05 | 1.82E+05 | 35.29 |
| | BDE | 8.45E+00 | 5.18E+02 | 7.38E+01 | 8.34E+01 | 8.37E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | dFDBLSHADE | 1.45E+01 | 4.60E+02 | 9.30E+01 | 1.22E+02 | 9.85E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | BeSD | 2.57E+01 | 2.68E+03 | 4.62E+02 | 7.49E+02 | 8.91E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | JADEGMO | 2.13E+03 | 2.37E+04 | 5.42E+03 | 6.69E+03 | 5.99E+03 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | JADE | 7.61E+02 | 1.34E+04 | 3.47E+03 | 3.96E+03 | 3.71E+03 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | meanDE | 4.72E+01 | 4.96E+02 | 1.26E+02 | 1.99E+02 | 1.59E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | DA2MODE | 0.00E+00 | 5.44E−01 | 0.00E+00 | **6.37E−02** | 1.31E−01 | 1.80E+05 | 5.00E+05 | 1.89E+05 | 2.92E+05 | 1.49E+05 | 66.67 |
| F9 | MDE | 3.97E+03 | 6.27E+03 | 5.20E+03 | 5.12E+03 | 6.71E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | WDE | 4.05E+03 | 5.19E+03 | 4.78E+03 | 4.71E+03 | 2.61E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | EODE | 4.15E+03 | 9.26E+03 | 6.34E+03 | 6.30E+03 | 1.35E+03 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | MTDE | 5.16E+03 | 7.90E+03 | 6.13E+03 | 6.29E+03 | 8.07E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | mDEW | 3.71E+03 | 4.66E+03 | 4.29E+03 | 4.16E+03 | 3.23E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | BSD | 3.85E+03 | 5.00E+03 | 4.28E+03 | 4.43E+03 | 4.11E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | QRDE | 5.43E+03 | 9.45E+03 | 7.69E+03 | 7.28E+03 | 1.18E+03 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | BDE | 2.31E+03 | 4.64E+03 | 3.78E+03 | 3.66E+03 | 8.29E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | dFDBLSHADE | 2.51E+03 | 3.57E+03 | 3.42E+03 | 3.32E+03 | 3.15E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | BeSD | 5.22E+03 | 6.36E+03 | 5.70E+03 | 5.79E+03 | 3.86E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | JADEGMO | 8.42E+03 | 1.25E+04 | 9.84E+03 | 1.01E+04 | 1.10E+03 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | JADE | 1.07E+04 | 1.44E+04 | 1.17E+04 | 1.20E+04 | 1.16E+03 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | meanDE | 2.47E+03 | 7.69E+03 | 4.67E+03 | 4.98E+03 | 1.32E+03 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | DA2MODE | 2.23E+03 | 3.74E+03 | 3.29E+03 | **3.21E+03** | 3.37E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| F10 | MDE | 4.31E+01 | 1.10E+02 | 6.90E+01 | 6.95E+01 | 1.87E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | WDE | 1.29E+02 | 2.05E+02 | 1.63E+02 | 1.65E+02 | 2.59E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | EODE | 4.11E+01 | 2.04E+02 | 7.90E+01 | 8.07E+01 | 3.54E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | MTDE | 5.28E+01 | 2.26E+02 | 1.17E+02 | 1.12E+02 | 4.84E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | mDEW | 3.28E+01 | 6.97E+01 | 5.16E+01 | 5.29E+01 | 1.05E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | BSD | 4.48E+01 | 1.08E+02 | 5.24E+01 | 6.55E+01 | 2.18E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | QRDE | 7.09E+01 | 7.80E+03 | 8.80E+02 | 2.05E+03 | 2.25E+03 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | BDE | 5.21E+01 | 7.89E+01 | 6.40E+01 | 6.38E+01 | 9.35E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | dFDBLSHADE | 1.44E+02 | 2.87E+02 | 1.85E+02 | 1.88E+02 | 3.82E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | BeSD | 4.93E+01 | 1.23E+02 | 9.09E+01 | 9.27E+01 | 1.95E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | JADEGMO | 2.65E+02 | 2.74E+03 | 4.02E+02 | 7.11E+02 | 7.81E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | JADE | 2.03E+02 | 2.35E+03 | 2.37E+02 | 6.39E+02 | 7.86E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | meanDE | 7.89E+01 | 2.13E+02 | 1.32E+02 | 1.47E+02 | 4.38E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | DA2MODE | 1.34E+01 | 6.47E+01 | 3.03E+01 | **3.02E+01** | 1.00E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| F11 | MDE | 3.12E+05 | 1.80E+06 | 6.14E+05 | 7.84E+05 | 4.85E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | WDE | 2.36E+05 | 5.83E+05 | 4.39E+05 | 4.46E+05 | 1.09E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | EODE | 3.86E+04 | 2.71E+05 | 9.61E+04 | 1.07E+05 | 6.14E+04 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | MTDE | 4.40E+04 | 1.81E+05 | 7.52E+04 | 8.56E+04 | 4.52E+04 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | mDEW | 8.05E+05 | 2.82E+06 | 1.60E+06 | 1.76E+06 | 6.30E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | BSD | 2.03E+05 | 6.81E+05 | 5.36E+05 | 4.89E+05 | 1.55E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | QRDE | 1.54E+05 | 3.97E+06 | 1.25E+06 | 1.70E+06 | 1.38E+06 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | BDE | 7.29E+04 | 4.39E+05 | 1.72E+05 | 2.02E+05 | 1.06E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | dFDBLSHADE | 2.28E+05 | 2.17E+06 | 9.96E+05 | 1.19E+06 | 6.85E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | BeSD | 5.04E+04 | 4.00E+05 | 1.32E+05 | 1.74E+05 | 1.09E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | JADEGMO | 5.08E+05 | 3.61E+07 | 3.38E+06 | 1.06E+07 | 1.24E+07 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | JADE | 7.35E+03 | 3.46E+09 | 1.88E+04 | 6.58E+08 | 1.19E+09 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | meanDE | 2.29E+04 | 3.15E+05 | 6.08E+04 | 1.14E+05 | 1.08E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | DA2MODE | 1.05E+03 | 3.30E+03 | 1.97E+03 | **2.01E+03** | 5.31E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| F12 | MDE | 2.34E+02 | 1.08E+04 | 1.60E+03 | 3.59E+03 | 3.59E+03 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | WDE | 6.42E+02 | 8.58E+02 | 7.04E+02 | 7.27E+02 | 7.23E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | EODE | 3.66E+01 | 2.98E+04 | 7.40E+02 | 3.93E+03 | 5.40E+03 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | MTDE | 2.23E+03 | 2.23E+04 | 7.56E+03 | 1.11E+04 | 7.34E+03 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | mDEW | 1.94E+02 | 1.41E+03 | 2.75E+02 | 4.69E+02 | 3.79E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | BSD | 2.26E+02 | 5.18E+03 | 5.75E+02 | 1.05E+03 | 1.29E+03 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | QRDE | 9.29E+02 | 2.29E+04 | 8.11E+03 | 1.01E+04 | 7.49E+03 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | BDE | 1.60E+02 | 7.39E+03 | 5.26E+03 | 4.38E+03 | 2.63E+03 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | dFDBLSHADE | 1.76E+03 | 1.07E+04 | 2.71E+03 | 4.49E+03 | 2.52E+03 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | BeSD | 2.01E+02 | 3.49E+03 | 5.91E+02 | 6.51E+02 | 7.11E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | JADEGMO | 8.48E+03 | 1.28E+09 | 3.03E+04 | 2.52E+07 | 1.79E+08 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | JADE | 6.90E+02 | 5.42E+08 | 8.26E+03 | 7.05E+07 | 1.40E+08 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | meanDE | 6.90E+02 | 1.51E+04 | 4.25E+03 | 5.29E+03 | 4.32E+03 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | DA2MODE | 2.03E+01 | 1.29E+02 | 5.28E+01 | **7.22E+01** | 3.55E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| F13 | MDE | 3.60E+03 | 1.49E+05 | 3.68E+04 | 4.77E+04 | 4.51E+04 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | WDE | 1.27E+02 | 1.96E+02 | 1.55E+02 | 1.60E+02 | 2.00E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | EODE | 2.08E+02 | 7.02E+03 | 8.81E+02 | 2.09E+03 | 2.20E+03 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | MTDE | 1.46E+02 | 6.43E+02 | 2.38E+02 | 3.33E+02 | 1.88E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | mDEW | 1.06E+02 | 4.65E+03 | 1.16E+03 | 1.33E+03 | 1.26E+03 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | BSD | 3.61E+03 | 1.12E+05 | 4.09E+04 | 5.30E+04 | 3.57E+04 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | QRDE | 4.52E+04 | 3.15E+06 | 7.64E+05 | 9.86E+05 | 9.50E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | BDE | 2.76E+02 | 6.05E+03 | 3.51E+03 | 3.28E+03 | 1.92E+03 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | dFDBLSHADE | 6.72E+02 | 3.80E+04 | 3.88E+03 | 7.34E+03 | 1.05E+04 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | BeSD | 9.63E+01 | 1.82E+02 | 1.24E+02 | 1.28E+02 | 2.07E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | JADEGMO | 3.94E+02 | 7.07E+03 | 8.33E+02 | 1.57E+03 | 1.71E+03 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | JADE | 1.99E+02 | 5.69E+04 | 1.16E+03 | 1.27E+04 | 1.87E+04 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | meanDE | 4.94E+02 | 4.09E+04 | 8.70E+02 | 7.27E+03 | 1.47E+04 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | DA2MODE | 1.64E+01 | 3.36E+01 | 2.80E+01 | **2.78E+01** | 2.50E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |

(*continued on next page*)

**Table E.13** (*continued*).

| Fun | Alg. | Error | | | | | Function evaluations | | | | | SR (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No. | Name | Best | Worst | Median | Mean | SD | Best | Worst | Median | Mean | SD | |
| F14 | MDE | 1.33E+02 | 1.38E+04 | 2.58E+03 | 2.91E+03 | 2.52E+03 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | WDE | 1.19E+02 | 1.99E+02 | 1.55E+02 | 1.58E+02 | 2.49E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | EODE | 4.25E+02 | 1.75E+04 | 3.48E+03 | 5.44E+03 | 4.71E+03 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | MTDE | 3.83E+02 | 1.11E+04 | 1.26E+03 | 2.20E+03 | 2.75E+03 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | mDEW | 5.28E+01 | 1.77E+02 | 7.67E+01 | 9.27E+01 | 4.33E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | BSD | 1.93E+02 | 1.36E+04 | 4.74E+03 | 6.53E+03 | 4.85E+03 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | QRDE | 1.26E+03 | 2.72E+04 | 5.41E+03 | 8.85E+03 | 7.35E+03 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | BDE | 6.37E+01 | 8.09E+03 | 6.24E+02 | 1.39E+03 | 2.00E+03 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | dFDBLSHADE | 3.78E+02 | 1.97E+04 | 2.01E+03 | 3.98E+03 | 5.63E+03 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | BeSD | 1.58E+03 | 7.64E+03 | 4.71E+03 | 4.37E+03 | 2.12E+03 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | JADEGMO | 1.47E+03 | 3.29E+04 | 7.85E+03 | 1.11E+04 | 8.92E+03 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | JADE | 1.70E+02 | 4.81E+05 | 5.74E+02 | 8.30E+04 | 1.75E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | meanDE | 3.89E+02 | 9.16E+03 | 1.70E+03 | 2.88E+03 | 3.12E+03 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | DA2MODE | 1.43E+01 | 6.41E+01 | 2.63E+01 | **2.92E+01** | 8.89E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| F15 | MDE | 8.56E+02 | 2.03E+03 | 1.19E+03 | 1.25E+03 | 2.81E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | WDE | 5.70E+02 | 1.45E+03 | 1.22E+03 | 1.14E+03 | 2.55E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | EODE | 7.20E+02 | 2.15E+03 | 1.23E+03 | 1.23E+03 | 3.70E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | MTDE | 4.67E+02 | 1.56E+03 | 1.21E+03 | 1.10E+03 | 3.86E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | mDEW | 8.78E+02 | 1.56E+03 | 1.35E+03 | 1.26E+03 | 2.08E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | BSD | 8.60E+02 | 1.28E+03 | 1.12E+03 | 1.07E+03 | 1.11E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | QRDE | 1.32E+03 | 2.86E+03 | 2.05E+03 | 2.08E+03 | 5.46E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | BDE | 8.47E+02 | 1.46E+03 | 1.05E+03 | 1.07E+03 | 2.05E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | dFDBLSHADE | 1.46E+02 | 6.23E+02 | 4.46E+02 | 3.91E+02 | 1.70E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | BeSD | 6.89E+02 | 1.03E+03 | 8.54E+02 | 8.73E+02 | 1.14E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | JADEGMO | 1.10E+03 | 2.23E+03 | 1.94E+03 | 1.86E+03 | 3.05E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | JADE | 1.43E+03 | 2.92E+03 | 2.06E+03 | 2.04E+03 | 4.24E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | meanDE | 2.51E+02 | 9.96E+02 | 4.31E+02 | 4.45E+02 | 2.23E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | DA2MODE | 1.47E+02 | 5.66E+02 | 3.80E+02 | **3.53E+02** | 1.00E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| F16 | MDE | 3.90E+02 | 1.15E+03 | 9.71E+02 | 8.76E+02 | 2.38E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | WDE | 4.29E+02 | 8.88E+02 | 8.34E+02 | 7.42E+02 | 1.60E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | EODE | 6.03E+02 | 1.24E+03 | 8.69E+02 | 8.90E+02 | 1.79E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | MTDE | 2.96E+02 | 1.11E+03 | 8.96E+02 | 8.40E+02 | 2.72E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | mDEW | 4.47E+02 | 1.10E+03 | 7.89E+02 | 7.76E+02 | 2.01E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | BSD | 4.80E+02 | 1.23E+03 | 8.51E+02 | 8.62E+02 | 2.74E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | QRDE | 9.20E+02 | 1.82E+03 | 1.35E+03 | 1.25E+03 | 2.82E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | BDE | 3.20E+02 | 9.68E+02 | 7.60E+02 | 6.77E+02 | 1.99E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | dFDBLSHADE | 1.17E+02 | 5.90E+02 | 3.79E+02 | 3.74E+02 | 1.18E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | BeSD | 6.61E+02 | 9.21E+02 | 7.50E+02 | 7.74E+02 | 8.84E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | JADEGMO | 1.05E+03 | 1.83E+03 | 1.31E+03 | 1.37E+03 | 2.00E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | JADE | 7.69E+02 | 1.59E+03 | 1.08E+03 | 1.13E+03 | 2.76E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | meanDE | 4.38E+02 | 1.27E+03 | 7.35E+02 | 7.99E+02 | 2.72E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | DA2MODE | 2.54E+02 | 5.40E+02 | 3.77E+02 | **3.73E+02** | 8.77E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| F17 | MDE | 1.02E+05 | 5.09E+05 | 2.22E+05 | 2.71E+05 | 1.20E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | WDE | 1.52E+03 | 5.32E+03 | 3.85E+03 | 3.90E+03 | 8.96E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | EODE | 4.19E+04 | 2.10E+05 | 6.53E+04 | 8.68E+04 | 5.41E+04 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | MTDE | 9.68E+02 | 1.29E+04 | 2.56E+03 | 4.35E+03 | 3.97E+03 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | mDEW | 1.23E+04 | 5.69E+04 | 2.35E+04 | 2.79E+04 | 1.42E+04 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | BSD | 6.95E+04 | 9.65E+05 | 3.72E+05 | 3.61E+05 | 2.42E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | QRDE | 2.48E+05 | 4.27E+06 | 1.01E+06 | 1.54E+06 | 1.26E+06 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | BDE | 2.17E+04 | 5.19E+04 | 2.62E+04 | 3.05E+04 | 1.07E+04 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | dFDBLSHADE | 1.86E+04 | 8.63E+04 | 3.31E+04 | 3.96E+04 | 2.08E+04 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | BeSD | 2.02E+03 | 1.88E+04 | 8.69E+03 | 8.21E+03 | 4.51E+03 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | JADEGMO | 2.33E+04 | 8.00E+06 | 8.82E+04 | 1.02E+06 | 2.57E+06 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | JADE | 5.48E+02 | 1.92E+06 | 5.44E+03 | 2.99E+05 | 5.24E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | meanDE | 1.73E+03 | 4.71E+04 | 1.99E+04 | 2.17E+04 | 1.29E+04 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | DA2MODE | 2.31E+01 | 3.81E+01 | 2.89E+01 | **2.90E+01** | 3.57E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| F18 | MDE | 4.22E+03 | 2.74E+04 | 1.55E+04 | 1.42E+04 | 8.06E+03 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | WDE | 4.08E+01 | 5.34E+01 | 5.16E+01 | 4.97E+01 | 4.07E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | EODE | 3.65E+03 | 3.47E+04 | 2.33E+04 | 2.02E+04 | 1.17E+04 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | MTDE | 1.75E+02 | 1.10E+03 | 3.12E+02 | 3.66E+02 | 2.15E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | mDEW | 2.07E+01 | 6.25E+01 | 4.41E+01 | 4.39E+01 | 1.34E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | BSD | 8.31E+01 | 2.84E+03 | 1.15E+02 | 3.99E+02 | 6.10E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | QRDE | 1.67E+03 | 4.22E+04 | 9.06E+03 | 1.32E+04 | 1.11E+04 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | BDE | 2.41E+02 | 2.44E+04 | 8.18E+03 | 1.01E+04 | 8.09E+03 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | dFDBLSHADE | 3.73E+02 | 3.61E+04 | 3.93E+03 | 8.73E+03 | 1.10E+04 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | BeSD | 3.49E+01 | 1.52E+04 | 1.18E+04 | 7.07E+03 | 6.66E+03 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | JADEGMO | 2.18E+02 | 9.49E+04 | 5.01E+02 | 8.95E+03 | 2.58E+04 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | JADE | 9.63E+01 | 5.89E+06 | 1.21E+04 | 1.08E+06 | 2.01E+06 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | meanDE | 1.04E+02 | 2.93E+04 | 6.85E+02 | 7.45E+03 | 1.04E+04 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | DA2MODE | 1.36E+01 | 2.54E+01 | 1.84E+01 | **1.88E+01** | 3.12E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| F19 | MDE | 3.93E+02 | 1.10E+03 | 5.66E+02 | 6.72E+02 | 2.18E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | WDE | 2.28E+02 | 7.95E+02 | 4.58E+02 | 5.13E+02 | 1.77E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | EODE | 5.77E+02 | 1.42E+03 | 8.80E+02 | 8.29E+02 | 1.58E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | MTDE | 5.31E+02 | 9.84E+02 | 6.42E+02 | 6.98E+02 | 1.70E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | mDEW | 3.87E+02 | 8.36E+02 | 5.39E+02 | 5.63E+02 | 1.36E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | BSD | 2.67E+02 | 9.15E+02 | 6.66E+02 | 6.49E+02 | 1.93E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | QRDE | 6.88E+02 | 1.84E+03 | 1.27E+03 | 1.26E+03 | 3.33E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | BDE | 3.48E+02 | 8.35E+02 | 5.77E+02 | 5.64E+02 | 1.23E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | dFDBLSHADE | 1.20E+02 | 4.81E+02 | 2.45E+02 | 2.53E+02 | 1.09E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | BeSD | 1.72E+02 | 6.33E+02 | 3.93E+02 | 3.76E+02 | 1.05E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | JADEGMO | 5.81E+02 | 2.00E+03 | 9.94E+02 | 1.16E+03 | 3.98E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | JADE | 7.42E+02 | 2.18E+03 | 9.74E+02 | 1.22E+03 | 5.00E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | meanDE | 1.79E+02 | 6.79E+02 | 2.78E+02 | 3.32E+02 | 1.60E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | DA2MODE | 8.65E+01 | 2.73E+02 | 1.29E+02 | **1.41E+02** | 4.08E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| F20 | MDE | 2.50E+02 | 3.13E+02 | 2.73E+02 | 2.72E+02 | 1.91E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | WDE | 3.43E+02 | 4.30E+02 | 4.03E+02 | 4.03E+02 | 2.21E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | EODE | 2.50E+02 | 3.49E+02 | 3.07E+02 | 3.02E+02 | 2.65E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | MTDE | 2.60E+02 | 2.96E+02 | 2.71E+02 | 2.75E+02 | 1.00E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | mDEW | 3.44E+02 | 4.23E+02 | 3.94E+02 | 3.87E+02 | 2.29E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | BSD | 2.97E+02 | 3.29E+02 | 3.21E+02 | 3.14E+02 | 1.25E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | QRDE | 2.86E+02 | 3.50E+02 | 3.09E+02 | 3.15E+02 | 2.12E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | BDE | 2.74E+02 | 3.69E+02 | 2.93E+02 | 3.02E+02 | 2.64E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | dFDBLSHADE | 2.35E+02 | 2.58E+02 | 2.47E+02 | 2.46E+02 | 6.51E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | BeSD | 3.19E+02 | 3.52E+02 | 3.31E+02 | 3.33E+02 | 8.34E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | JADEGMO | 3.94E+02 | 6.07E+02 | 4.88E+02 | 4.93E+02 | 6.19E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | JADE | 4.09E+02 | 8.12E+02 | 4.83E+02 | 5.47E+02 | 1.60E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | meanDE | 2.50E+02 | 3.05E+02 | 2.77E+02 | 2.76E+02 | 1.30E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | DA2MODE | 2.11E+02 | 2.24E+02 | 2.17E+02 | **2.18E+02** | 2.99E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |

(*continued on next page*)

**Table E.13** (*continued*).

| Fun | Alg. | Error | | | | | Function evaluations | | | | | SR (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No. | Name | Best | Worst | Median | Mean | SD | Best | Worst | Median | Mean | SD | |
| F21 | MDE | 4.46E+03 | 7.03E+03 | 4.92E+03 | 5.54E+03 | 8.92E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | WDE | 1.53E+02 | 5.56E+03 | 5.04E+03 | 3.79E+03 | 2.26E+03 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | EODE | 1.00E+02 | 9.79E+03 | 7.32E+03 | 6.07E+03 | 2.72E+03 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | MTDE | 5.70E+03 | 7.62E+03 | 6.61E+03 | 6.71E+03 | 6.20E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | mDEW | 1.00E+02 | 5.31E+03 | 5.15E+03 | 4.35E+03 | 1.73E+03 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | BSD | 1.00E+02 | 5.53E+03 | 5.48E+03 | 4.51E+03 | 1.94E+03 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | QRDE | 5.03E+03 | 8.82E+03 | 7.06E+03 | 7.13E+03 | 1.04E+03 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | BDE | 3.71E+03 | 5.70E+03 | 4.53E+03 | 4.40E+03 | 6.75E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | dFDBLSHADE | 3.13E+03 | 4.41E+03 | 3.86E+03 | 3.85E+03 | 3.76E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | BeSD | 1.00E+02 | 6.75E+03 | 1.00E+02 | 1.35E+03 | 2.56E+03 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | JADEGMO | 7.37E+03 | 1.36E+04 | 1.07E+04 | 1.10E+04 | 1.88E+03 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | JADE | 1.03E+02 | 1.22E+04 | 1.08E+04 | 9.80E+03 | 2.80E+03 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | meanDE | 1.00E+02 | 6.55E+03 | 5.13E+03 | 4.39E+03 | 2.32E+03 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | DA2MODE | 1.00E+02 | 1.04E+02 | 1.00E+02 | **1.00E+02** | 6.48E−01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| F22 | MDE | 4.78E+02 | 5.32E+02 | 5.12E+02 | 5.05E+02 | 1.84E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | WDE | 6.46E+02 | 7.30E+02 | 6.93E+02 | 6.91E+02 | 2.73E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | EODE | 5.02E+02 | 6.10E+02 | 5.32E+02 | 5.28E+02 | 1.82E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | MTDE | 4.90E+02 | 5.44E+02 | 5.11E+02 | 5.18E+02 | 1.67E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | mDEW | 5.82E+02 | 6.85E+02 | 6.29E+02 | 6.24E+02 | 2.47E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | BSD | 5.42E+02 | 6.16E+02 | 5.79E+02 | 5.79E+02 | 2.14E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | QRDE | 4.95E+02 | 6.22E+02 | 5.34E+02 | 5.34E+02 | 3.40E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | BDE | 4.88E+02 | 5.98E+02 | 5.37E+02 | 5.35E+02 | 3.47E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | dFDBLSHADE | 4.49E+02 | 5.38E+02 | 4.98E+02 | 4.88E+02 | 2.22E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | BeSD | 5.58E+02 | 6.62E+02 | 5.97E+02 | 5.97E+02 | 2.61E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | JADEGMO | 7.35E+02 | 1.35E+03 | 8.52E+02 | 8.81E+02 | 1.67E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | JADE | 6.38E+02 | 1.13E+03 | 7.20E+02 | 7.57E+02 | 1.37E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | meanDE | 4.80E+02 | 5.55E+02 | 5.12E+02 | 5.16E+02 | 2.66E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | DA2MODE | 4.32E+02 | 4.58E+02 | 4.43E+02 | **4.43E+02** | 5.45E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| F23 | MDE | 5.67E+02 | 6.14E+02 | 5.88E+02 | 5.91E+02 | 1.48E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | WDE | 8.03E+02 | 9.06E+02 | 8.44E+02 | 8.37E+02 | 2.66E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | EODE | 5.39E+02 | 6.39E+02 | 5.71E+02 | 5.79E+02 | 2.59E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | MTDE | 5.47E+02 | 6.05E+02 | 5.78E+02 | 5.73E+02 | 1.90E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | mDEW | 7.18E+02 | 8.88E+02 | 7.98E+02 | 7.99E+02 | 5.26E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | BSD | 6.54E+02 | 7.45E+02 | 7.01E+02 | 7.10E+02 | 3.18E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | QRDE | 5.95E+02 | 7.27E+02 | 6.53E+02 | 6.62E+02 | 4.42E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | BDE | 5.90E+02 | 7.68E+02 | 6.53E+02 | 6.70E+02 | 4.83E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | dFDBLSHADE | 5.39E+02 | 5.81E+02 | 5.55E+02 | 5.59E+02 | 1.36E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | BeSD | 6.09E+02 | 7.13E+02 | 6.62E+02 | 6.63E+02 | 3.47E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | JADEGMO | 7.33E+02 | 1.28E+03 | 8.55E+02 | 9.30E+02 | 1.75E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | JADE | 6.65E+02 | 8.70E+02 | 6.97E+02 | 7.31E+02 | 5.73E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | meanDE | 5.50E+02 | 6.40E+02 | 5.95E+02 | 5.95E+02 | 2.50E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | DA2MODE | 5.15E+02 | 5.32E+02 | 5.22E+02 | **5.23E+02** | 3.30E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| F24 | MDE | 5.24E+02 | 5.85E+02 | 5.62E+02 | 5.59E+02 | 1.52E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | WDE | 4.97E+02 | 5.66E+02 | 5.40E+02 | 5.34E+02 | 1.68E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | EODE | 4.80E+02 | 5.94E+02 | 5.53E+02 | 5.49E+02 | 3.42E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | MTDE | 4.80E+02 | 5.61E+02 | 5.26E+02 | 5.30E+02 | 2.83E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | mDEW | 4.95E+02 | 5.39E+02 | 5.21E+02 | 5.15E+02 | 1.62E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | BSD | 5.72E+02 | 6.09E+02 | 5.86E+02 | 5.92E+02 | 1.33E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | QRDE | 4.76E+02 | 5.63E+02 | 4.80E+02 | 5.09E+02 | 3.32E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | BDE | 4.56E+02 | 5.83E+02 | 5.29E+02 | 5.37E+02 | 3.80E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | dFDBLSHADE | 5.29E+02 | 5.94E+02 | 5.65E+02 | 5.64E+02 | 1.85E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | BeSD | 5.11E+02 | 5.91E+02 | 5.71E+02 | 5.65E+02 | 2.44E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | JADEGMO | 5.16E+02 | 6.09E+02 | 5.51E+02 | 5.52E+02 | 2.82E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | JADE | 4.61E+02 | 2.12E+03 | 1.22E+03 | 1.13E+03 | 6.25E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | meanDE | 4.61E+02 | 5.84E+02 | 5.54E+02 | 5.42E+02 | 3.68E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | DA2MODE | 4.31E+02 | 4.65E+02 | 4.31E+02 | **4.32E+02** | 4.78E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| F25 | MDE | 1.82E+03 | 2.29E+03 | 2.03E+03 | 2.08E+03 | 1.45E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | WDE | 7.87E+02 | 2.04E+03 | 1.14E+03 | 1.27E+03 | 4.37E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | EODE | 1.75E+03 | 2.54E+03 | 2.39E+03 | 2.32E+03 | 1.99E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | MTDE | 1.85E+03 | 2.52E+03 | 1.95E+03 | 2.09E+03 | 2.14E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | mDEW | 3.12E+02 | 3.64E+03 | 1.49E+03 | 1.63E+03 | 1.07E+03 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | BSD | 2.83E+03 | 4.64E+03 | 3.15E+03 | 3.33E+03 | 5.31E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | QRDE | 1.87E+03 | 2.60E+03 | 2.40E+03 | 2.25E+03 | 2.47E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | BDE | 2.24E+03 | 2.94E+03 | 2.37E+03 | 2.44E+03 | 2.03E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | dFDBLSHADE | 1.59E+03 | 2.28E+03 | 1.99E+03 | 1.97E+03 | 1.74E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | BeSD | 3.00E+02 | 3.47E+03 | 2.84E+03 | 2.21E+03 | 1.25E+03 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | JADEGMO | 3.49E+03 | 5.69E+03 | 4.62E+03 | 4.82E+03 | 5.74E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | JADE | 2.16E+03 | 5.76E+03 | 3.89E+03 | 4.03E+03 | 9.33E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | meanDE | 3.00E+02 | 3.33E+03 | 2.23E+03 | 2.25E+03 | 6.88E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | DA2MODE | 3.00E+02 | 3.00E+02 | 3.00E+02 | **3.00E+02** | 3.31E−13 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| F26 | MDE | 5.67E+02 | 6.97E+02 | 6.54E+02 | 6.44E+02 | 3.49E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | WDE | 6.54E+02 | 7.95E+02 | 7.16E+02 | 7.35E+02 | 4.99E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | EODE | 5.62E+02 | 6.70E+02 | 5.95E+02 | 5.95E+02 | 3.02E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | MTDE | 6.05E+02 | 8.07E+02 | 6.37E+02 | 6.66E+02 | 7.24E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | mDEW | 6.51E+02 | 7.48E+02 | 7.06E+02 | 7.08E+02 | 3.45E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | BSD | 6.13E+02 | 7.68E+02 | 6.78E+02 | 6.77E+02 | 5.14E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | QRDE | 5.62E+02 | 7.88E+02 | 6.01E+02 | 6.28E+02 | 5.78E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | BDE | 5.63E+02 | 6.99E+02 | 6.14E+02 | 6.14E+02 | 4.47E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | dFDBLSHADE | 5.78E+02 | 7.68E+02 | 6.77E+02 | 6.74E+02 | 5.04E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | BeSD | 5.63E+02 | 7.48E+02 | 6.08E+02 | 6.09E+02 | 3.69E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | JADEGMO | 7.30E+02 | 1.20E+03 | 9.07E+02 | 9.42E+02 | 1.51E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | JADE | 6.54E+02 | 1.39E+03 | 9.59E+02 | 9.12E+02 | 2.09E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | meanDE | 6.40E+02 | 8.03E+02 | 7.36E+02 | 7.23E+02 | 5.36E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | DA2MODE | 5.00E+02 | 5.00E+02 | 5.00E+02 | **5.00E+02** | 2.31E−04 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| F27 | MDE | 4.70E+02 | 5.15E+02 | 5.03E+02 | 4.99E+02 | 1.57E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | WDE | 4.74E+02 | 5.08E+02 | 4.93E+02 | 4.94E+02 | 1.19E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | EODE | 4.12E+02 | 5.89E+02 | 4.99E+02 | 4.89E+02 | 2.73E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | MTDE | 4.59E+02 | 5.08E+02 | 5.01E+02 | 4.94E+02 | 1.92E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | mDEW | 4.59E+02 | 5.40E+02 | 4.59E+02 | 4.79E+02 | 2.74E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | BSD | 5.07E+02 | 5.18E+02 | 5.08E+02 | 5.09E+02 | 2.78E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | QRDE | 4.59E+02 | 3.56E+03 | 4.78E+02 | 7.62E+02 | 7.36E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | BDE | 4.59E+02 | 5.95E+02 | 5.07E+02 | 5.01E+02 | 2.94E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | dFDBLSHADE | 4.70E+02 | 5.47E+02 | 5.15E+02 | 5.11E+02 | 2.40E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | BeSD | 5.06E+02 | 5.21E+02 | 5.12E+02 | 5.12E+02 | 3.63E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | JADEGMO | 5.05E+02 | 6.64E+03 | 6.09E+02 | 1.49E+03 | 1.82E+03 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | JADE | 4.59E+02 | 2.84E+03 | 4.70E+02 | 8.91E+02 | 8.16E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | meanDE | 4.62E+02 | 5.14E+02 | 4.99E+02 | 4.90E+02 | 1.63E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | DA2MODE | 4.44E+02 | 4.63E+02 | 4.44E+02 | **4.44E+02** | 3.71E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |

(*continued on next page*)

**Table E.13** (*continued*).

| Fun | Alg. | Error | | | | | Function evaluations | | | | | SR (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No. | Name | Best | Worst | Median | Mean | SD | Best | Worst | Median | Mean | SD | |
| F28 | MDE | 3.79E+02 | 1.10E+03 | 5.98E+02 | 6.21E+02 | 2.24E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | WDE | 7.40E+02 | 1.03E+03 | 8.86E+02 | 8.65E+02 | 1.01E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | EODE | 4.71E+02 | 1.06E+03 | 8.21E+02 | 7.89E+02 | 1.46E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | MTDE | 5.51E+02 | 1.32E+03 | 9.70E+02 | 1.01E+03 | 2.46E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | mDEW | 8.24E+02 | 1.21E+03 | 1.02E+03 | 1.03E+03 | 1.25E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | BSD | 4.68E+02 | 1.08E+03 | 7.77E+02 | 7.92E+02 | 1.62E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | QRDE | 3.88E+02 | 1.39E+03 | 9.02E+02 | 8.50E+02 | 2.52E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | BDE | 3.46E+02 | 8.23E+02 | 6.11E+02 | 6.40E+02 | 1.39E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | dFDBLSHADE | 4.26E+02 | 1.53E+03 | 5.35E+02 | 7.35E+02 | 3.36E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | BeSD | 5.56E+02 | 9.50E+02 | 6.49E+02 | 6.70E+02 | 7.96E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | JADEGMO | 1.38E+03 | 3.58E+03 | 1.68E+03 | 1.83E+03 | 4.58E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | JADE | 1.05E+03 | 2.34E+03 | 1.79E+03 | 1.80E+03 | 3.89E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | meanDE | 6.55E+02 | 1.22E+03 | 9.22E+02 | 9.18E+02 | 1.73E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | DA2MODE | 2.56E+02 | 4.22E+02 | 2.79E+02 | **2.87E+02** | 3.37E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| F29 | MDE | 6.05E+05 | 1.28E+06 | 8.44E+05 | 8.17E+05 | 1.50E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | WDE | 8.49E+05 | 1.07E+06 | 9.57E+05 | 9.79E+05 | 5.49E+04 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | EODE | 5.80E+05 | 9.14E+05 | 6.02E+05 | 6.91E+05 | 1.43E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | MTDE | 6.80E+05 | 1.22E+06 | 9.89E+05 | 9.62E+05 | 1.68E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | mDEW | 6.13E+05 | 8.48E+05 | 6.57E+05 | 7.23E+05 | 9.30E+04 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | BSD | 7.36E+05 | 9.14E+05 | 8.07E+05 | 8.21E+05 | 6.34E+04 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | QRDE | 6.03E+05 | 3.08E+06 | 1.24E+06 | 1.29E+06 | 4.72E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | BDE | 7.25E+05 | 1.39E+06 | 7.55E+05 | 8.87E+05 | 2.44E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | dFDBLSHADE | 6.29E+05 | 1.01E+06 | 7.02E+05 | 7.30E+05 | 1.06E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | BeSD | 6.86E+05 | 8.65E+05 | 8.11E+05 | 7.99E+05 | 5.45E+04 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | JADEGMO | 1.37E+06 | 5.94E+06 | 3.24E+06 | 3.19E+06 | 1.46E+06 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | JADE | 5.91E+05 | 7.23E+07 | 6.98E+05 | 1.33E+07 | 2.46E+07 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | meanDE | 5.80E+05 | 7.36E+05 | 6.28E+05 | 6.42E+05 | 5.08E+04 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |
| | DA2MODE | 2.13E+02 | 2.31E+02 | 2.19E+02 | **2.19E+02** | 3.28E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0.00 |

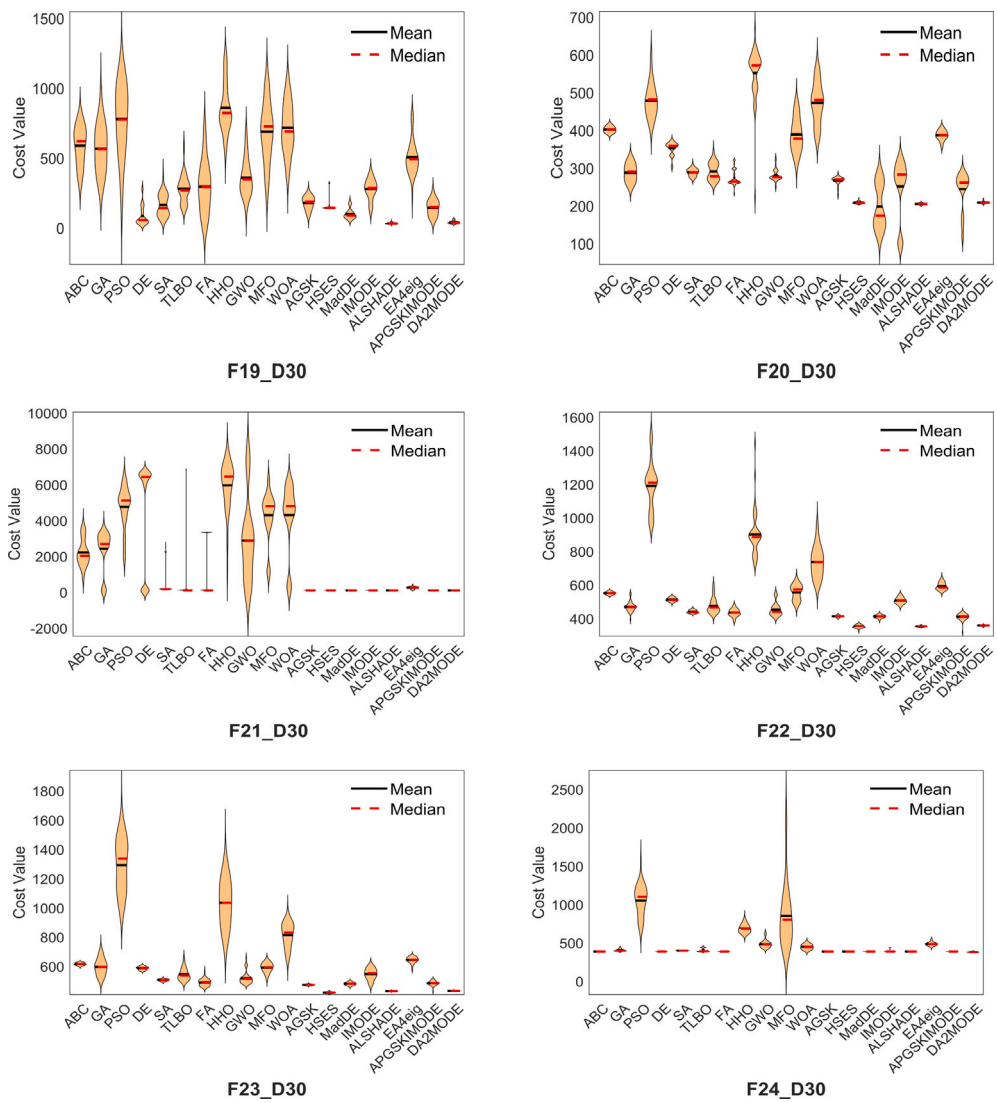



**Fig. F.9d.** Violin plots for the best fitness in 51 runs for all the algorithms in CEC2017–2018, F19–F24 (30D).

**Table E.14**
The results metrics for the error and function evaluation metrics for 14 DE variants, CEC2017–2018 (F1-F5, 100 Dim).

| Fun | Alg. | Error | | | | | Function evaluations | | | | | SR (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No. | Name | Best | Worst | Median | Mean | SD | Best | Worst | Median | Mean | SD | |
| F1 | MDE | 2.26E+01 | 2.39E+04 | 7.70E+03 | 8.65E+03 | 7.48E+03 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | WDE | 1.12E+07 | 1.73E+07 | 1.37E+07 | 1.42E+07 | 2.09E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | EODE | 5.02E+02 | 2.37E+04 | 3.02E+03 | 4.78E+03 | 5.33E+03 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | MTDE | 1.24E+02 | 1.83E+04 | 2.48E+03 | 6.23E+03 | 7.76E+03 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | mDEW | 6.22E−01 | 1.68E+04 | 3.01E+03 | 5.15E+03 | 5.63E+03 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | BSD | 1.10E+00 | 1.00E+04 | 1.20E+03 | 3.19E+03 | 3.86E+03 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | QRDE | 1.26E+02 | 6.13E+04 | 3.26E+03 | 1.12E+04 | 1.72E+04 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | BDE | 1.16E+03 | 8.98E+03 | 3.27E+03 | 4.03E+03 | 2.59E+03 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | dFDBLSHADE | 3.15E+06 | 4.42E+08 | 2.21E+07 | 4.47E+07 | 8.50E+07 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | BeSD | 5.24E+01 | 1.61E+03 | 2.24E+02 | 4.40E+02 | 5.32E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | JADEGMO | 1.94E+08 | 8.88E+09 | 1.60E+09 | 1.85E+09 | 1.80E+09 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | JADE | 4.54E+02 | 7.82E+10 | 4.32E+10 | 3.43E+10 | 2.97E+10 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | meanDE | 2.36E+01 | 3.95E+08 | 2.53E+04 | 6.11E+07 | 1.38E+08 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | DA2MODE | 1.18E−08 | 2.21E−04 | 1.41E−06 | **8.36E−06** | 3.14E−05 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| F2 | MDE | 3.19E+05 | 4.68E+05 | 4.05E+05 | 4.02E+05 | 3.39E+04 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | WDE | 2.74E+05 | 3.77E+05 | 3.40E+05 | 3.38E+05 | 3.12E+04 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | EODE | 3.73E+04 | 6.22E+04 | 5.26E+04 | 5.10E+04 | 8.11E+03 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | MTDE | 4.10E−02 | 4.55E+00 | 1.50E−01 | 5.19E−01 | 1.10E+00 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | mDEW | 9.89E+04 | 1.51E+05 | 1.14E+05 | 1.20E+05 | 1.52E+04 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | BSD | 1.04E+05 | 1.38E+05 | 1.24E+05 | 1.20E+05 | 1.19E+04 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | QRDE | 3.45E+05 | 5.25E+05 | 4.43E+05 | 4.28E+05 | 4.65E+04 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | BDE | 6.53E+03 | 1.47E+04 | 8.91E+03 | 9.59E+03 | 2.66E+03 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | dFDBLSHADE | 3.49E+04 | 9.69E+04 | 5.67E+04 | 5.51E+04 | 1.63E+04 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | BeSD | 6.41E+03 | 1.98E+04 | 1.27E+04 | 1.36E+04 | 3.67E+03 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | JADEGMO | 1.09E+05 | 9.96E+05 | 2.24E+05 | 2.65E+05 | 2.01E+05 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | JADE | 3.40E−06 | 3.35E+05 | 1.14E−03 | 4.77E+04 | 1.09E+05 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | meanDE | 2.45E+02 | 5.01E+03 | 1.67E+03 | 2.04E+03 | 1.70E+03 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | DA2MODE | 3.78E−06 | 2.05E−04 | 4.47E−05 | **5.55E−05** | 4.94E−05 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| F3 | MDE | 1.59E+02 | 2.58E+02 | 2.30E+02 | 2.21E+02 | 2.65E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | WDE | 3.07E+02 | 3.94E+02 | 3.65E+02 | 3.67E+02 | 1.57E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | EODE | 1.50E+02 | 3.42E+02 | 2.25E+02 | 2.19E+02 | 4.67E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | MTDE | 1.75E+02 | 2.90E+02 | 2.52E+02 | 2.35E+02 | 4.30E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | mDEW | 2.49E+02 | 3.42E+02 | 3.09E+02 | 3.11E+02 | 2.61E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | BSD | 1.46E+02 | 2.86E+02 | 2.10E+02 | 2.05E+02 | 4.86E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | QRDE | 1.97E+02 | 3.71E+02 | 2.23E+02 | 2.31E+02 | 2.97E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | BDE | 1.47E+02 | 3.10E+02 | 1.74E+02 | 2.09E+02 | 6.03E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | dFDBLSHADE | 2.87E+02 | 4.91E+02 | 3.37E+02 | 3.69E+02 | 6.62E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | BeSD | 1.55E+02 | 2.99E+02 | 2.44E+02 | 2.38E+02 | 4.60E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | JADEGMO | 4.02E+02 | 7.76E+02 | 5.80E+02 | 5.83E+02 | 1.12E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | JADE | 9.81E+01 | 1.12E+04 | 2.72E+02 | 3.10E+03 | 4.10E+03 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | meanDE | 2.04E+02 | 4.00E+02 | 2.32E+02 | 2.57E+02 | 5.11E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | DA2MODE | 2.51E+01 | 1.75E+02 | 1.05E+02 | **1.04E+02** | 2.62E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| F4 | MDE | 1.26E+02 | 2.17E+02 | 1.58E+02 | 1.63E+02 | 2.65E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | WDE | 5.28E+02 | 6.76E+02 | 6.10E+02 | 6.06E+02 | 5.12E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | EODE | 2.69E+02 | 6.61E+02 | 4.39E+02 | 4.73E+02 | 1.21E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | MTDE | 2.88E+02 | 3.39E+02 | 3.02E+02 | 3.08E+02 | 1.94E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | mDEW | 4.84E+02 | 5.89E+02 | 5.28E+02 | 5.19E+02 | 2.41E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | BSD | 3.44E+02 | 4.30E+02 | 3.77E+02 | 3.80E+02 | 2.76E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | QRDE | 2.38E+02 | 4.13E+02 | 3.29E+02 | 3.15E+02 | 5.50E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | BDE | 2.90E+02 | 3.94E+02 | 3.37E+02 | 3.39E+02 | 3.33E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | dFDBLSHADE | 1.34E+02 | 3.09E+02 | 2.02E+02 | 2.10E+02 | 3.72E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | BeSD | 4.48E+02 | 5.55E+02 | 5.09E+02 | 5.10E+02 | 2.57E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | JADEGMO | 8.03E+02 | 1.08E+03 | 8.97E+02 | 9.17E+02 | 6.88E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | JADE | 6.79E+02 | 1.09E+03 | 8.07E+02 | 8.40E+02 | 1.11E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | meanDE | 1.94E+02 | 3.08E+02 | 2.54E+02 | 2.66E+02 | 3.12E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | DA2MODE | 7.05E+01 | 1.35E+02 | 9.85E+01 | **9.97E+01** | 1.44E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| F5 | MDE | 3.03E−01 | 1.49E+00 | 5.85E−01 | 6.54E−01 | 3.50E−01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | WDE | 8.40E+00 | 1.17E+01 | 9.81E+00 | 1.01E+01 | 1.05E+00 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | EODE | 1.26E+00 | 7.55E+00 | 3.20E+00 | 3.84E+00 | 1.91E+00 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | MTDE | 1.23E+01 | 2.36E+01 | 1.80E+01 | 1.92E+01 | 2.85E+00 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | mDEW | 5.10E−03 | 3.32E−02 | 8.56E−03 | 1.22E−02 | 8.13E−03 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | BSD | 0.00E+00 | 8.82E−07 | 1.17E−08 | 1.50E−07 | 2.46E−07 | 3.61E+05 | 1.00E+06 | 1.00E+06 | 7.54E+05 | 3.09E+05 | 39.22 |
| | QRDE | 3.57E−05 | 4.11E−02 | 2.53E−03 | 1.34E−02 | 1.60E−02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | BDE | 0.00E+00 | 0.00E+00 | 0.00E+00 | **0.00E+00** | 0.00E+00 | 5.64E+05 | 6.93E+05 | 6.26E+05 | 6.24E+05 | 3.34E+04 | 100.00 |
| | dFDBLSHADE | 4.00E+00 | 1.55E+01 | 1.14E+01 | 9.50E+00 | 4.19E+00 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | BeSD | 3.38E−02 | 4.56E−01 | 7.64E−02 | 1.10E−01 | 8.96E−02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | JADEGMO | 3.96E+01 | 7.14E+01 | 5.22E+01 | 5.31E+01 | 8.35E+00 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | JADE | 9.43E+00 | 5.41E+01 | 2.34E+01 | 2.83E+01 | 1.46E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | meanDE | 8.52E+00 | 1.95E+01 | 1.11E+01 | 1.23E+01 | 3.07E+00 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | DA2MODE | 4.64E−03 | 5.57E−01 | 1.84E−01 | 2.00E−01 | 1.08E−01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| F6 | MDE | 2.83E+02 | 3.94E+02 | 3.34E+02 | 3.33E+02 | 3.98E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | WDE | 9.73E+02 | 1.27E+03 | 1.20E+03 | 1.18E+03 | 9.53E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | EODE | 4.70E+02 | 6.65E+02 | 5.60E+02 | 5.44E+02 | 6.14E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | MTDE | 6.95E+02 | 1.13E+03 | 1.05E+03 | 9.66E+02 | 1.42E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | mDEW | 7.72E+02 | 9.14E+02 | 8.70E+02 | 8.55E+02 | 4.42E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | BSD | 4.77E+02 | 6.37E+02 | 5.53E+02 | 5.50E+02 | 4.59E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | QRDE | 3.15E+02 | 5.58E+02 | 3.69E+02 | 4.01E+02 | 6.99E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | BDE | 4.12E+02 | 5.54E+02 | 4.81E+02 | 4.83E+02 | 3.88E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | dFDBLSHADE | 5.01E+02 | 7.40E+02 | 5.23E+02 | 5.69E+02 | 7.86E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | BeSD | 5.54E+02 | 7.59E+02 | 6.99E+02 | 6.92E+02 | 5.08E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | JADEGMO | 1.60E+03 | 2.57E+03 | 2.04E+03 | 2.07E+03 | 3.06E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | JADE | 9.85E+02 | 1.60E+03 | 1.47E+03 | 1.41E+03 | 1.67E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | meanDE | 4.81E+02 | 8.07E+02 | 6.09E+02 | 6.08E+02 | 7.43E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | DA2MODE | 1.56E+02 | 2.07E+02 | 1.74E+02 | **1.74E+02** | 1.05E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| F7 | MDE | 1.40E+02 | 2.16E+02 | 1.75E+02 | 1.74E+02 | 2.04E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | WDE | 5.65E+02 | 7.03E+02 | 6.30E+02 | 6.31E+02 | 4.77E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | EODE | 2.76E+02 | 4.51E+02 | 3.45E+02 | 3.51E+02 | 5.69E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | MTDE | 3.27E+02 | 3.87E+02 | 3.42E+02 | 3.46E+02 | 1.12E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | mDEW | 4.87E+02 | 5.84E+02 | 5.26E+02 | 5.29E+02 | 2.22E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | BSD | 3.24E+02 | 4.35E+02 | 3.98E+02 | 3.84E+02 | 4.23E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | QRDE | 2.58E+02 | 4.69E+02 | 2.96E+02 | 3.38E+02 | 7.63E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | BDE | 2.95E+02 | 4.10E+02 | 3.30E+02 | 3.35E+02 | 3.63E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | dFDBLSHADE | 1.75E+02 | 2.36E+02 | 1.96E+02 | 1.98E+02 | 1.97E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | BeSD | 4.03E+02 | 5.74E+02 | 5.25E+02 | 5.12E+02 | 4.53E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | JADEGMO | 8.52E+02 | 1.14E+03 | 9.16E+02 | 9.39E+02 | 6.59E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | JADE | 6.93E+02 | 9.35E+02 | 8.60E+02 | 8.31E+02 | 8.90E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | meanDE | 2.00E+02 | 3.61E+02 | 2.58E+02 | 2.74E+02 | 4.52E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | DA2MODE | 6.37E+01 | 1.46E+02 | 8.95E+01 | **9.47E+01** | 1.84E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |

(*continued on next page*)

**Table E.14** (*continued*).

| Fun | Alg. | Error | | | | | Function evaluations | | | | | SR (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No. | Name | Best | Worst | Median | Mean | SD | Best | Worst | Median | Mean | SD | |
| F8 | MDE | 2.41E+02 | 1.32E+03 | 6.79E+02 | 7.01E+02 | 3.10E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | WDE | 2.39E+04 | 3.11E+04 | 2.53E+04 | 2.65E+04 | 2.77E+03 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | EODE | 8.60E+02 | 7.60E+03 | 1.69E+03 | 2.79E+03 | 1.96E+03 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | MTDE | 2.87E+03 | 9.17E+03 | 6.34E+03 | 6.12E+03 | 1.81E+03 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | mDEW | 2.28E+04 | 3.38E+04 | 2.63E+04 | 2.62E+04 | 2.48E+03 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | BSD | 1.00E+04 | 2.22E+04 | 1.49E+04 | 1.48E+04 | 3.06E+03 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | QRDE | 8.95E−02 | 6.38E+02 | 5.94E+01 | 1.45E+02 | 1.82E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | BDE | 1.75E+03 | 7.87E+03 | 3.10E+03 | 3.83E+03 | 2.13E+03 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | dFDBLSHADE | 5.42E+02 | 3.62E+03 | 1.97E+03 | 1.99E+03 | 1.09E+03 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | BeSD | 1.29E+04 | 2.11E+04 | 1.85E+04 | 1.80E+04 | 2.20E+03 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | JADEGMO | 1.89E+04 | 4.73E+04 | 3.04E+04 | 3.01E+04 | 8.23E+03 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | JADE | 6.12E+03 | 2.98E+04 | 1.27E+04 | 1.51E+04 | 7.59E+03 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | meanDE | 1.68E+03 | 3.66E+03 | 2.90E+03 | 2.57E+03 | 6.61E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | DA2MODE | 4.48E−01 | 1.15E+01 | 3.63E+00 | **4.21E+00** | 2.22E+00 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| F9 | MDE | 1.13E+04 | 1.54E+04 | 1.24E+04 | 1.26E+04 | 1.07E+03 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | WDE | 1.12E+04 | 1.26E+04 | 1.17E+04 | 1.17E+04 | 4.11E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | EODE | 1.41E+04 | 2.17E+04 | 1.50E+04 | 1.69E+04 | 2.73E+03 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | MTDE | 1.27E+04 | 1.58E+04 | 1.44E+04 | 1.44E+04 | 1.12E+03 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | mDEW | 9.53E+03 | 1.19E+04 | 1.06E+04 | 1.07E+04 | 7.36E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | BSD | 1.01E+04 | 1.27E+04 | 1.13E+04 | 1.13E+04 | 9.03E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | QRDE | 1.36E+04 | 2.72E+04 | 1.77E+04 | 1.79E+04 | 3.49E+03 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | BDE | 9.43E+03 | 1.20E+04 | 1.05E+04 | 1.07E+04 | 9.08E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | dFDBLSHADE | 9.91E+03 | 1.17E+04 | 1.04E+04 | 1.07E+04 | 5.93E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | BeSD | 1.40E+04 | 1.57E+04 | 1.48E+04 | 1.48E+04 | 2.94E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | JADEGMO | 2.18E+04 | 2.86E+04 | 2.35E+04 | 2.42E+04 | 1.86E+03 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | JADE | 1.23E+04 | 3.10E+04 | 2.58E+04 | 2.44E+04 | 5.13E+03 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | meanDE | 1.04E+04 | 1.51E+04 | 1.34E+04 | 1.30E+04 | 1.47E+03 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | DA2MODE | 8.64E+03 | 1.07E+04 | 9.62E+03 | **9.65E+03** | 4.61E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| F10 | MDE | 2.58E+02 | 6.68E+02 | 4.40E+02 | 4.56E+02 | 1.35E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | WDE | 1.17E+03 | 1.59E+03 | 1.46E+03 | 1.42E+03 | 1.42E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | EODE | 1.88E+02 | 6.32E+02 | 2.93E+02 | 3.35E+02 | 1.13E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | MTDE | 5.99E+02 | 9.23E+02 | 6.66E+02 | 6.93E+02 | 9.38E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | mDEW | 2.57E+02 | 6.51E+02 | 5.05E+02 | 5.25E+02 | 8.66E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | BSD | 2.34E+02 | 6.32E+02 | 3.29E+02 | 3.82E+02 | 1.41E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | QRDE | 4.36E+02 | 2.91E+04 | 2.00E+04 | 1.70E+04 | 9.79E+03 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | BDE | 1.54E+02 | 4.24E+02 | 2.35E+02 | **2.52E+02** | 8.29E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | dFDBLSHADE | 1.24E+03 | 5.15E+03 | 1.71E+03 | 2.17E+03 | 1.22E+03 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | BeSD | 2.42E+02 | 4.56E+02 | 3.69E+02 | 3.65E+02 | 5.94E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | JADEGMO | 3.11E+03 | 9.35E+04 | 5.36E+03 | 1.07E+04 | 1.50E+04 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | JADE | 8.33E+02 | 1.30E+05 | 3.89E+04 | 5.15E+04 | 5.37E+04 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | meanDE | 5.96E+02 | 8.64E+03 | 1.12E+03 | 1.24E+03 | 1.12E+03 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | DA2MODE | 1.54E+02 | 6.50E+02 | 2.64E+02 | 2.81E+02 | 9.48E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| F11 | MDE | 8.54E+05 | 2.27E+06 | 1.64E+06 | 1.50E+06 | 4.25E+05 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | WDE | 4.44E+06 | 1.05E+07 | 7.47E+06 | 7.05E+06 | 1.82E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | EODE | 4.02E+05 | 1.49E+06 | 7.14E+05 | 7.87E+05 | 3.08E+05 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | MTDE | 5.51E+05 | 1.04E+06 | 9.55E+05 | 9.00E+05 | 1.72E+05 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | mDEW | 1.30E+07 | 3.15E+07 | 1.74E+07 | 2.13E+07 | 7.01E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | BSD | 5.60E+05 | 1.50E+06 | 1.02E+06 | 1.02E+06 | 2.38E+05 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | QRDE | 1.04E+06 | 5.67E+07 | 3.82E+06 | 1.30E+07 | 1.94E+07 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | BDE | 3.97E+05 | 1.16E+06 | 5.16E+05 | 6.18E+05 | 2.23E+05 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | dFDBLSHADE | 7.05E+06 | 4.89E+07 | 1.24E+07 | 1.61E+07 | 9.21E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | BeSD | 2.45E+05 | 8.35E+05 | 6.46E+05 | 6.38E+05 | 1.45E+05 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | JADEGMO | 2.48E+07 | 2.41E+09 | 9.88E+07 | 4.82E+08 | 7.72E+08 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | JADE | 9.31E+04 | 2.80E+10 | 3.08E+05 | 7.56E+09 | 1.03E+10 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | meanDE | 2.88E+05 | 1.15E+07 | 1.27E+06 | 3.00E+06 | 3.79E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | DA2MODE | 1.25E+04 | 1.04E+05 | 3.44E+04 | **3.78E+04** | 1.91E+04 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| F12 | MDE | 2.38E+02 | 1.32E+04 | 3.13E+03 | 3.84E+03 | 3.37E+03 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | WDE | 1.65E+03 | 1.97E+03 | 1.87E+03 | 1.81E+03 | 1.10E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | EODE | 6.10E+02 | 2.19E+04 | 5.32E+03 | 7.29E+03 | 6.03E+03 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | MTDE | 1.50E+03 | 2.03E+04 | 3.95E+03 | 7.14E+03 | 6.01E+03 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | mDEW | 1.01E+03 | 3.21E+03 | 2.19E+03 | 2.18E+03 | 6.36E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | BSD | 9.72E+02 | 9.34E+03 | 4.20E+03 | 4.00E+03 | 2.67E+03 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | QRDE | 6.13E+02 | 3.06E+04 | 3.02E+03 | 6.45E+03 | 7.85E+03 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | BDE | 1.83E+02 | 6.33E+03 | 2.91E+03 | 3.19E+03 | 2.05E+03 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | dFDBLSHADE | 4.41E+03 | 2.00E+04 | 9.36E+03 | 1.06E+04 | 5.35E+03 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | BeSD | 7.10E+02 | 4.60E+03 | 2.25E+03 | 2.37E+03 | 1.41E+03 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | JADEGMO | 1.50E+04 | 1.24E+05 | 4.07E+04 | 4.56E+04 | 2.65E+04 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | JADE | 2.51E+03 | 1.96E+09 | 9.92E+03 | 3.18E+08 | 6.12E+08 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | meanDE | 3.21E+03 | 1.15E+04 | 7.60E+03 | 7.44E+03 | 2.17E+03 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | DA2MODE | 1.41E+02 | 5.01E+02 | 2.52E+02 | **2.52E+02** | 6.94E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| F13 | MDE | 1.77E+05 | 7.38E+05 | 3.33E+05 | 3.19E+05 | 1.37E+05 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | WDE | 5.07E+02 | 7.30E+02 | 6.18E+02 | 6.20E+02 | 6.53E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | EODE | 1.97E+04 | 1.51E+05 | 5.50E+04 | 6.13E+04 | 2.48E+04 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | MTDE | 7.67E+03 | 1.01E+05 | 6.35E+04 | 5.73E+04 | 3.13E+04 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | mDEW | 2.14E+04 | 6.13E+04 | 4.81E+04 | 4.72E+04 | 1.34E+04 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | BSD | 9.37E+04 | 3.64E+05 | 2.10E+05 | 2.13E+05 | 7.55E+04 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | QRDE | 2.33E+05 | 2.07E+07 | 1.01E+06 | 3.89E+06 | 6.42E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | BDE | 1.51E+04 | 8.99E+04 | 3.65E+04 | 4.08E+04 | 2.41E+04 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | dFDBLSHADE | 3.81E+04 | 2.56E+05 | 9.15E+04 | 1.16E+05 | 6.53E+04 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | BeSD | 6.05E+03 | 4.23E+04 | 2.21E+04 | 2.23E+04 | 9.32E+03 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | JADEGMO | 3.31E+04 | 5.42E+07 | 3.62E+05 | 5.38E+06 | 1.35E+07 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | JADE | 1.12E+03 | 4.47E+06 | 4.95E+03 | 3.95E+05 | 1.02E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | meanDE | 1.53E+04 | 1.08E+05 | 2.98E+04 | 4.23E+04 | 2.53E+04 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | DA2MODE | 8.37E+01 | 2.57E+02 | 1.79E+02 | **1.73E+02** | 4.57E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |

(*continued on next page*)

**Table E.14** (*continued*).

| Fun | Alg. | Error | | | | | Function evaluations | | | | | SR (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No. | Name | Best | Worst | Median | Mean | SD | Best | Worst | Median | Mean | SD | |
| F14 | MDE | 2.41E+02 | 4.34E+03 | 5.95E+02 | 1.17E+03 | 1.25E+03 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | WDE | 4.17E+02 | 5.28E+02 | 4.86E+02 | 4.70E+02 | 3.81E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | EODE | 3.59E+02 | 1.53E+04 | 8.22E+02 | 3.48E+03 | 4.85E+03 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | MTDE | 7.03E+02 | 2.09E+04 | 4.47E+03 | 7.48E+03 | 5.62E+03 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | mDEW | 2.76E+02 | 7.50E+02 | 5.03E+02 | 4.81E+02 | 1.17E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | BSD | 1.61E+02 | 4.11E+03 | 4.70E+02 | 6.76E+02 | 6.86E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | QRDE | 2.52E+02 | 1.67E+04 | 3.36E+03 | 3.60E+03 | 4.66E+03 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | BDE | 7.62E+01 | 4.28E+03 | 5.96E+02 | 1.65E+03 | 1.77E+03 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | dFDBLSHADE | 1.15E+03 | 2.24E+04 | 2.97E+03 | 7.44E+03 | 6.78E+03 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | BeSD | 1.94E+02 | 1.81E+03 | 4.58E+02 | 5.38E+02 | 4.05E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | JADEGMO | 1.39E+03 | 2.71E+04 | 1.46E+04 | 1.41E+04 | 9.61E+03 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | JADE | 5.27E+02 | 1.36E+09 | 5.22E+03 | 1.61E+08 | 3.90E+08 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | meanDE | 3.36E+02 | 8.51E+03 | 8.42E+02 | 1.50E+03 | 1.34E+03 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | DA2MODE | 1.60E+02 | 3.96E+02 | 2.81E+02 | **2.76E+02** | 6.34E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| F15 | MDE | 2.71E+03 | 4.44E+03 | 3.16E+03 | 3.17E+03 | 3.98E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | WDE | 2.77E+03 | 3.50E+03 | 3.24E+03 | 3.17E+03 | 2.26E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | EODE | 3.84E+03 | 6.48E+03 | 4.22E+03 | 4.46E+03 | 9.09E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | MTDE | 2.44E+03 | 3.92E+03 | 2.99E+03 | 3.13E+03 | 4.77E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | mDEW | 2.55E+03 | 3.75E+03 | 3.24E+03 | 3.17E+03 | 4.05E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | BSD | 2.46E+03 | 3.45E+03 | 3.19E+03 | 3.08E+03 | 3.55E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | QRDE | 4.83E+03 | 6.50E+03 | 5.44E+03 | 5.46E+03 | 4.88E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | BDE | 2.34E+03 | 3.91E+03 | 3.50E+03 | 3.18E+03 | 4.73E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | dFDBLSHADE | 1.16E+03 | 2.93E+03 | 1.63E+03 | 1.91E+03 | 6.47E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | BeSD | 2.42E+03 | 3.24E+03 | 2.76E+03 | 2.77E+03 | 2.46E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | JADEGMO | 4.48E+03 | 7.81E+03 | 6.05E+03 | 6.06E+03 | 8.61E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | JADE | 5.11E+03 | 7.58E+03 | 6.30E+03 | 6.41E+03 | 7.94E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | meanDE | 1.85E+03 | 3.09E+03 | 2.46E+03 | 2.34E+03 | 3.64E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | DA2MODE | 6.61E+02 | 2.10E+03 | 1.45E+03 | **1.42E+03** | 4.00E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| F16 | MDE | 1.62E+03 | 3.01E+03 | 2.35E+03 | 2.42E+03 | 4.14E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | WDE | 2.15E+03 | 2.79E+03 | 2.41E+03 | 2.46E+03 | 2.06E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | EODE | 2.21E+03 | 3.59E+03 | 2.93E+03 | 2.89E+03 | 4.22E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | MTDE | 2.12E+03 | 3.68E+03 | 2.79E+03 | 2.74E+03 | 3.94E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | mDEW | 1.82E+03 | 2.87E+03 | 2.33E+03 | 2.42E+03 | 2.58E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | BSD | 1.45E+03 | 2.49E+03 | 2.25E+03 | 2.10E+03 | 3.84E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | QRDE | 2.70E+03 | 4.34E+03 | 3.95E+03 | 3.81E+03 | 5.80E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | BDE | 1.63E+03 | 2.93E+03 | 2.37E+03 | 2.24E+03 | 3.87E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | dFDBLSHADE | 6.84E+02 | 1.86E+03 | 1.40E+03 | 1.41E+03 | 3.14E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | BeSD | 1.35E+03 | 2.21E+03 | 1.69E+03 | 1.70E+03 | 2.43E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | JADEGMO | 3.20E+03 | 5.39E+03 | 4.22E+03 | 4.24E+03 | 7.46E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | JADE | 2.78E+03 | 4.49E+03 | 3.36E+03 | 3.48E+03 | 4.99E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | meanDE | 1.63E+03 | 2.86E+03 | 1.92E+03 | 2.03E+03 | 3.68E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | DA2MODE | 6.70E+02 | 2.09E+03 | 1.29E+03 | **1.24E+03** | 2.82E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| F17 | MDE | 4.44E+05 | 1.89E+06 | 1.07E+06 | 1.06E+06 | 3.91E+05 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | WDE | 2.75E+04 | 8.31E+04 | 6.27E+04 | 6.50E+04 | 1.55E+04 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | EODE | 1.57E+05 | 5.52E+05 | 4.18E+05 | 3.77E+05 | 1.23E+05 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | MTDE | 3.15E+04 | 1.25E+05 | 1.06E+05 | 9.69E+04 | 2.82E+04 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | mDEW | 5.32E+05 | 2.33E+06 | 1.11E+06 | 1.30E+06 | 5.82E+05 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | BSD | 2.33E+05 | 6.39E+05 | 4.36E+05 | 4.22E+05 | 1.42E+05 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | QRDE | 1.62E+06 | 8.43E+06 | 2.68E+06 | 3.71E+06 | 2.31E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | BDE | 6.82E+04 | 1.90E+05 | 1.08E+05 | 1.23E+05 | 3.97E+04 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | dFDBLSHADE | 7.76E+04 | 6.92E+05 | 2.41E+05 | 2.78E+05 | 1.28E+05 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | BeSD | 3.43E+04 | 1.24E+05 | 6.15E+04 | 7.06E+04 | 2.97E+04 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | JADEGMO | 1.82E+05 | 1.77E+07 | 4.44E+05 | 2.94E+06 | 5.52E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | JADE | 6.95E+03 | 3.52E+06 | 1.06E+04 | 7.72E+05 | 1.30E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | meanDE | 4.45E+04 | 1.99E+05 | 9.40E+04 | 1.19E+05 | 4.49E+04 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | DA2MODE | 1.55E+02 | 7.30E+02 | 2.76E+02 | **2.93E+02** | 1.05E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| F18 | MDE | 2.42E+02 | 1.13E+04 | 1.36E+03 | 2.71E+03 | 3.71E+03 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | WDE | 1.36E+02 | 2.11E+02 | 1.90E+02 | **1.79E+02** | 2.63E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | EODE | 1.07E+02 | 1.15E+04 | 1.32E+03 | 2.82E+03 | 3.29E+03 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | MTDE | 2.15E+02 | 3.03E+04 | 1.80E+03 | 4.96E+03 | 7.82E+03 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | mDEW | 1.60E+02 | 4.97E+02 | 2.26E+02 | 2.48E+02 | 7.66E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | BSD | 2.63E+02 | 3.78E+03 | 1.20E+03 | 1.46E+03 | 1.08E+03 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | QRDE | 3.84E+02 | 1.52E+04 | 3.97E+03 | 5.22E+03 | 5.06E+03 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | BDE | 9.09E+01 | 5.90E+03 | 3.82E+02 | 1.40E+03 | 1.72E+03 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | dFDBLSHADE | 3.18E+02 | 2.97E+04 | 2.90E+03 | 3.42E+03 | 5.10E+03 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | BeSD | 1.84E+02 | 1.50E+03 | 5.22E+02 | 6.76E+02 | 4.81E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | JADEGMO | 1.07E+03 | 1.01E+06 | 7.25E+04 | 1.08E+05 | 1.96E+05 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | JADE | 3.13E+02 | 1.05E+04 | 4.15E+03 | 3.85E+03 | 3.52E+03 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | meanDE | 1.39E+03 | 2.68E+06 | 4.48E+03 | 2.67E+05 | 8.05E+05 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | DA2MODE | 1.25E+02 | 2.95E+02 | 1.86E+02 | 1.87E+02 | 3.12E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| F19 | MDE | 1.40E+03 | 3.00E+03 | 2.60E+03 | 2.37E+03 | 4.11E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | WDE | 1.30E+03 | 2.62E+03 | 2.19E+03 | 2.12E+03 | 4.14E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | EODE | 2.40E+03 | 3.72E+03 | 2.81E+03 | 2.92E+03 | 4.14E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | MTDE | 1.75E+03 | 3.16E+03 | 2.25E+03 | 2.32E+03 | 4.92E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | mDEW | 2.06E+03 | 2.76E+03 | 2.36E+03 | 2.40E+03 | 2.41E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | BSD | 2.03E+03 | 2.69E+03 | 2.13E+03 | 2.23E+03 | 1.73E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | QRDE | 2.49E+03 | 4.17E+03 | 3.50E+03 | 3.41E+03 | 5.68E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | BDE | 1.16E+03 | 2.89E+03 | 1.81E+03 | 1.95E+03 | 4.51E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | dFDBLSHADE | 1.39E+03 | 2.22E+03 | 1.65E+03 | 1.64E+03 | 2.15E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | BeSD | 1.49E+03 | 2.41E+03 | 2.07E+03 | 2.05E+03 | 2.51E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | JADEGMO | 2.68E+03 | 5.90E+03 | 3.30E+03 | 3.54E+03 | 6.45E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | JADE | 1.88E+03 | 5.40E+03 | 3.41E+03 | 3.63E+03 | 1.03E+03 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | meanDE | 7.05E+02 | 2.54E+03 | 1.60E+03 | 1.64E+03 | 5.86E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | DA2MODE | 1.02E+03 | 1.69E+03 | 1.32E+03 | **1.33E+03** | 1.46E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| F20 | MDE | 3.60E+02 | 4.44E+02 | 3.95E+02 | 3.97E+02 | 2.53E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | WDE | 7.61E+02 | 9.15E+02 | 8.46E+02 | 8.32E+02 | 4.95E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | EODE | 3.91E+02 | 6.65E+02 | 5.15E+02 | 5.16E+02 | 6.51E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | MTDE | 5.17E+02 | 6.07E+02 | 5.63E+02 | 5.57E+02 | 2.59E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | mDEW | 7.14E+02 | 8.18E+02 | 7.44E+02 | 7.55E+02 | 2.78E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | BSD | 5.15E+02 | 5.87E+02 | 5.51E+02 | 5.54E+02 | 2.40E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | QRDE | 4.76E+02 | 6.28E+02 | 5.23E+02 | 5.45E+02 | 5.77E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | BDE | 5.16E+02 | 6.83E+02 | 5.59E+02 | 5.78E+02 | 5.45E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | dFDBLSHADE | 4.05E+02 | 4.88E+02 | 4.42E+02 | 4.44E+02 | 2.42E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | BeSD | 5.61E+02 | 6.61E+02 | 6.35E+02 | 6.25E+02 | 2.57E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | JADEGMO | 1.11E+03 | 1.35E+03 | 1.24E+03 | 1.23E+03 | 7.06E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | JADE | 9.79E+02 | 1.77E+03 | 1.18E+03 | 1.14E+03 | 1.18E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | meanDE | 4.72E+02 | 6.61E+02 | 5.14E+02 | 5.30E+02 | 5.50E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | DA2MODE | 2.64E+02 | 2.99E+02 | 2.87E+02 | **2.86E+02** | 8.18E+00 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |

(*continued on next page*)

**Table E.14** (*continued*).

| Fun | Alg. | Error | | | | | Function evaluations | | | | | SR (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No. | Name | Best | Worst | Median | Mean | SD | Best | Worst | Median | Mean | SD | |
| F21 | MDE | 1.15E+04 | 1.59E+04 | 1.35E+04 | 1.35E+04 | 1.37E+03 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | WDE | 1.24E+04 | 1.41E+04 | 1.33E+04 | 1.33E+04 | 4.99E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | EODE | 1.29E+04 | 2.33E+04 | 1.75E+04 | 1.73E+04 | 3.22E+03 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | MTDE | 1.20E+04 | 1.71E+04 | 1.46E+04 | 1.46E+04 | 1.36E+03 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | mDEW | 1.17E+04 | 1.30E+04 | 1.25E+04 | 1.25E+04 | 4.46E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | BSD | 1.23E+04 | 1.37E+04 | 1.33E+04 | 1.31E+04 | 4.35E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | QRDE | 1.43E+04 | 2.72E+04 | 1.76E+04 | 1.91E+04 | 4.14E+03 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | BDE | 1.03E+04 | 1.32E+04 | 1.17E+04 | 1.17E+04 | 1.02E+03 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | dFDBLSHADE | 1.04E+04 | 1.22E+04 | 1.16E+04 | 1.14E+04 | 5.51E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | BeSD | 1.56E+04 | 1.72E+04 | 1.64E+04 | 1.63E+04 | 4.19E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | JADEGMO | 2.36E+04 | 3.08E+04 | 2.64E+04 | 2.69E+04 | 2.09E+03 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | JADE | 2.44E+04 | 3.05E+04 | 2.80E+04 | 2.82E+04 | 1.64E+03 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | meanDE | 7.98E+03 | 1.58E+04 | 1.31E+04 | 1.28E+04 | 1.94E+03 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | DA2MODE | 1.00E+02 | 1.03E+02 | 1.00E+02 | **1.00E+02** | 3.51E−01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| F22 | MDE | 6.77E+02 | 7.55E+02 | 6.94E+02 | 7.08E+02 | 2.77E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | WDE | 9.18E+02 | 9.95E+02 | 9.65E+02 | 9.64E+02 | 1.95E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | EODE | 7.59E+02 | 9.13E+02 | 8.44E+02 | 8.38E+02 | 5.14E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | MTDE | 8.47E+02 | 1.04E+03 | 9.41E+02 | 9.23E+02 | 5.78E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | mDEW | 7.93E+02 | 8.74E+02 | 8.48E+02 | 8.42E+02 | 2.38E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | BSD | 7.44E+02 | 8.11E+02 | 7.89E+02 | 7.79E+02 | 2.36E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | QRDE | 6.77E+02 | 8.16E+02 | 7.64E+02 | 7.57E+02 | 4.11E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | BDE | 6.77E+02 | 7.76E+02 | 7.33E+02 | 7.26E+02 | 2.92E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | dFDBLSHADE | 6.98E+02 | 8.78E+02 | 8.18E+02 | 7.88E+02 | 6.60E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | BeSD | 8.35E+02 | 9.22E+02 | 8.74E+02 | 8.78E+02 | 1.93E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | JADEGMO | 1.46E+03 | 2.40E+03 | 1.75E+03 | 1.86E+03 | 2.90E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | JADE | 7.75E+02 | 1.67E+03 | 1.30E+03 | 1.22E+03 | 2.87E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | meanDE | 8.66E+02 | 1.23E+03 | 1.02E+03 | 1.02E+03 | 1.02E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | DA2MODE | 5.85E+02 | 6.43E+02 | 6.16E+02 | **6.15E+02** | 1.38E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| F23 | MDE | 1.05E+03 | 1.16E+03 | 1.10E+03 | 1.10E+03 | 3.23E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | WDE | 1.48E+03 | 1.67E+03 | 1.58E+03 | 1.58E+03 | 5.83E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | EODE | 1.08E+03 | 1.27E+03 | 1.17E+03 | 1.17E+03 | 4.43E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | MTDE | 1.30E+03 | 1.45E+03 | 1.37E+03 | 1.37E+03 | 5.91E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | mDEW | 1.28E+03 | 1.47E+03 | 1.39E+03 | 1.39E+03 | 4.43E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | BSD | 1.15E+03 | 1.30E+03 | 1.20E+03 | 1.21E+03 | 4.90E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | QRDE | 1.13E+03 | 1.24E+03 | 1.18E+03 | 1.18E+03 | 2.52E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | BDE | 1.13E+03 | 1.34E+03 | 1.24E+03 | 1.24E+03 | 5.97E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | dFDBLSHADE | 1.16E+03 | 1.31E+03 | 1.18E+03 | 1.20E+03 | 3.89E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | BeSD | 1.22E+03 | 1.51E+03 | 1.41E+03 | 1.41E+03 | 7.17E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | JADEGMO | 2.05E+03 | 3.39E+03 | 2.34E+03 | 2.44E+03 | 3.15E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | JADE | 1.27E+03 | 1.89E+03 | 1.64E+03 | 1.62E+03 | 1.90E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | meanDE | 1.27E+03 | 1.50E+03 | 1.38E+03 | 1.40E+03 | 8.27E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | DA2MODE | 9.30E+02 | 9.85E+02 | 9.56E+02 | **9.58E+02** | 1.06E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| F24 | MDE | 7.67E+02 | 8.80E+02 | 8.19E+02 | 8.13E+02 | 3.79E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | WDE | 8.34E+02 | 9.30E+02 | 8.76E+02 | 8.74E+02 | 3.23E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | EODE | 6.46E+02 | 9.24E+02 | 7.94E+02 | 7.90E+02 | 5.32E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | MTDE | 6.74E+02 | 8.77E+02 | 7.58E+02 | 7.71E+02 | 5.57E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | mDEW | 7.36E+02 | 9.03E+02 | 8.39E+02 | 8.50E+02 | 4.01E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | BSD | 7.66E+02 | 9.43E+02 | 8.32E+02 | 8.32E+02 | 4.56E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | QRDE | 6.37E+02 | 7.96E+02 | 7.10E+02 | 7.26E+02 | 5.16E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | BDE | 6.69E+02 | 9.43E+02 | 7.86E+02 | 7.94E+02 | 7.07E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | dFDBLSHADE | 7.67E+02 | 1.05E+03 | 9.21E+02 | 9.25E+02 | 6.90E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | BeSD | 7.49E+02 | 8.61E+02 | 8.34E+02 | 8.21E+02 | 3.50E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | JADEGMO | 8.85E+02 | 1.29E+03 | 1.08E+03 | 1.08E+03 | 1.22E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | JADE | 7.06E+02 | 8.97E+03 | 4.53E+03 | 3.55E+03 | 2.89E+03 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | meanDE | 6.69E+02 | 9.04E+02 | 8.62E+02 | 8.22E+02 | 7.91E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | DA2MODE | 6.12E+02 | 8.26E+02 | 7.12E+02 | **7.14E+02** | 4.18E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| F25 | MDE | 4.94E+03 | 6.02E+03 | 5.11E+03 | 5.27E+03 | 3.80E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | WDE | 2.40E+03 | 1.17E+04 | 1.04E+04 | 9.38E+03 | 3.09E+03 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | EODE | 3.00E+02 | 8.30E+03 | 7.20E+03 | 6.32E+03 | 2.54E+03 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | MTDE | 7.53E+03 | 1.05E+04 | 8.36E+03 | 8.55E+03 | 9.23E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | mDEW | 7.85E+03 | 9.43E+03 | 8.53E+03 | 8.71E+03 | 5.35E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | BSD | 8.71E+03 | 1.25E+04 | 1.03E+04 | 1.04E+04 | 1.05E+03 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | QRDE | 5.91E+03 | 7.52E+03 | 6.88E+03 | 6.87E+03 | 4.43E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | BDE | 6.02E+03 | 8.12E+03 | 7.09E+03 | 7.22E+03 | 6.48E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | dFDBLSHADE | 5.60E+03 | 7.78E+03 | 6.62E+03 | 6.58E+03 | 6.27E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | BeSD | 1.00E+04 | 1.81E+04 | 1.60E+04 | 1.49E+04 | 3.09E+03 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | JADEGMO | 1.47E+04 | 2.70E+04 | 1.69E+04 | 1.74E+04 | 2.27E+03 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | JADE | 5.97E+03 | 1.78E+04 | 1.28E+04 | 1.29E+04 | 4.00E+03 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | meanDE | 7.62E+03 | 1.36E+04 | 1.04E+04 | 1.03E+04 | 1.28E+03 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | DA2MODE | 3.00E+02 | 4.49E+03 | 4.07E+03 | **3.16E+03** | 1.69E+03 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| F26 | MDE | 7.08E+02 | 8.27E+02 | 7.53E+02 | 7.70E+02 | 3.96E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | WDE | 8.55E+02 | 9.67E+02 | 9.18E+02 | 9.16E+02 | 2.78E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | EODE | 6.76E+02 | 8.91E+02 | 7.27E+02 | 7.45E+02 | 6.69E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | MTDE | 9.16E+02 | 1.18E+03 | 1.02E+03 | 1.04E+03 | 9.52E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | mDEW | 7.96E+02 | 8.73E+02 | 8.48E+02 | 8.37E+02 | 2.22E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | BSD | 8.25E+02 | 8.97E+02 | 8.61E+02 | 8.59E+02 | 2.34E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | QRDE | 6.50E+02 | 7.66E+02 | 6.98E+02 | 7.06E+02 | 3.58E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | BDE | 7.06E+02 | 9.17E+02 | 8.00E+02 | 8.05E+02 | 7.41E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | dFDBLSHADE | 7.86E+02 | 9.61E+02 | 8.82E+02 | 8.70E+02 | 4.46E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | BeSD | 8.34E+02 | 1.10E+03 | 9.31E+02 | 9.46E+02 | 6.82E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | JADEGMO | 7.37E+02 | 3.16E+03 | 1.13E+03 | 1.30E+03 | 6.47E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | JADE | 8.63E+02 | 2.12E+03 | 9.23E+02 | 1.17E+03 | 4.70E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | meanDE | 8.40E+02 | 1.24E+03 | 1.05E+03 | 1.05E+03 | 1.45E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | DA2MODE | 5.00E+02 | 5.00E+02 | 5.00E+02 | **5.00E+02** | 1.19E−04 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| F27 | MDE | 4.86E+02 | 6.66E+02 | 5.67E+02 | 5.67E+02 | 4.25E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | WDE | 6.48E+02 | 7.30E+02 | 7.11E+02 | 7.03E+02 | 2.63E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | EODE | 5.41E+02 | 5.71E+02 | 5.49E+02 | 5.52E+02 | 1.00E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | MTDE | 5.80E+02 | 6.31E+02 | 6.15E+02 | 6.06E+02 | 2.01E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | mDEW | 5.75E+02 | 7.07E+02 | 6.33E+02 | 6.42E+02 | 4.68E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | BSD | 4.99E+02 | 6.19E+02 | 5.63E+02 | 5.55E+02 | 3.73E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | QRDE | 1.64E+03 | 1.26E+04 | 1.02E+04 | 7.73E+03 | 4.30E+03 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | BDE | 4.89E+02 | 6.19E+02 | 5.71E+02 | 5.61E+02 | 4.23E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | dFDBLSHADE | 6.60E+02 | 1.03E+03 | 7.86E+02 | 8.00E+02 | 9.18E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | BeSD | 5.75E+02 | 6.47E+02 | 6.24E+02 | 6.18E+02 | 2.43E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | JADEGMO | 7.96E+02 | 1.61E+04 | 2.11E+03 | 3.80E+03 | 5.02E+03 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | JADE | 5.37E+02 | 1.17E+04 | 5.85E+02 | 3.27E+03 | 4.50E+03 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | meanDE | 5.58E+02 | 6.71E+02 | 6.10E+02 | 6.17E+02 | 2.92E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | DA2MODE | 4.87E+02 | 5.19E+02 | 4.95E+02 | **4.96E+02** | 1.00E+01 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |

(*continued on next page*)

**Table E.14** (*continued*).

| Fun | Alg. | Error | | | | | Function evaluations | | | | | SR (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No. | Name | Best | Worst | Median | Mean | SD | Best | Worst | Median | Mean | SD | |
| F28 | MDE | 2.22E+03 | 3.07E+03 | 2.76E+03 | 2.75E+03 | 1.67E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | WDE | 2.61E+03 | 3.14E+03 | 2.88E+03 | 2.83E+03 | 1.82E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | EODE | 2.03E+03 | 4.75E+03 | 2.80E+03 | 3.33E+03 | 7.89E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | MTDE | 2.89E+03 | 4.23E+03 | 3.97E+03 | 3.70E+03 | 4.89E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | mDEW | 2.46E+03 | 4.07E+03 | 3.58E+03 | 3.55E+03 | 3.12E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | BSD | 2.51E+03 | 3.18E+03 | 2.82E+03 | 2.79E+03 | 2.24E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | QRDE | 3.26E+03 | 3.78E+03 | 3.77E+03 | 3.61E+03 | 1.87E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | BDE | 1.70E+03 | 3.10E+03 | 2.64E+03 | 2.52E+03 | 4.50E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | dFDBLSHADE | 1.98E+03 | 3.67E+03 | 2.78E+03 | 2.70E+03 | 4.62E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | BeSD | 2.57E+03 | 3.57E+03 | 3.06E+03 | 3.06E+03 | 3.06E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | JADEGMO | 4.73E+03 | 7.60E+03 | 5.97E+03 | 6.20E+03 | 8.31E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | JADE | 3.40E+03 | 8.40E+03 | 5.35E+03 | 5.57E+03 | 1.68E+03 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | meanDE | 2.30E+03 | 3.82E+03 | 3.05E+03 | 3.08E+03 | 4.31E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | DA2MODE | 7.67E+02 | 1.61E+03 | 1.15E+03 | **1.16E+03** | 2.05E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| F29 | MDE | 3.41E+03 | 9.32E+03 | 4.61E+03 | 6.00E+03 | 2.40E+03 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | WDE | 9.66E+03 | 1.64E+04 | 1.38E+04 | 1.35E+04 | 2.37E+03 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | EODE | 3.02E+03 | 6.72E+04 | 4.18E+03 | 1.62E+04 | 2.27E+04 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | MTDE | 3.54E+03 | 1.71E+04 | 1.02E+04 | 1.03E+04 | 4.01E+03 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | mDEW | 3.85E+03 | 1.49E+04 | 5.55E+03 | 6.88E+03 | 2.99E+03 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | BSD | 5.62E+03 | 1.04E+04 | 6.45E+03 | 7.10E+03 | 1.69E+03 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | QRDE | 4.12E+03 | 1.17E+05 | 3.10E+04 | 4.85E+04 | 3.98E+04 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | BDE | 3.68E+03 | 1.03E+04 | 5.28E+03 | 6.11E+03 | 2.23E+03 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | dFDBLSHADE | 5.43E+03 | 4.03E+04 | 1.15E+04 | 1.47E+04 | 9.07E+03 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | BeSD | 3.14E+03 | 1.25E+04 | 6.08E+03 | 6.31E+03 | 2.71E+03 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | JADEGMO | 1.51E+05 | 1.91E+07 | 8.24E+05 | 3.90E+06 | 6.19E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | JADE | 3.24E+03 | 6.68E+09 | 3.60E+03 | 1.05E+09 | 1.97E+09 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | meanDE | 3.99E+03 | 1.67E+04 | 5.18E+03 | 8.40E+03 | 5.11E+03 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |
| | DA2MODE | 3.65E+02 | 9.81E+02 | 5.65E+02 | **5.99E+02** | 1.38E+02 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 1.00E+06 | 0.00E+00 | 0.00 |

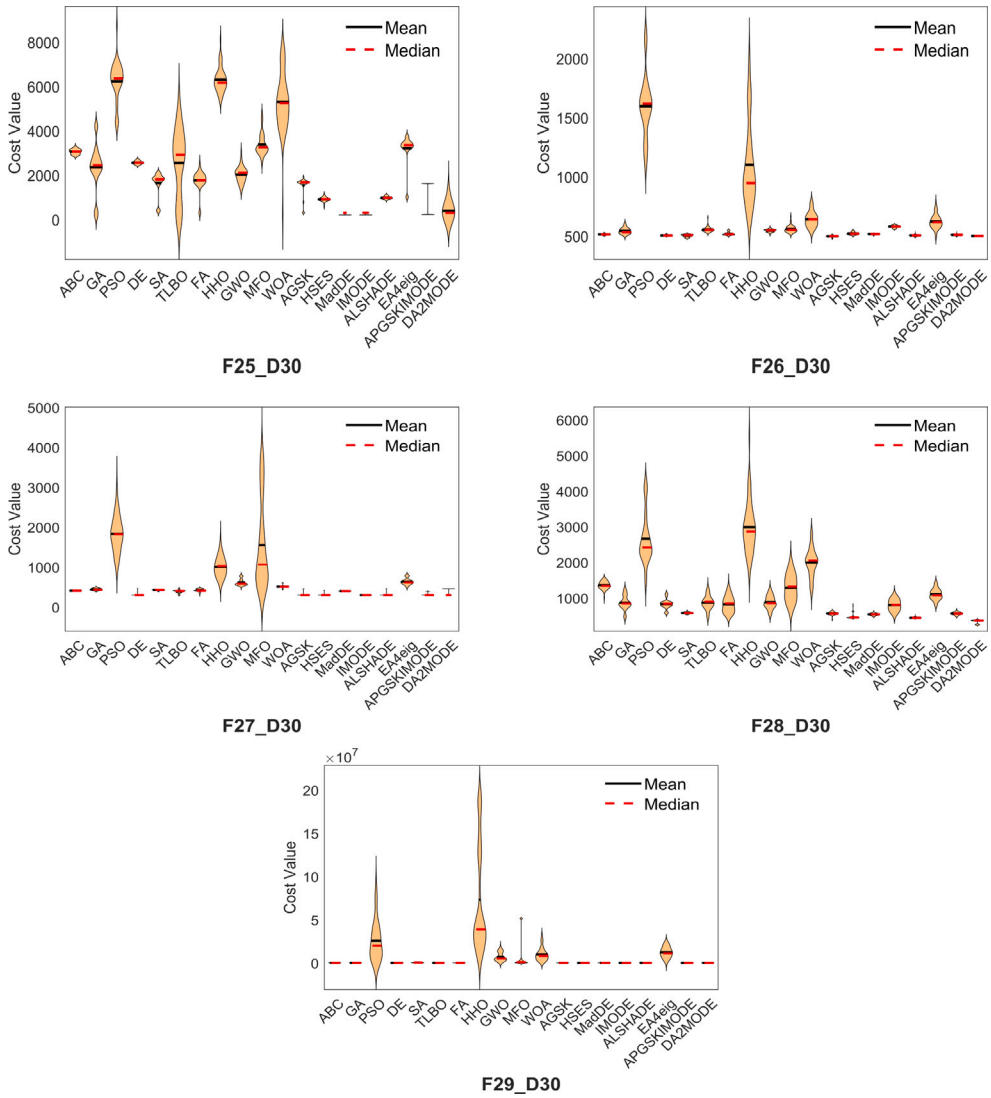



**Fig. F.9e.** Violin plots for the best fitness in 51 runs for all the algorithms in CEC2017–2018, F25–F29 (30D).

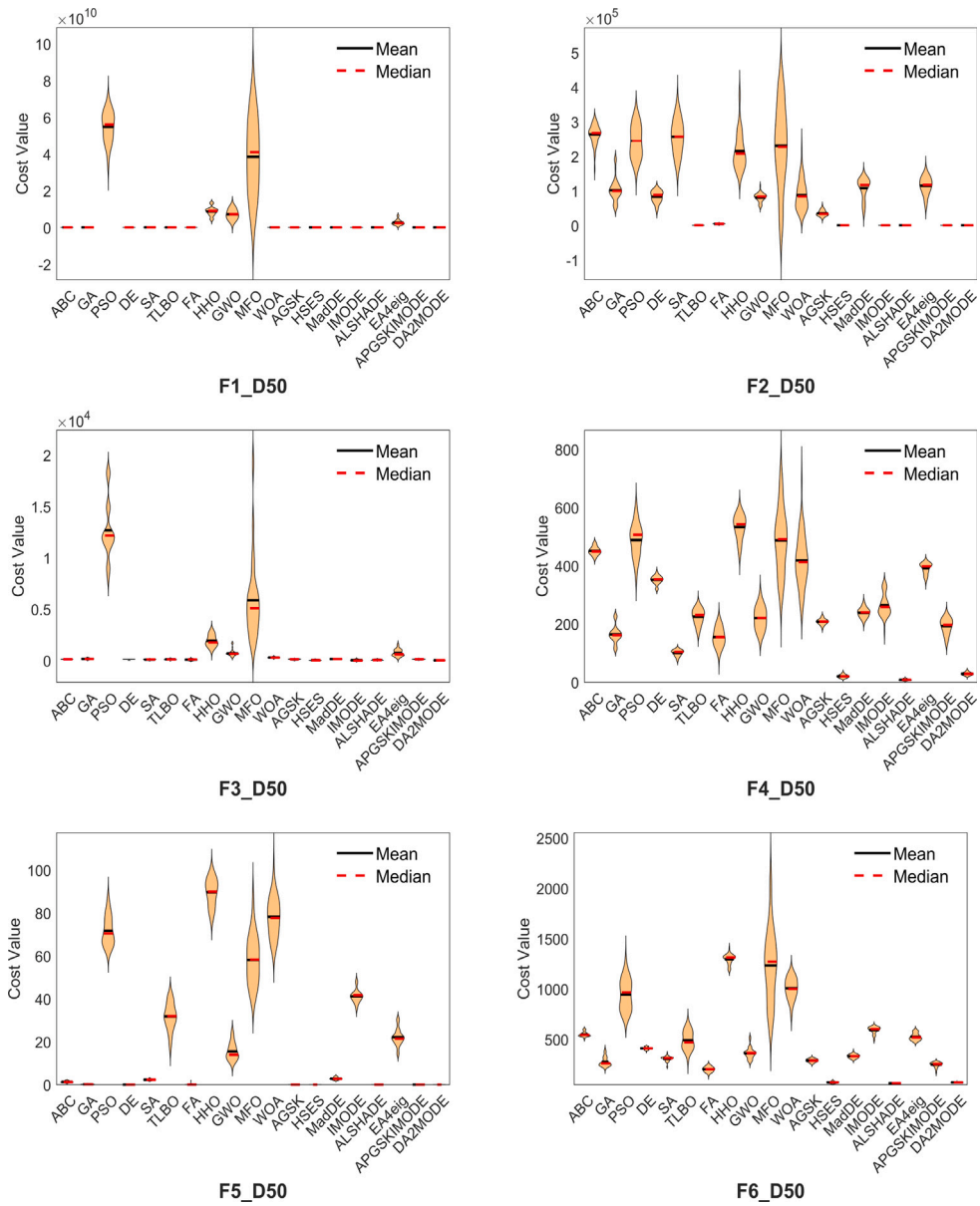



**Fig. F.10a.** Violin plots for the best fitness in 51 runs for all the algorithms in CEC2017-2018, F1-F6 (50D).

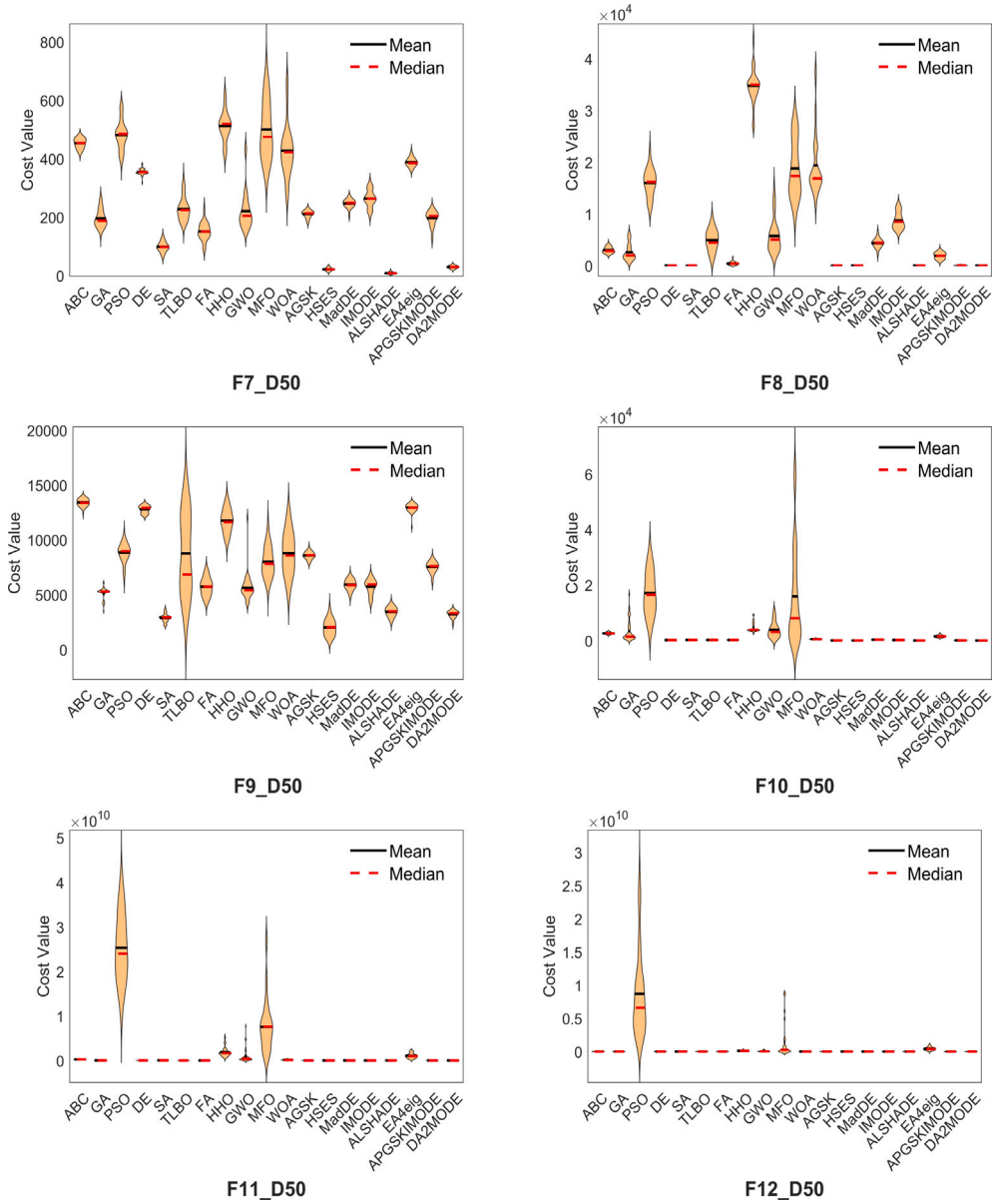



**Fig. F.10b.** Violin plots for the best fitness in 51 runs for all the algorithms in CEC2017-2018, F7-F12 (50D).

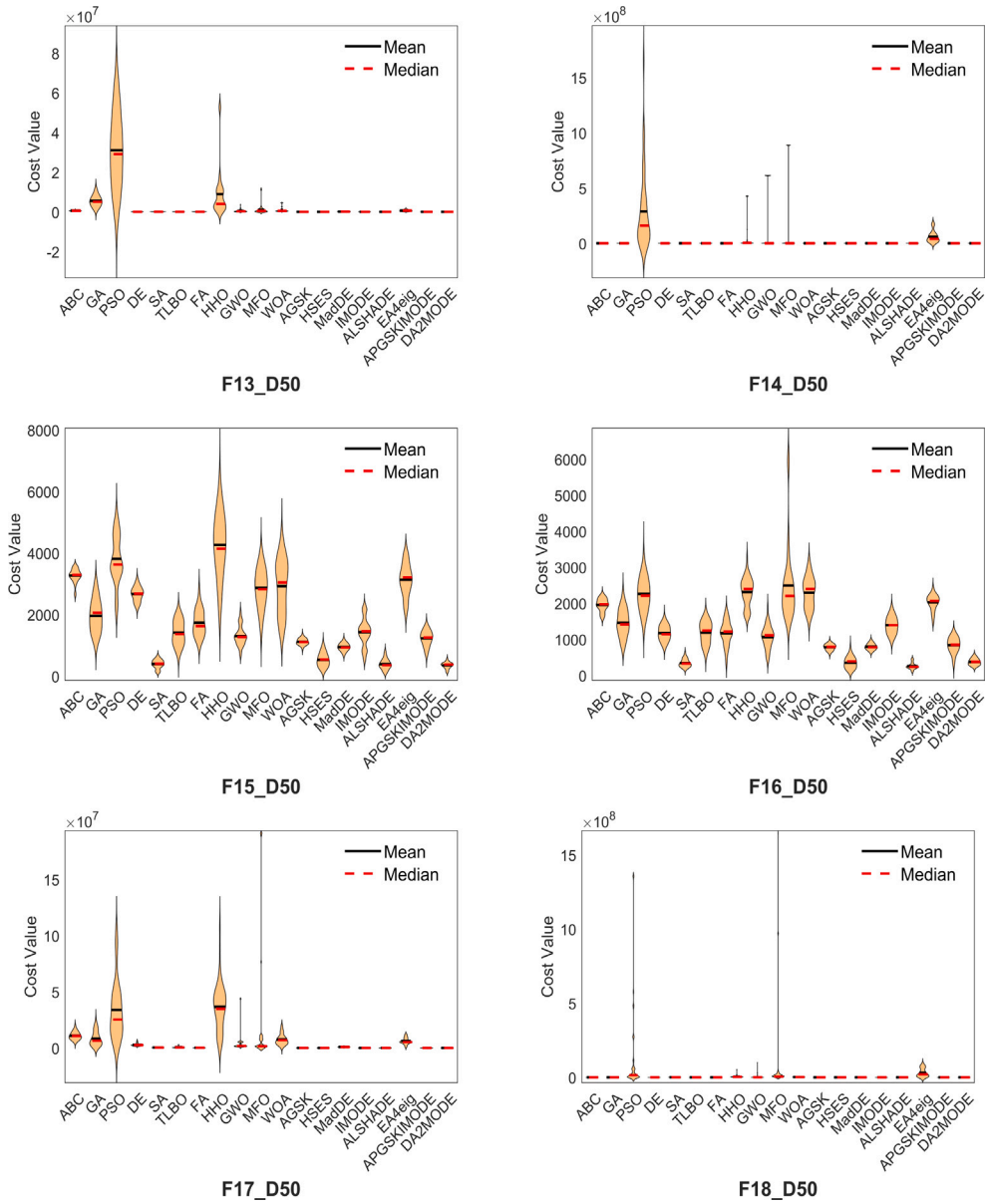



**Fig. F.10c.** Violin plots for the best fitness in 51 runs for all the algorithms in CEC2017-2018, F13-F18 (50D).

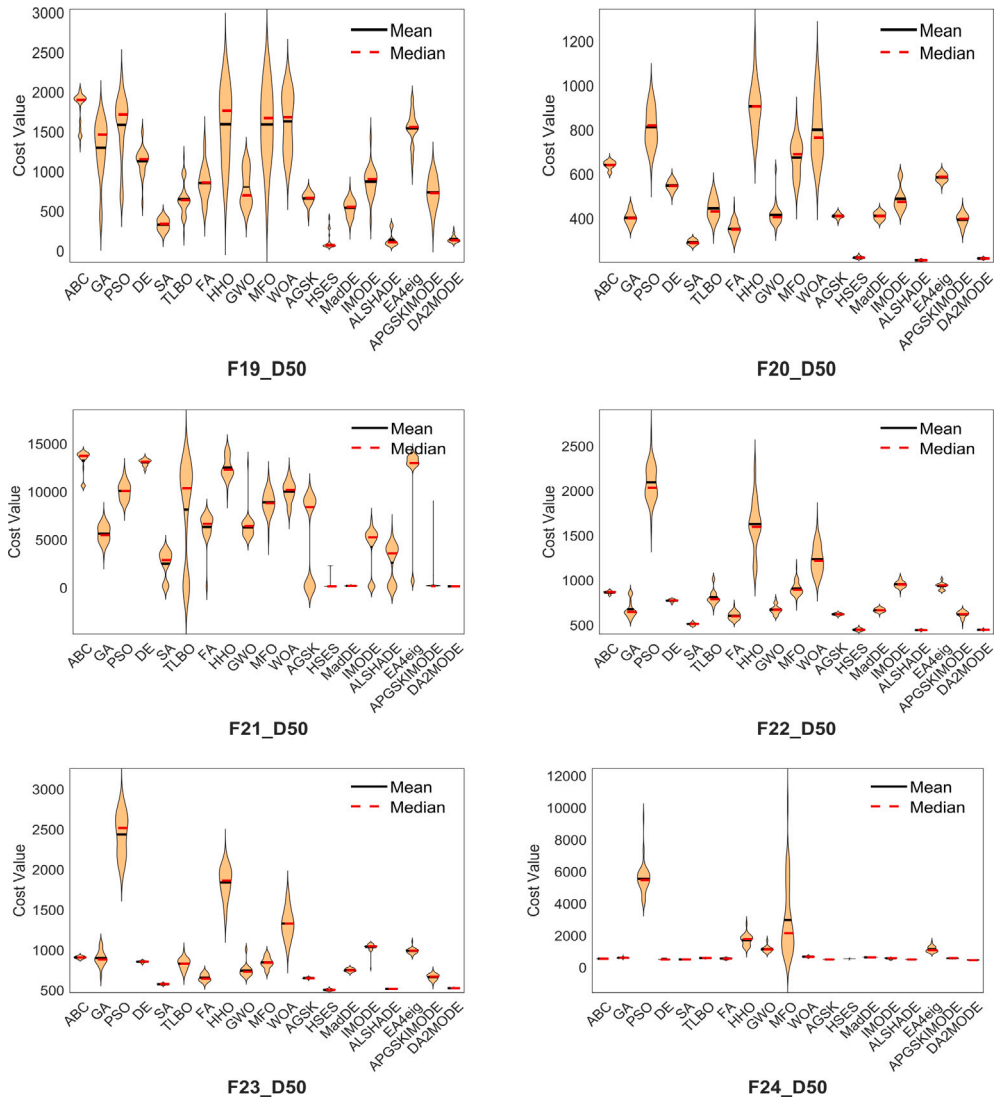



**Fig. F.10d.** Violin plots for the best fitness in 51 runs for all the algorithms in CEC2017-2018, F19-F24 (50D).

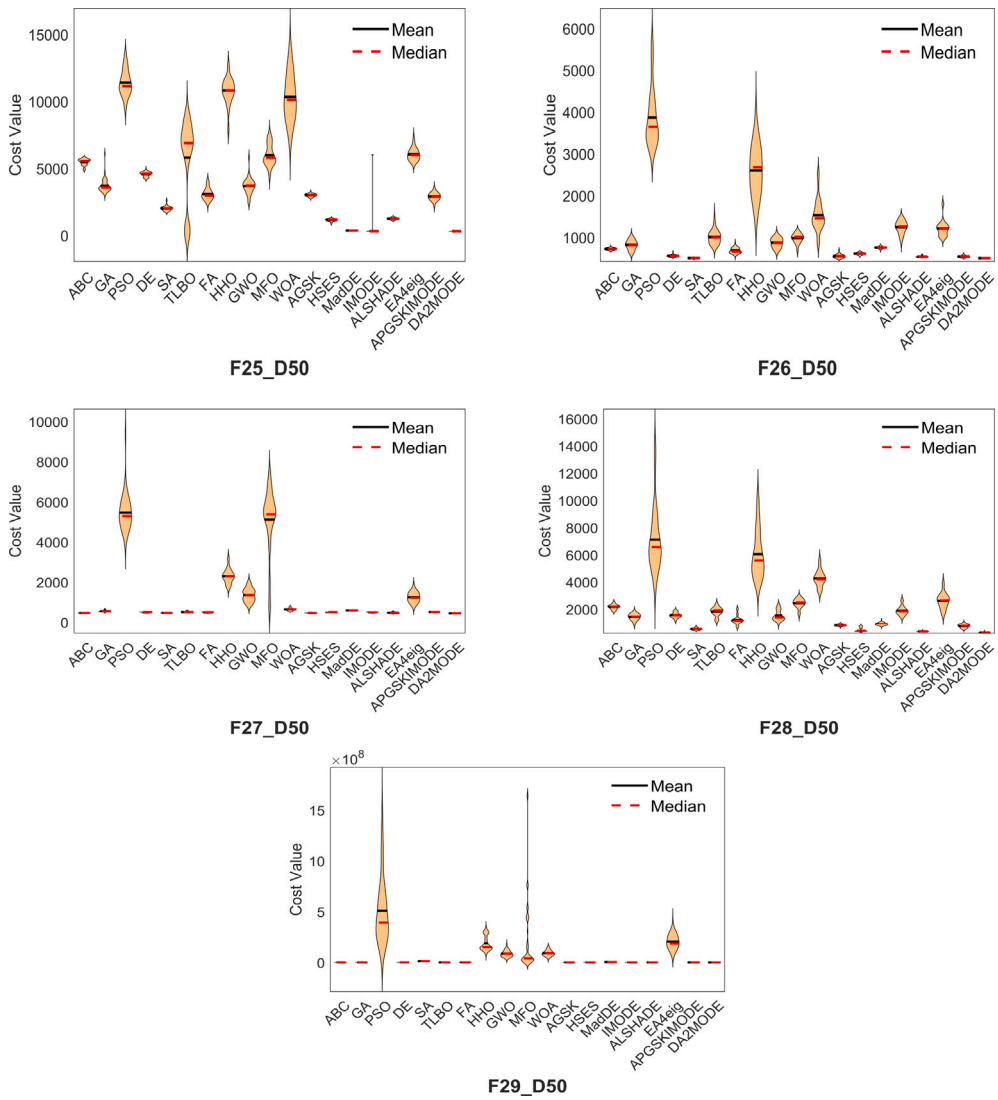



**Fig. F.10e.** Violin plots for the best fitness in 51 runs for all the algorithms in CEC2017-2018, F25-F29 (50D).

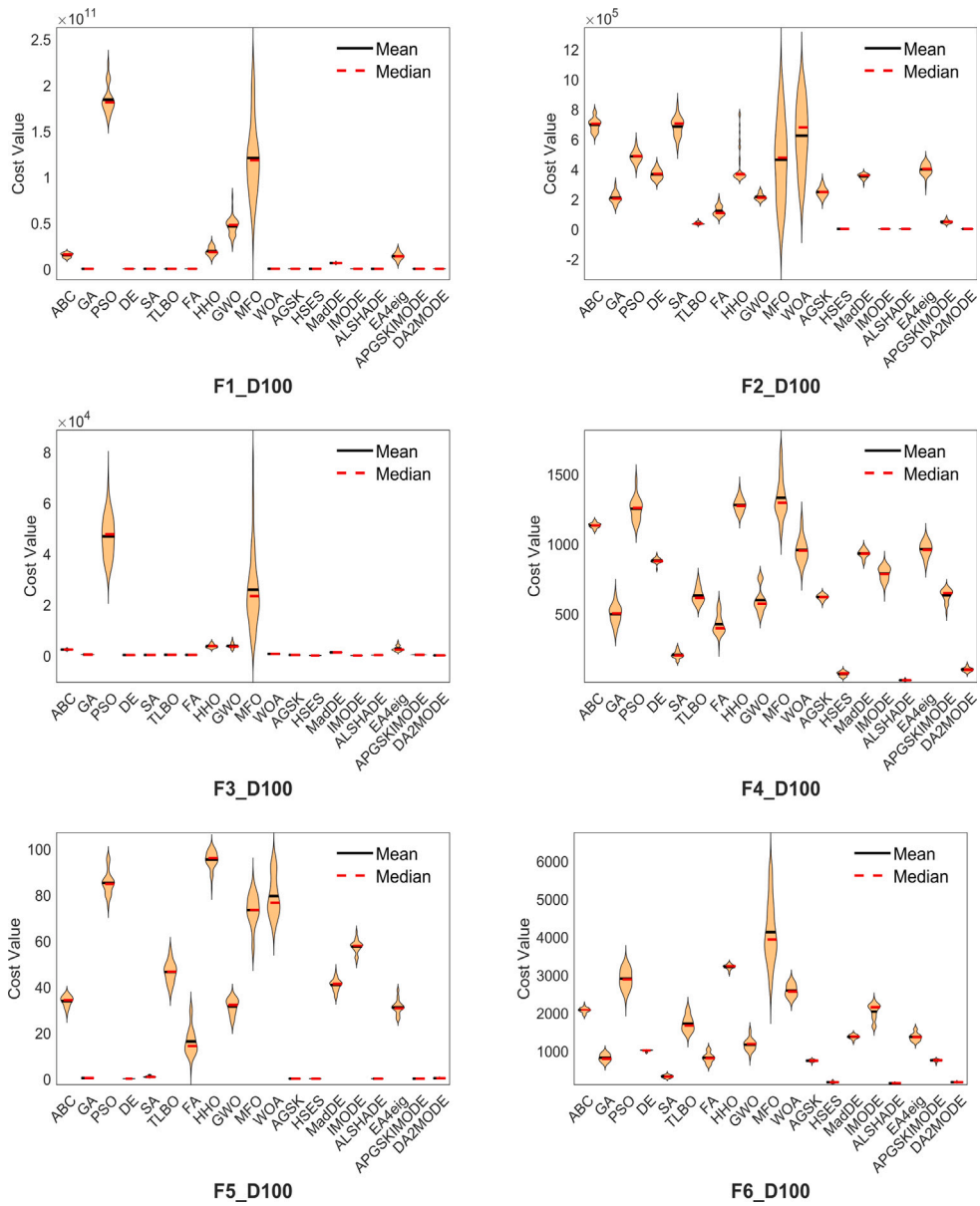



**Fig. F.11a.** Violin plots for the best fitness in 51 runs for all the algorithms in CEC2017-2018, F1-F6 (100D).

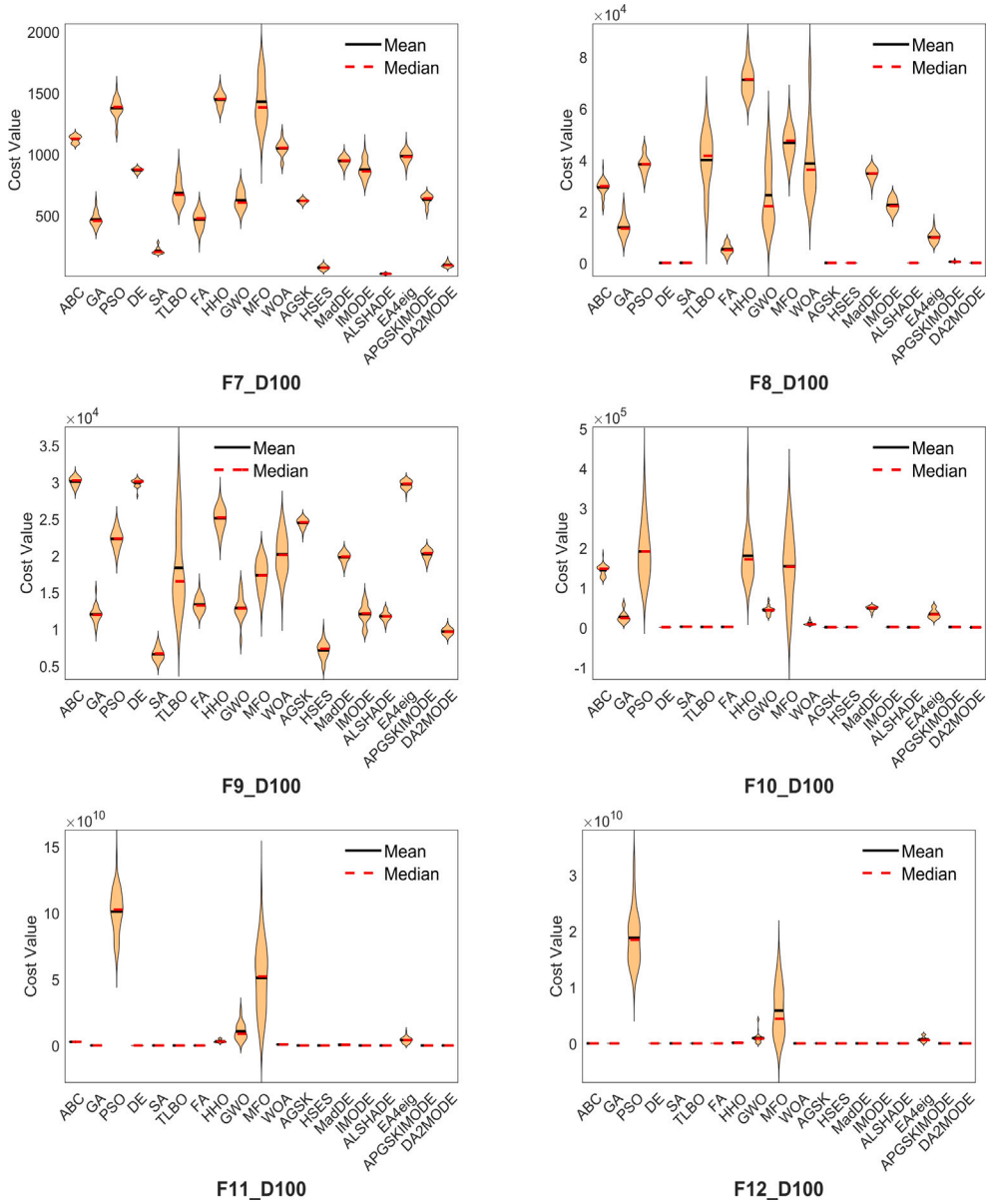



**Fig. F.11b.** Violin plots for the best fitness in 51 runs for all the algorithms in CEC2017-2018, F7-F12 (100D).

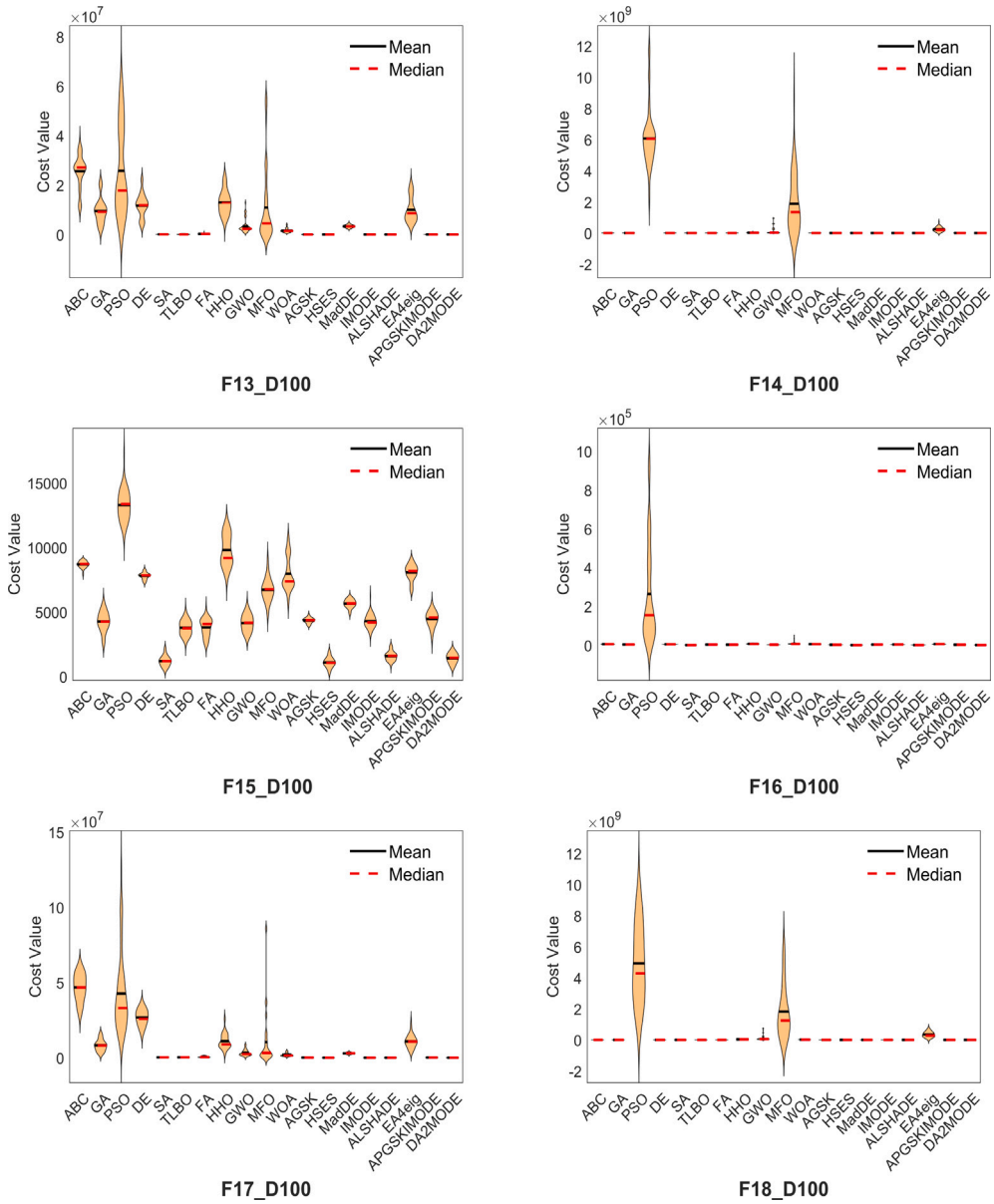



**Fig. F.11c.** Violin plots for the best fitness in 51 runs for all the algorithms in CEC2017-2018, F13-F18 (100D).

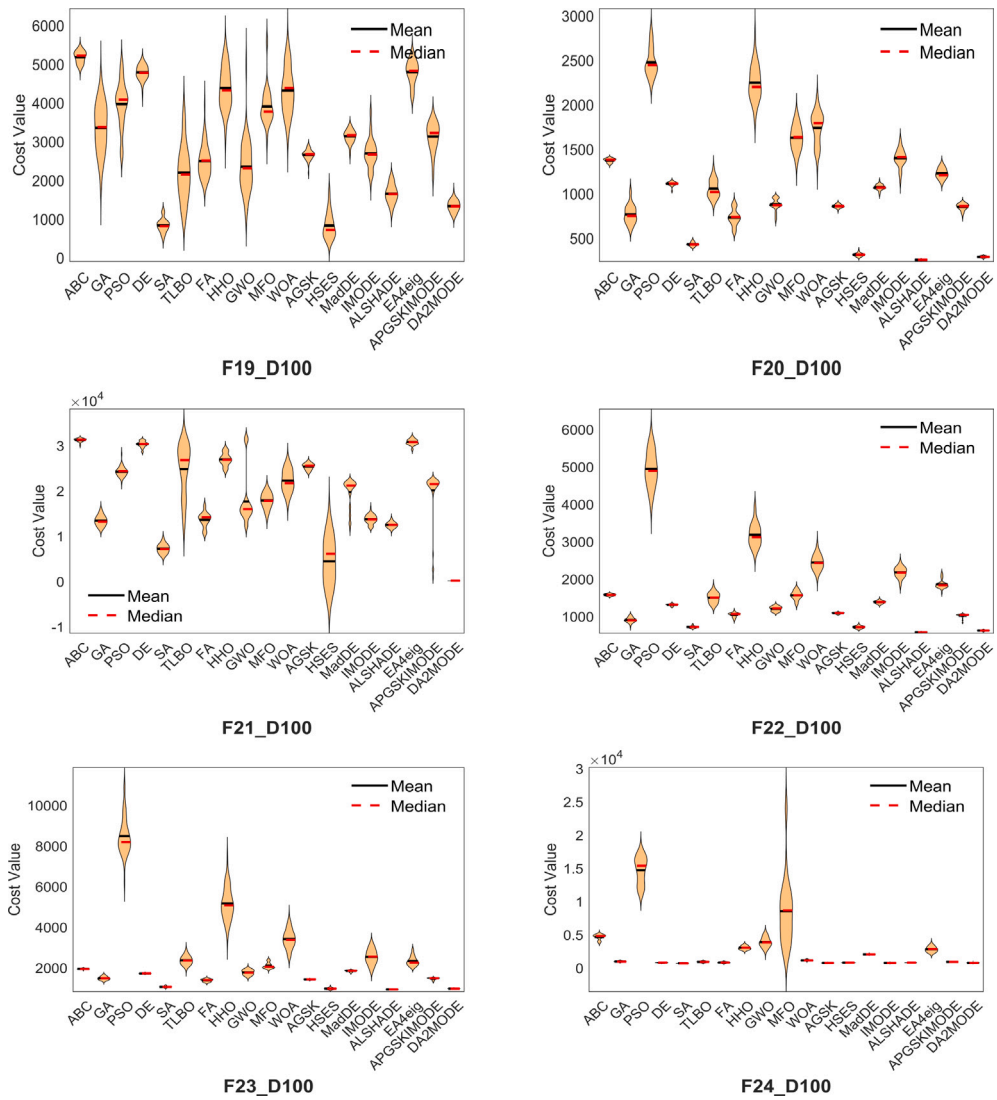



**Fig. F.11d.** Violin plots for the best fitness in 51 runs for all the algorithms in CEC2017-2018, F19-F24 (100D).

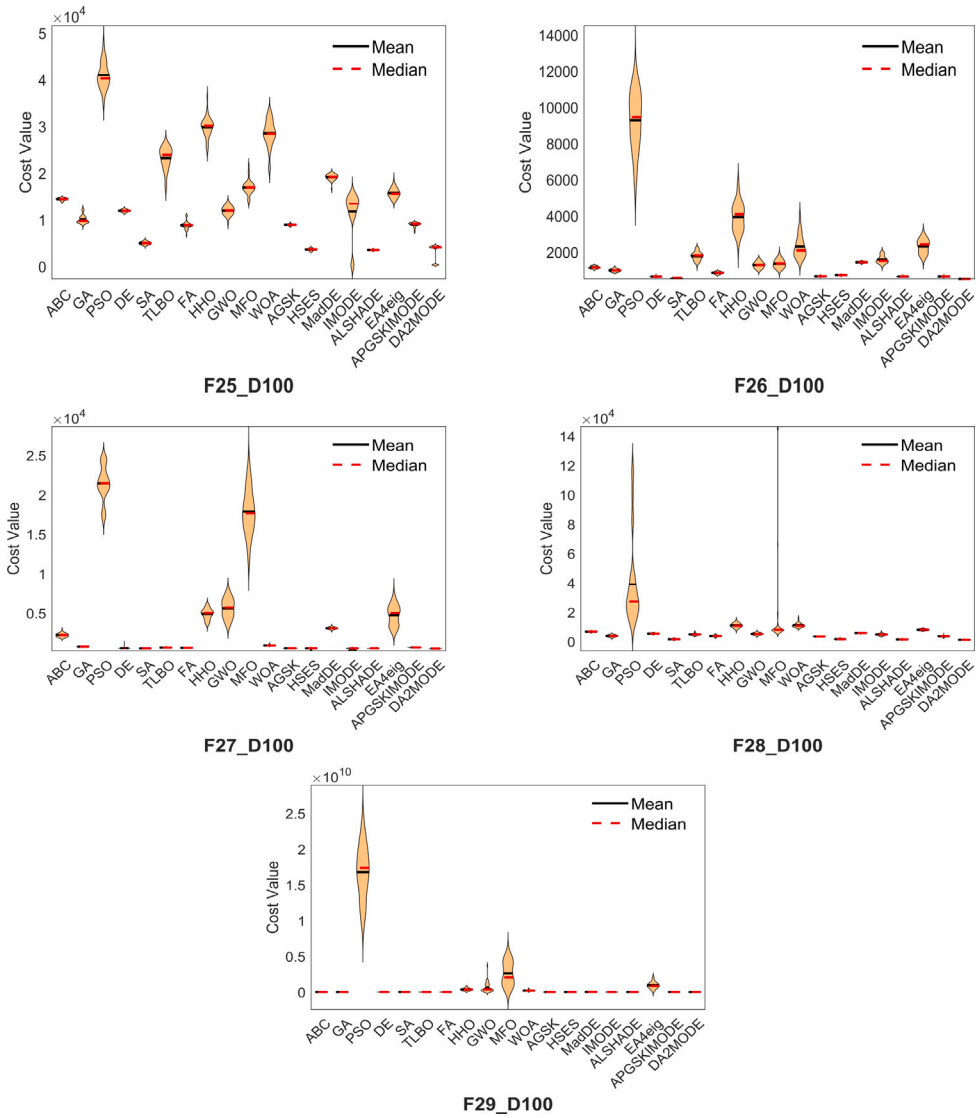



**Fig. F.11e.** Violin plots for the best fitness in 51 runs for all the algorithms in CEC2017-2018, F25-F29 (100D).

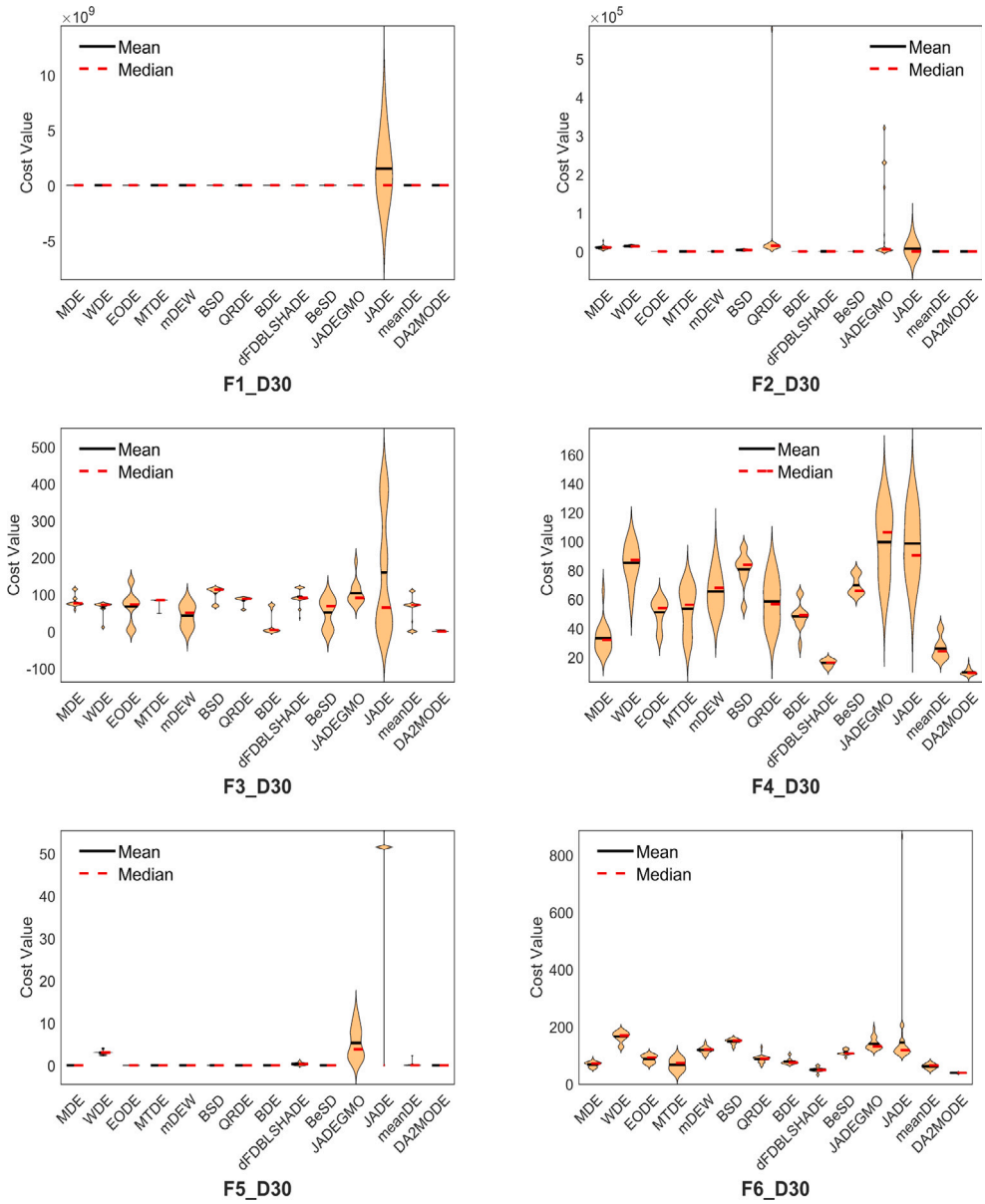



**Fig. F.12a.** Violin plots for the best fitness in 51 runs for 14 DE variants in CEC2017-2018, F1-F6 (30D).

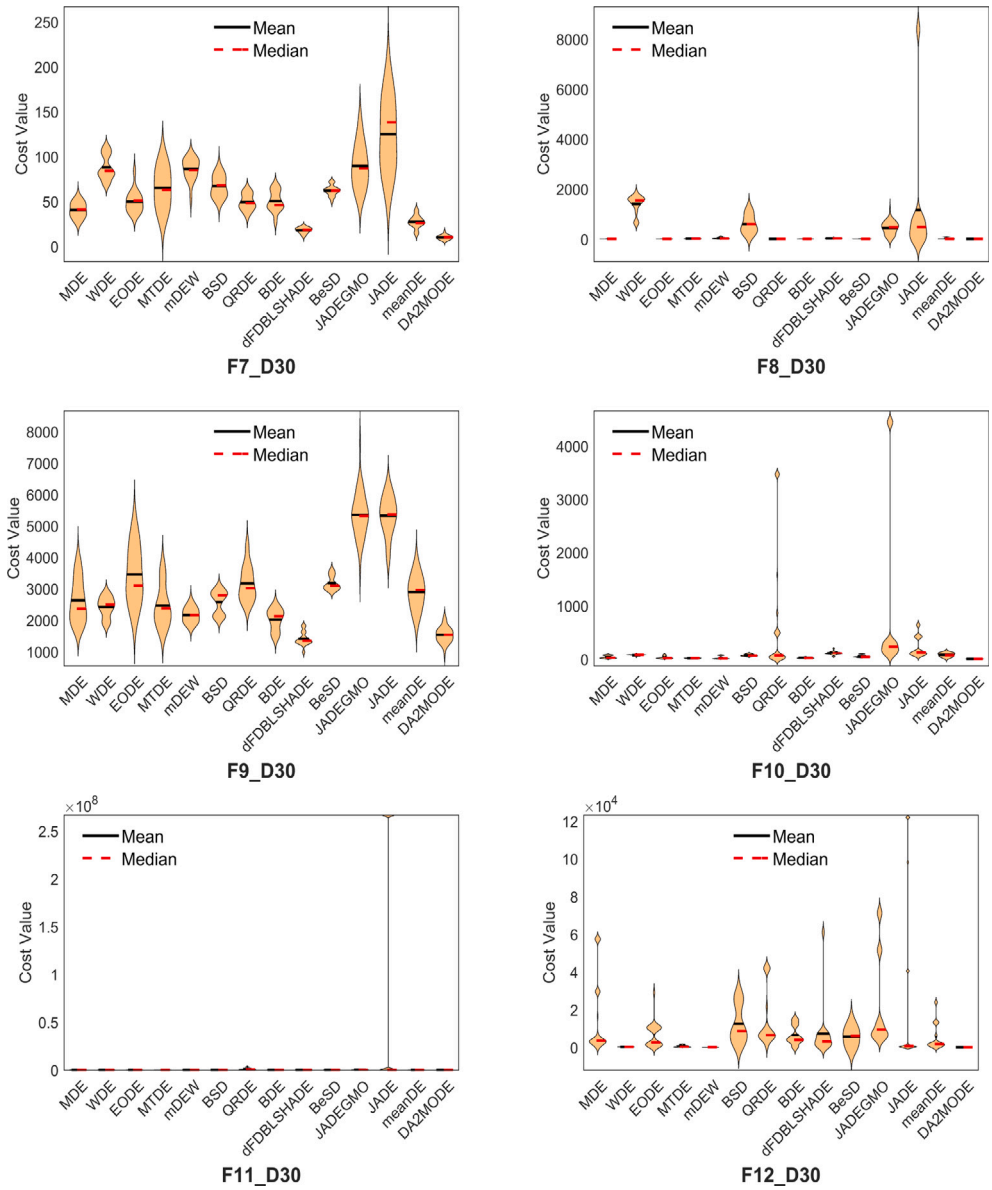



**Fig. F.12b.** Violin plots for the best fitness in 51 runs for 14 DE variants in CEC2017-2018, F7-F12 (30D)

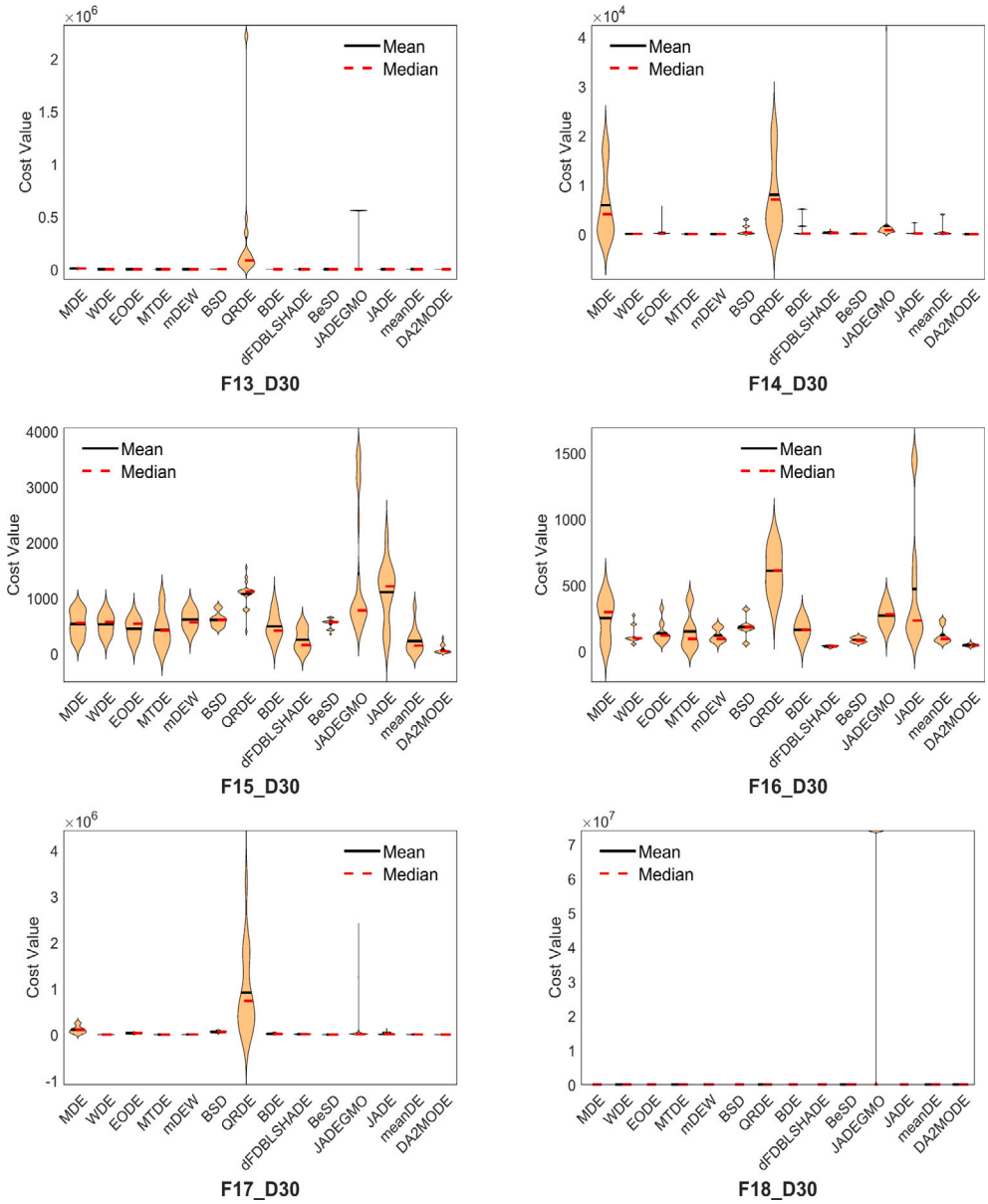



**Fig. F.12c.** Violin plots for the best fitness in 51 runs for 14 DE variants in CEC2017-2018, F13-F18 (30D).

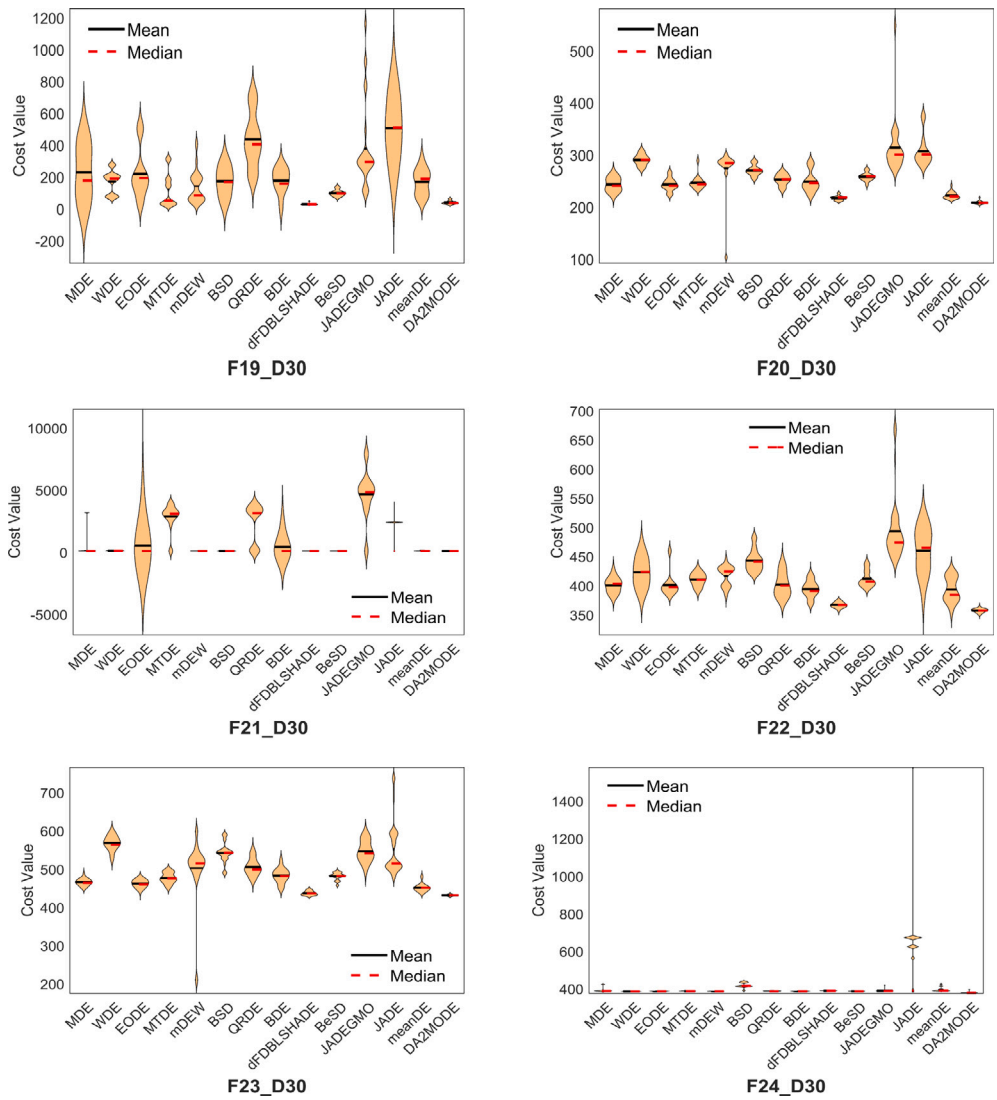



**Fig. F.12d.** Violin plots for the best fitness in 51 runs for 14 DE variants in CEC2017-2018, F19-F24 (30D).

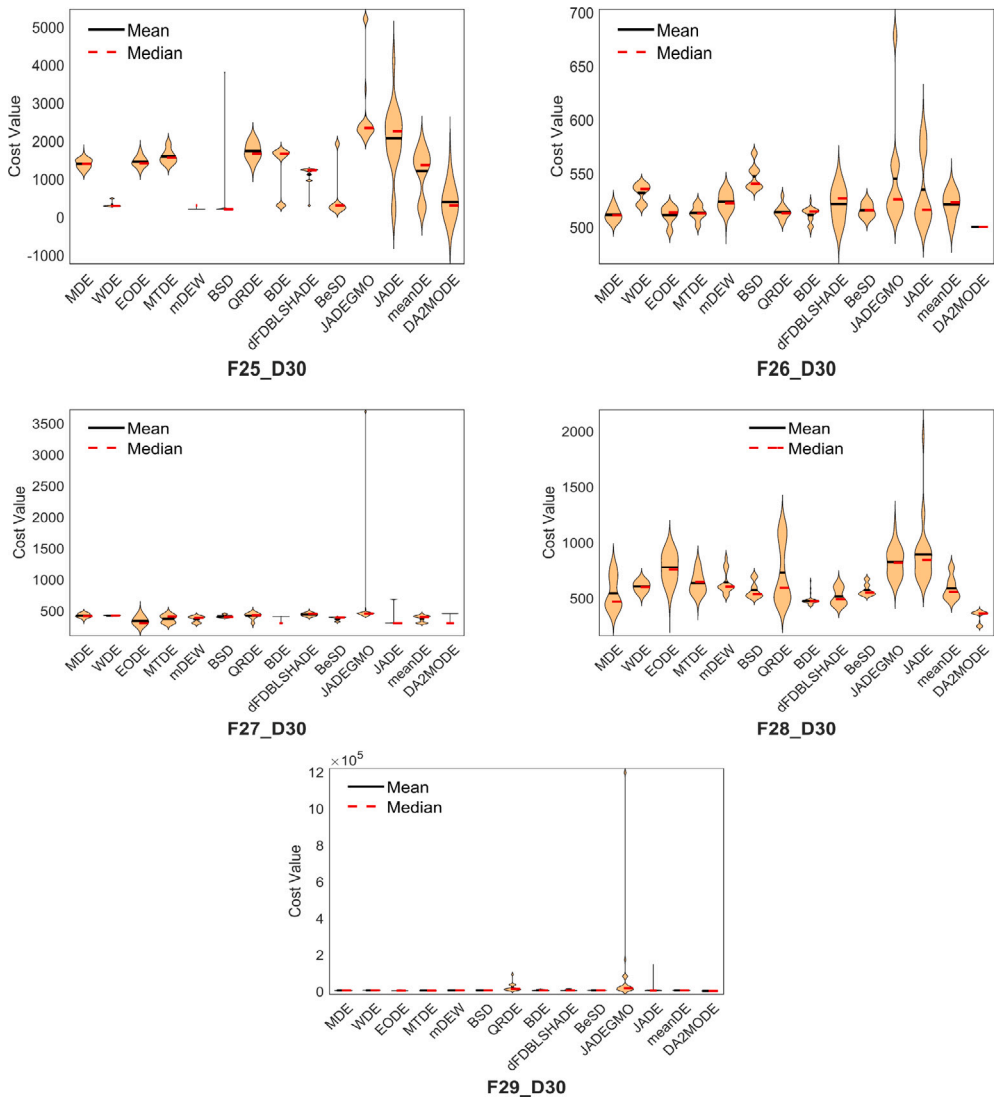



**Fig. F.12e.** Violin plots for the best fitness in 51 runs for 14 DE variants in CEC2017-2018, F25-F29 (30D).

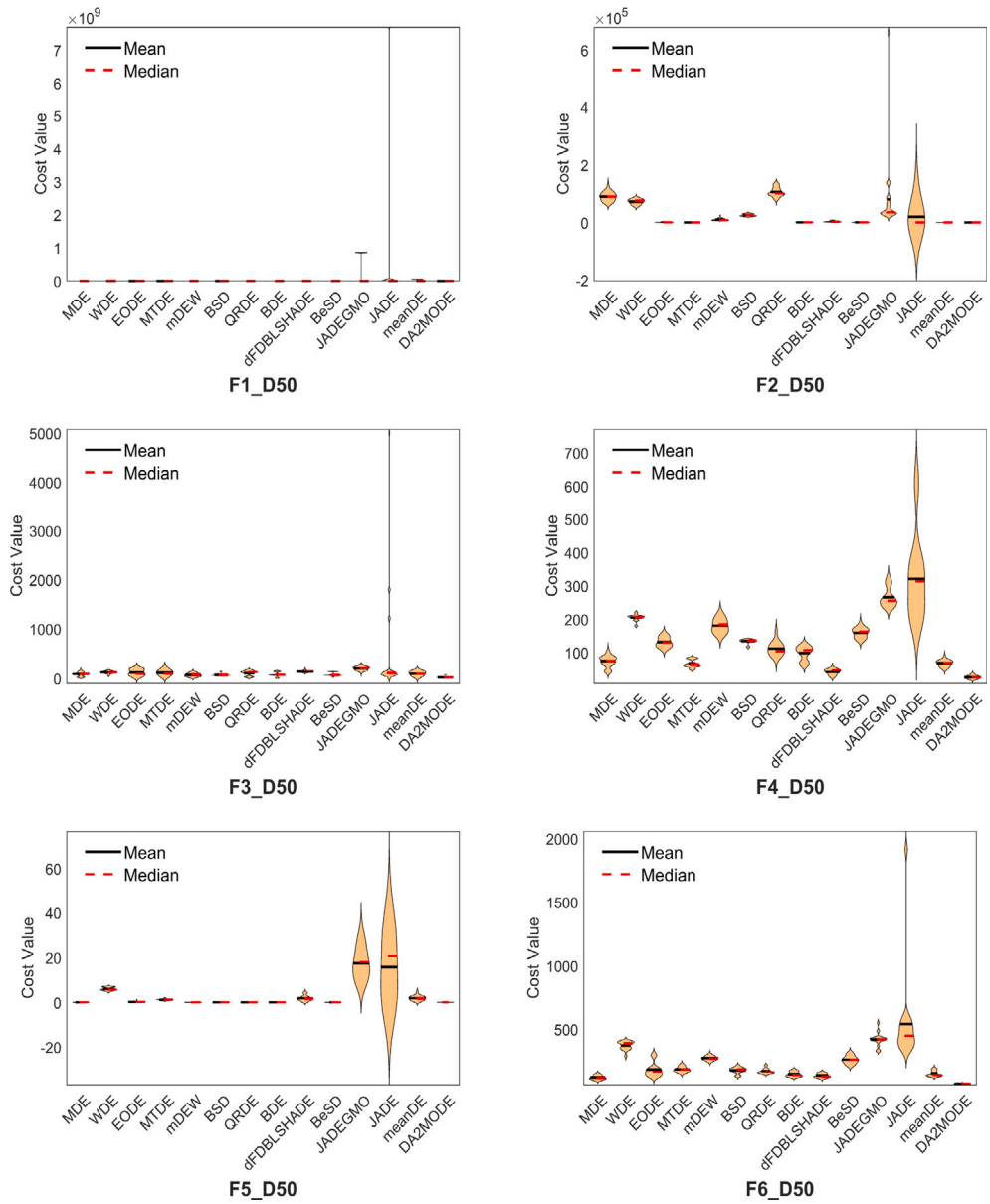



**Fig. F.13a.** Violin plots for the best fitness in 51 runs for 14 DE variants in CEC2017-2018, F1-F6 (50D).

## Appendix G. CEC2017-2018 convergence plots

### G.1. Part 1: Meta-heuristic algorithms and CEC winners

See Figs. G.15a–G.15e, Figs. G.16a–G.16e and Figs. G.17a–G.17e.

### G.2. Part 2: Advanced DE variants

See Figs. G.18a–G.18e, Figs. G.19a–G.19e and Figs. G.20a–G.20e.

## Appendix H. CEC2013-LSGO benchmark results tables

See Table H.15

## Appendix I. CEC2013-LSGO violin plots

See Figs. I.21a–I.21c.

## Appendix J. Engineering optimization benchmark problem definitions

### J.1. F1: Design of tension/compression spring

Minimize: $f(X) = (x_3 + 2)x_2x_1^2$,

subject to:

$$g_1(X) = 1 - \frac{x_3x_2^3}{71785x_1^4} \le 0,$$

$$g_2(X) = \frac{4x_2^2 - x_1x_2}{12566(x_3x_1^3 - x_1^4)} + \frac{1}{5108x_1^2} - 1 \le 0,$$

$$g_3(X) = 1 - \frac{140.45x_1}{x_2^2x_3} \le 0,$$

$$g_4(X) = \frac{x_1 + x_2}{1.5} - 1 \le 0,$$

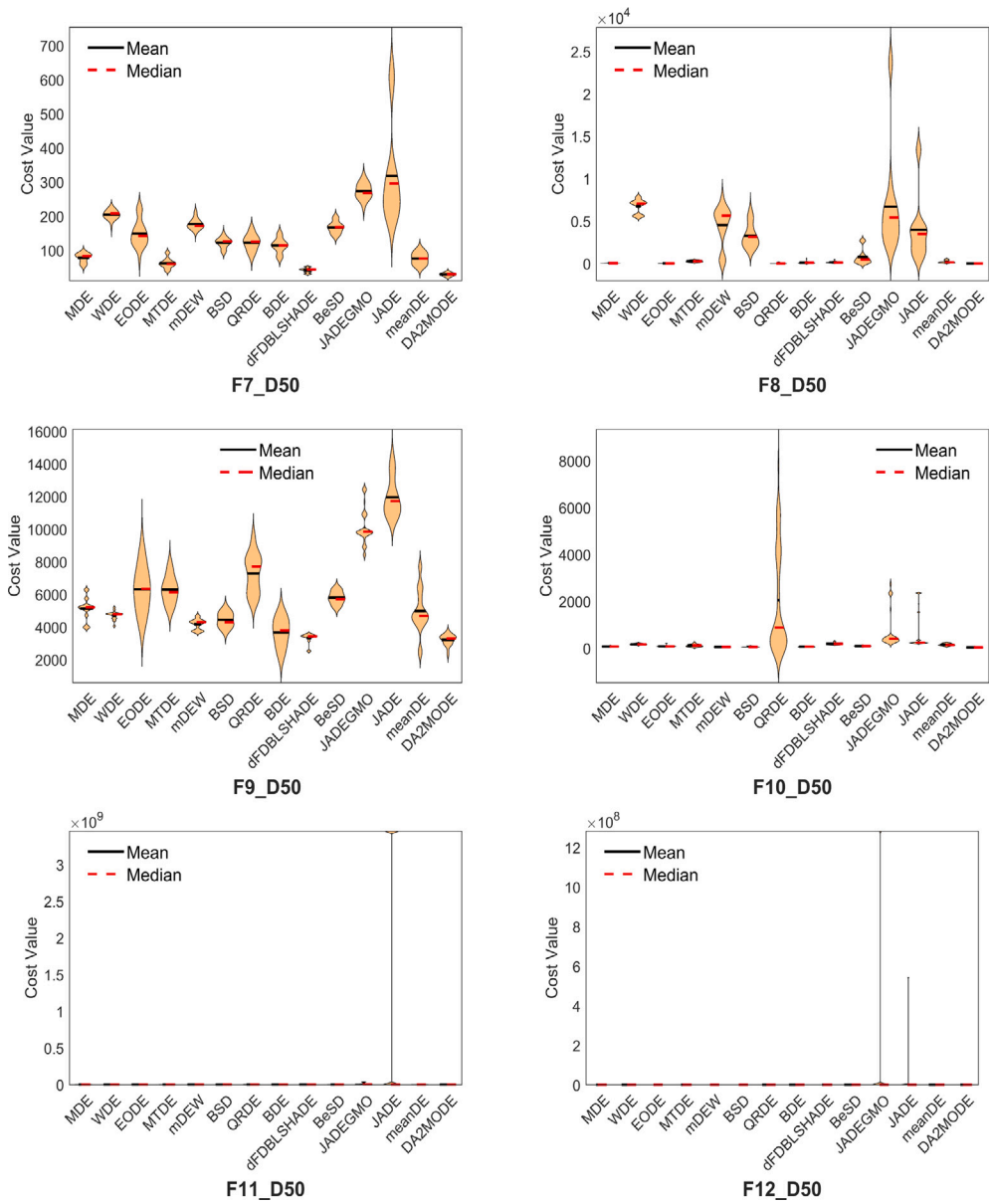



**Fig. F.13b.** Violin plots for the best fitness in 51 runs for 14 DE variants in CEC2017-2018, F7-F12 (50D).

variable range:

$$\begin{aligned} &0.05 \le x_1 \le 2, \\ &0.25 \le x_2 \le 1.3, \\ &2 \le x_3 \le 15, \\ &\text{where:} \\ &x_1 \text{ is the mean coil diameter } (D), \\ &x_2 \text{ is the wire diameter } (d), \\ &x_3 \text{ is the number of active coils } (N). \end{aligned} \tag{J.1}$$

### J.2. F2: Cantilever beam problem

$$\begin{aligned} &\text{minimize:} \quad f(X) = 0.0624(x_1 + x_2 + x_3 + x_4 + x_5), \\ &\text{subject to:} \quad g(X) = \frac{61}{x_1^3} + \frac{37}{x_2^3} + \frac{19}{x_3^3} + \frac{7}{x_4^3} + \frac{1}{x_5^3} - 1 \le 0, \\ &\text{variable range:} \quad 0.01 \le x_i \le 100, \quad i = 1, \dots, 5. \end{aligned} \tag{J.2}$$

### J.3. F3: Optimal design of I-shaped beam

$$\begin{aligned} &\text{Minimize:} \\ &f(X) = \frac{5000}{x_3(x_2 - 2x_4)^3/12 + (x_1 x_4^3/6) + 2bx_4(x_2 - x_4/2)^2}, \\ &\text{Subject to:} \\ &g_1(X) = 2x_1x_3 + x_3(x_2 - 2x_4) \le 300, \\ &g_2(X) = \frac{18x_2 \times 10^4}{x_3(x_2 - 2x_4)^3 + 2x_1x_3(4x_2 + 3x_2(x_2 - 2x_4))} + \frac{15x_1 \times 10^3}{(x_2 - 2x_4)x_3^2 + 2x_3x_1} \le 56, \\ &\text{Variable range:} \\ &10 \le x_1 \le 80, \quad 10 \le x_2 \le 50, \quad 0.9 \le x_3 \le 5, \quad 0.9 \le x_4 \le 5, \\ &\text{where:} \\ &x_1\text{: Width of the flange } (b), \\ &x_2\text{: Height of the section } (h), \\ &x_3\text{: Thickness of the web } (t_w), \\ &x_4\text{: Thickness of the flange } (t_f). \end{aligned} \tag{J.3}$$

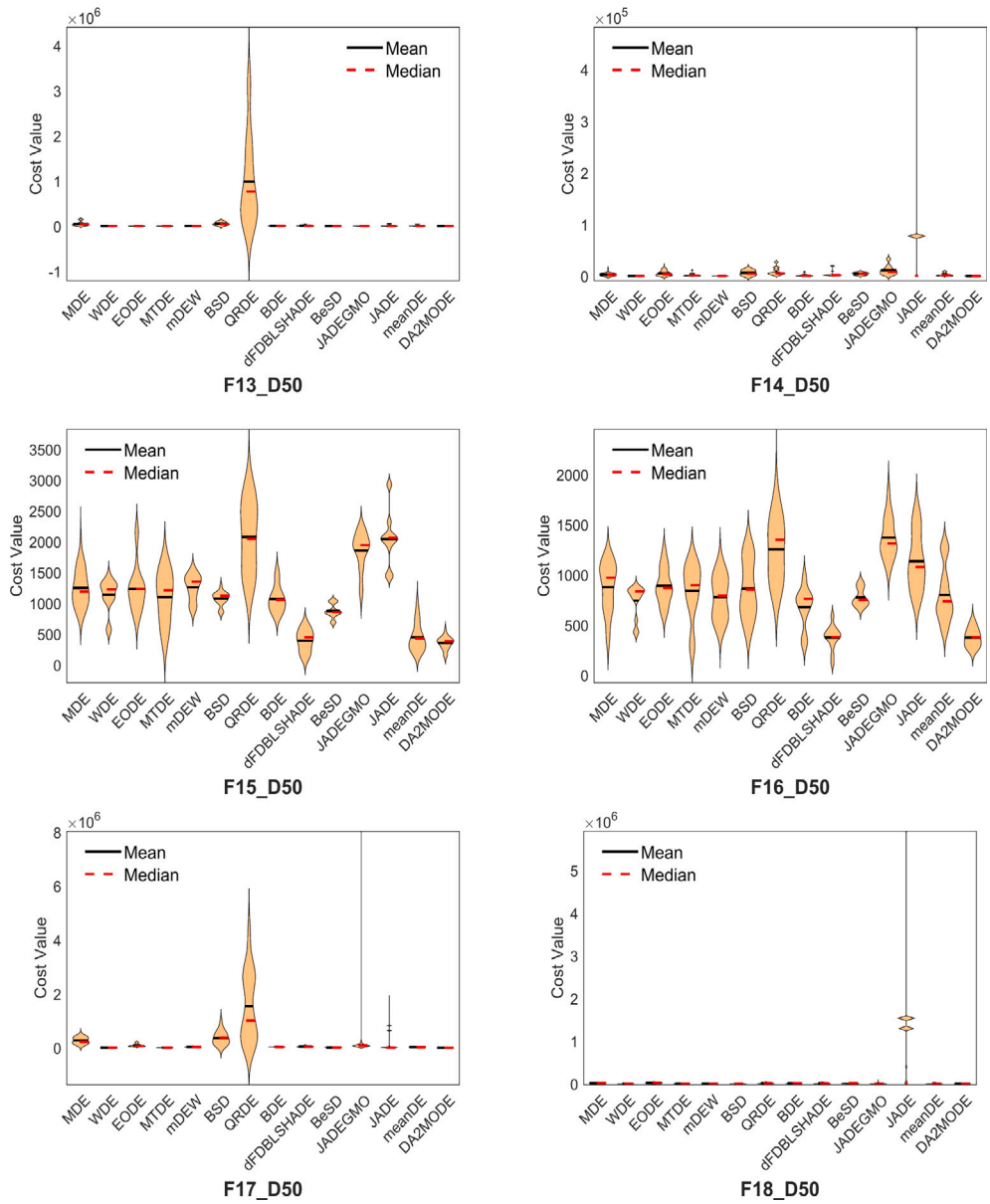



**Fig. F.13c.** Violin plots for the best fitness in 51 runs for 14 DE variants in CEC2017-2018, F13-F18 (50D).

### *J.4. F4: Design of welded beam*

$$
\begin{aligned}
&\text{Minimize:} \quad f(X) = 1.10471x_1^2x_2 + 0.04811x_3x_4(14.0 + x_2),\\
&\text{Subject to:}\\
&g_1(X) = \tau(x) - \tau_{\max} \le 0,\\
&g_2(X) = \sigma(x) - \sigma_{\max} \le 0,\\
&g_3(X) = \delta(x) - \delta_{\max} \le 0,\\
&g_4(X) = x_1 - x_4 \le 0,\\
&g_5(X) = P - P_c(x) \le 0,\\
&g_6(X) = 0.125 - x_1 \le 0,\\
&g_7(X) = 1.10471x_1^2x_2 + 0.04811x_3x_4(14.0 + x_2) - 5.0 \le 0,\\
&\text{where:}\\
&\tau(x) = \sqrt{(\tau')^2 + 2\tau'\tau''\frac{x_2}{R} + (\tau'')^2}, \quad \tau' = \frac{P}{\sqrt{2}x_1x_2}, \quad \tau'' = \frac{MR}{J},\\
&M = P\left(L + \frac{x_2}{2}\right), \quad R = \sqrt{\frac{x_2^2}{4} + \left(\frac{x_1 + x_3}{2}\right)^2},\\
&J = 2\left[x_1x_2\sqrt{\frac{x_2^2}{4} + \left(\frac{x_1 + x_3}{2}\right)^2}\right],\\
&\sigma(x) = \frac{6PL}{x_4x_3^2}, \quad \delta(x) = \frac{6PL^3}{Ex_3x_4^3},\\
&P_c(x) = \frac{4.013E\sqrt{x_3^2x_4^6/36}}{L^2}\left(1 - \frac{x_3}{2L}\sqrt{\frac{E}{4G}}\right),
\end{aligned}
\tag{J.4}
$$

$$
\begin{aligned}
&P = 6000\,\text{lb}, \quad L = 14\,\text{in}, \quad \delta_{\max} = 0.25\,\text{in},\\
\text{Constants:}\quad &E = 30 \times 10^6\,\text{psi}, \quad G = 12 \times 10^6\,\text{psi},\\
&\tau_{\max} = 13,600\,\text{psi}, \quad \sigma_{\max} = 30,000\,\text{psi}.
\end{aligned}
$$

$$
\text{Variable ranges:}\quad \begin{aligned} &0.1 \le x_1, \quad x_4 \le 2,\\ &0.1 \le x_2, \quad x_3 \le 10. \end{aligned}
$$

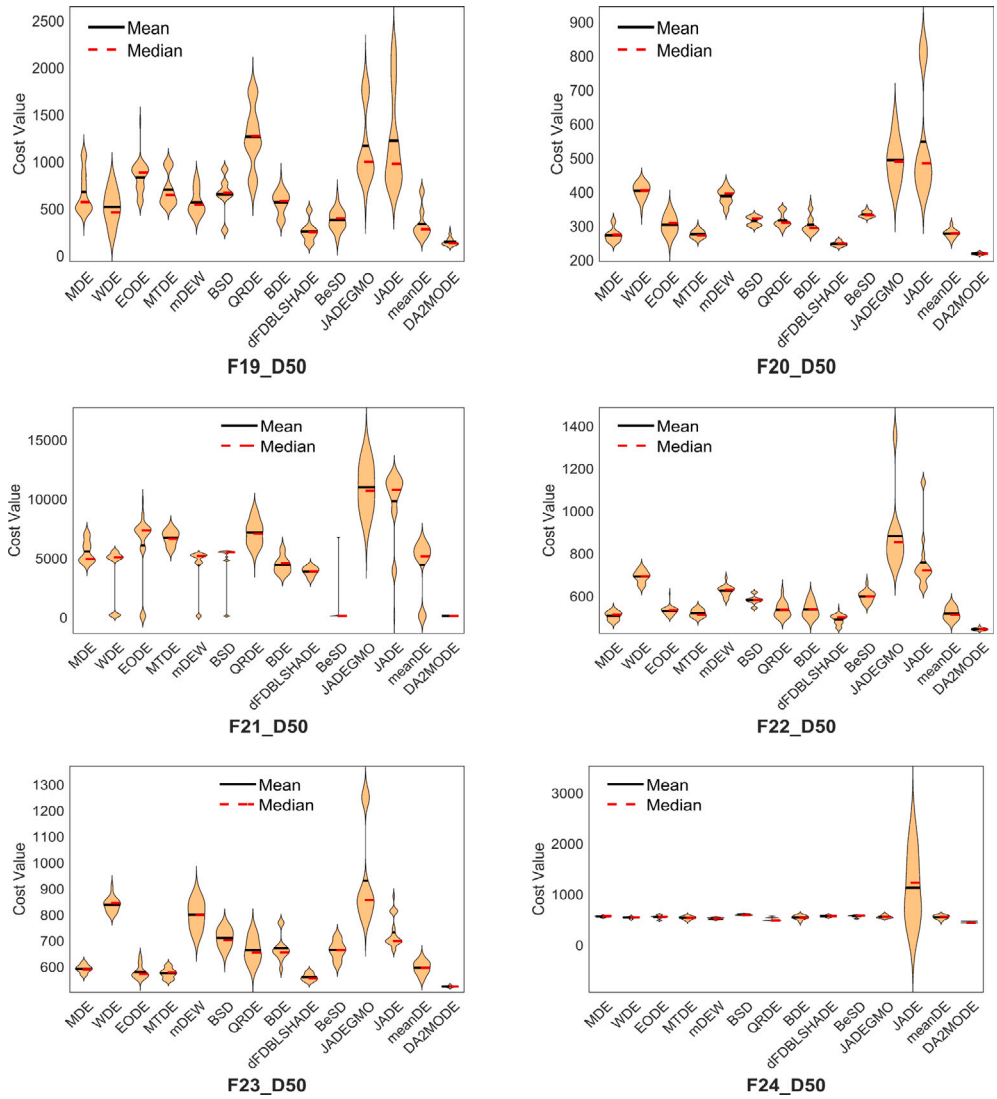



**Fig. F.13d.** Violin plots for the best fitness in 51 runs for 14 DE variants in CEC2017-2018, F19-F24 (50D).

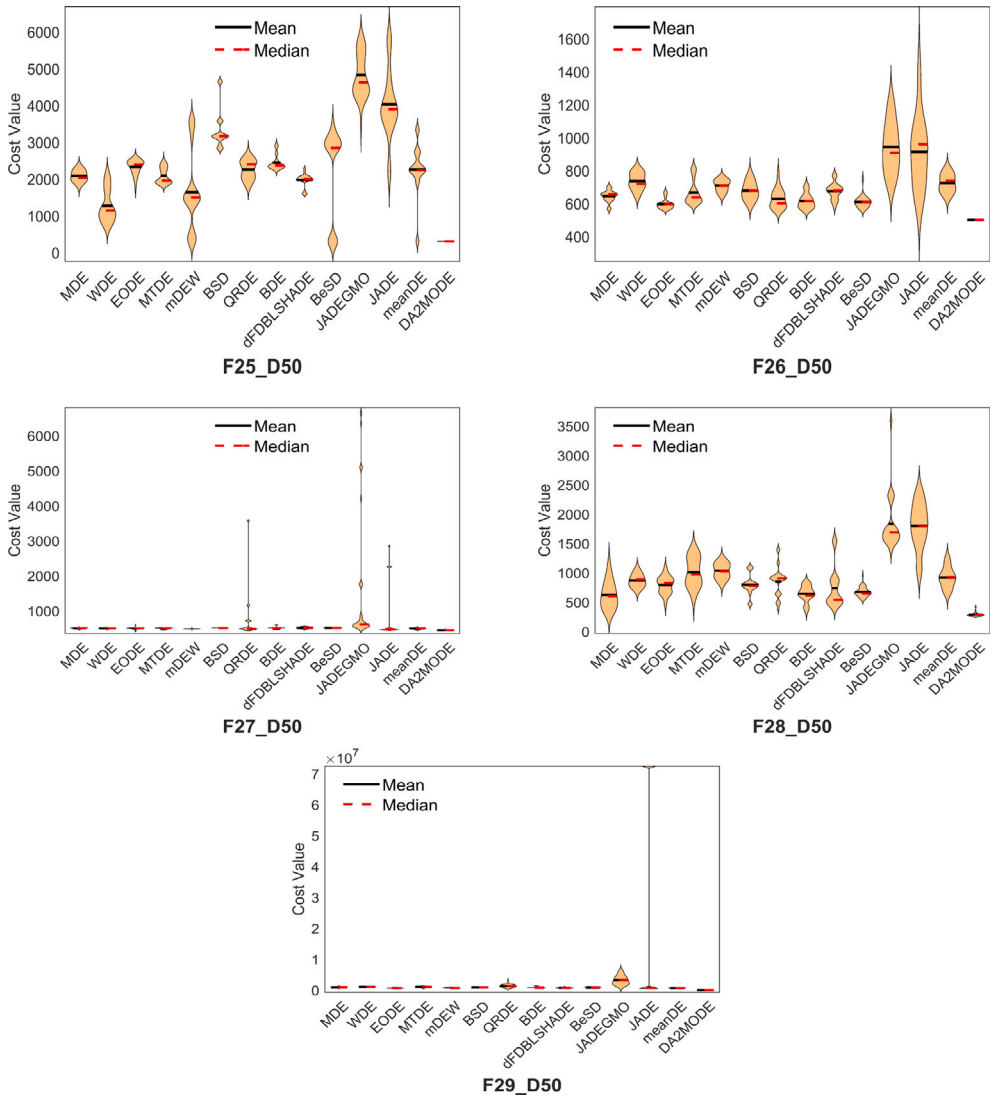



**Fig. F.13e.** Violin plots for the best fitness in 51 runs for 14 DE variants in CEC2017-2018, F25-F29 (50D).

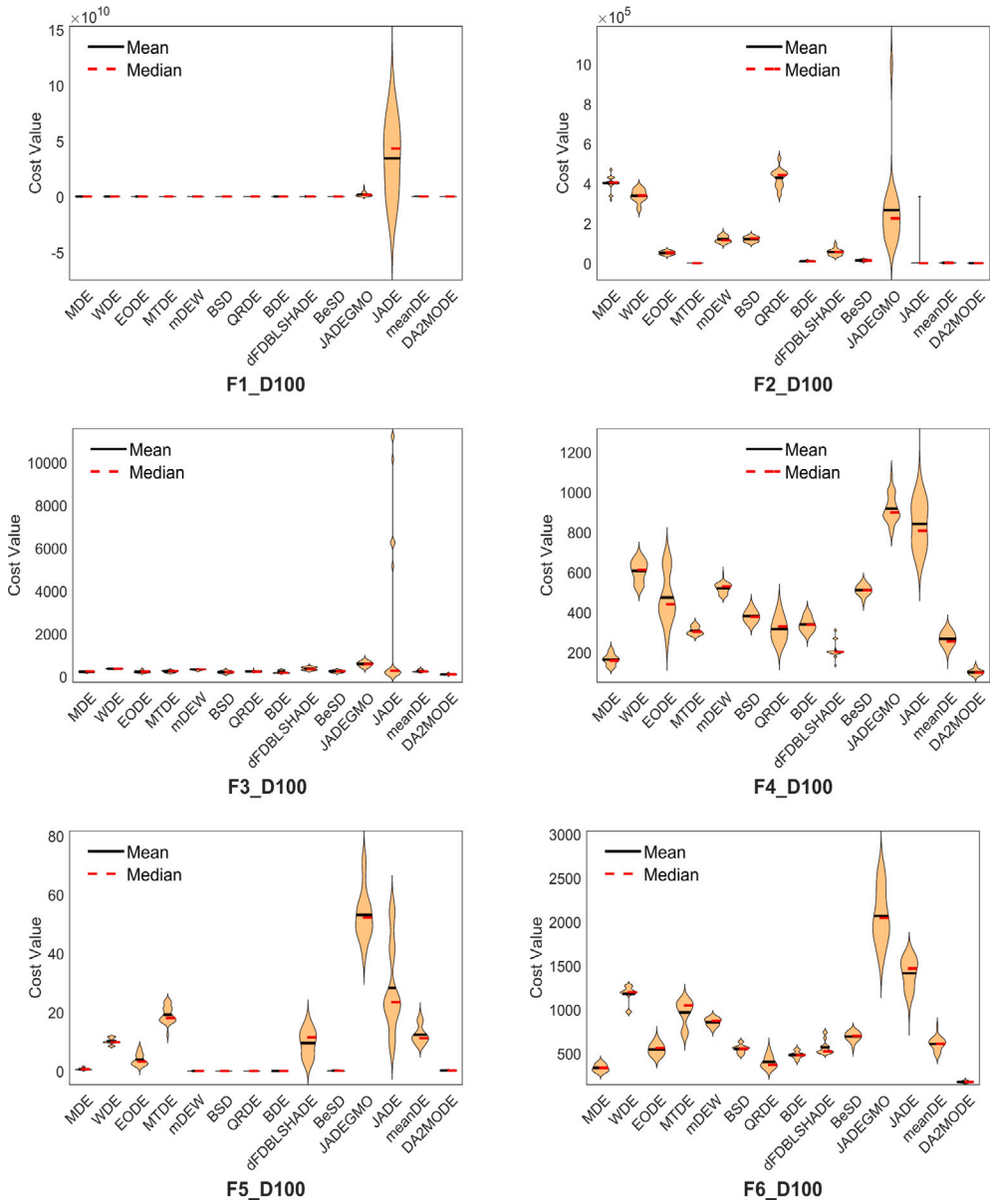



**Fig. F.14a.** Violin plots for the best fitness in 51 runs for 14 DE variants in CEC2017-2018, F1-F6 (100D).

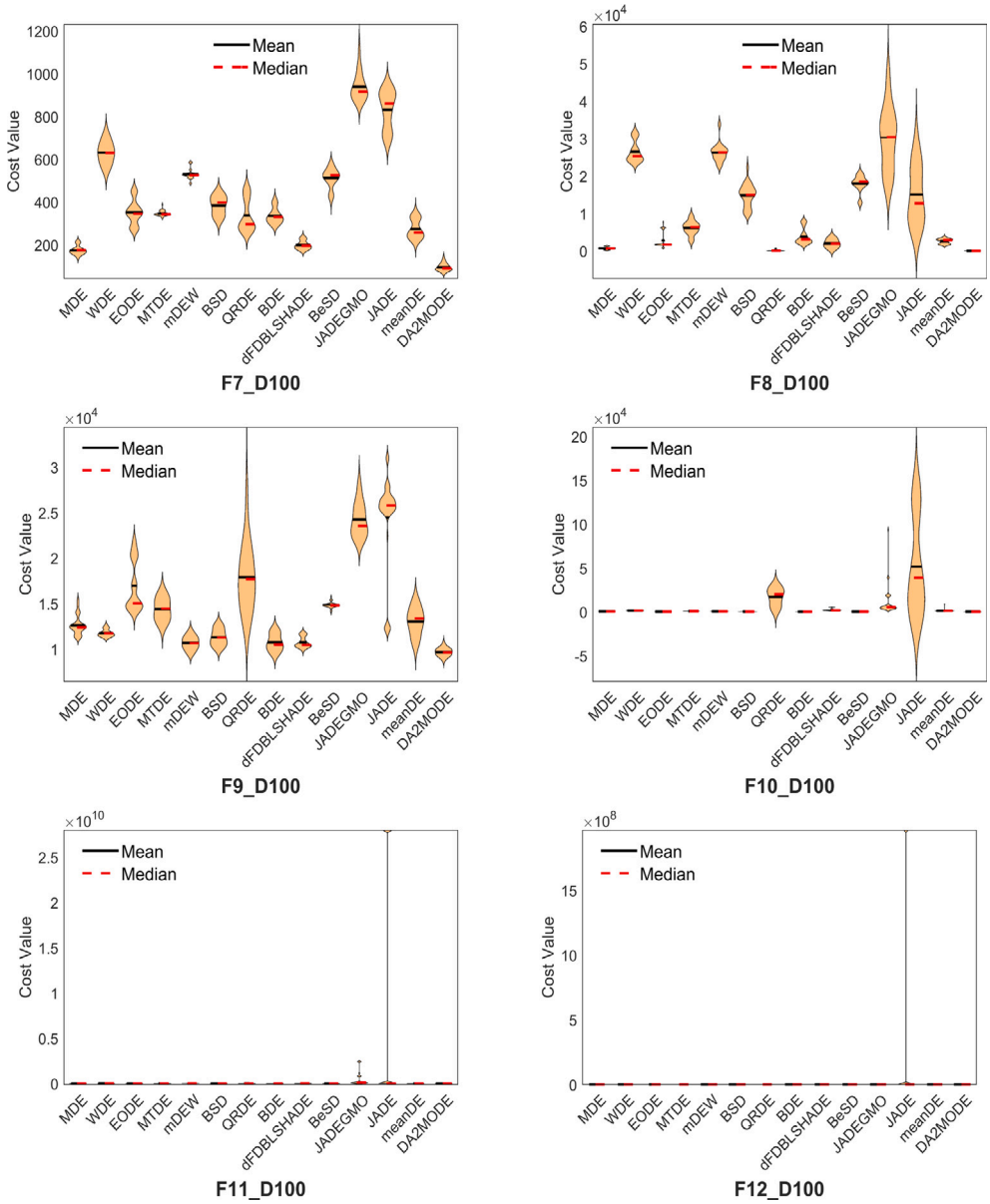



**Fig. F.14b.** Violin plots for the best fitness in 51 runs for 14 DE variants in CEC2017-2018, F7-F12 (100D).

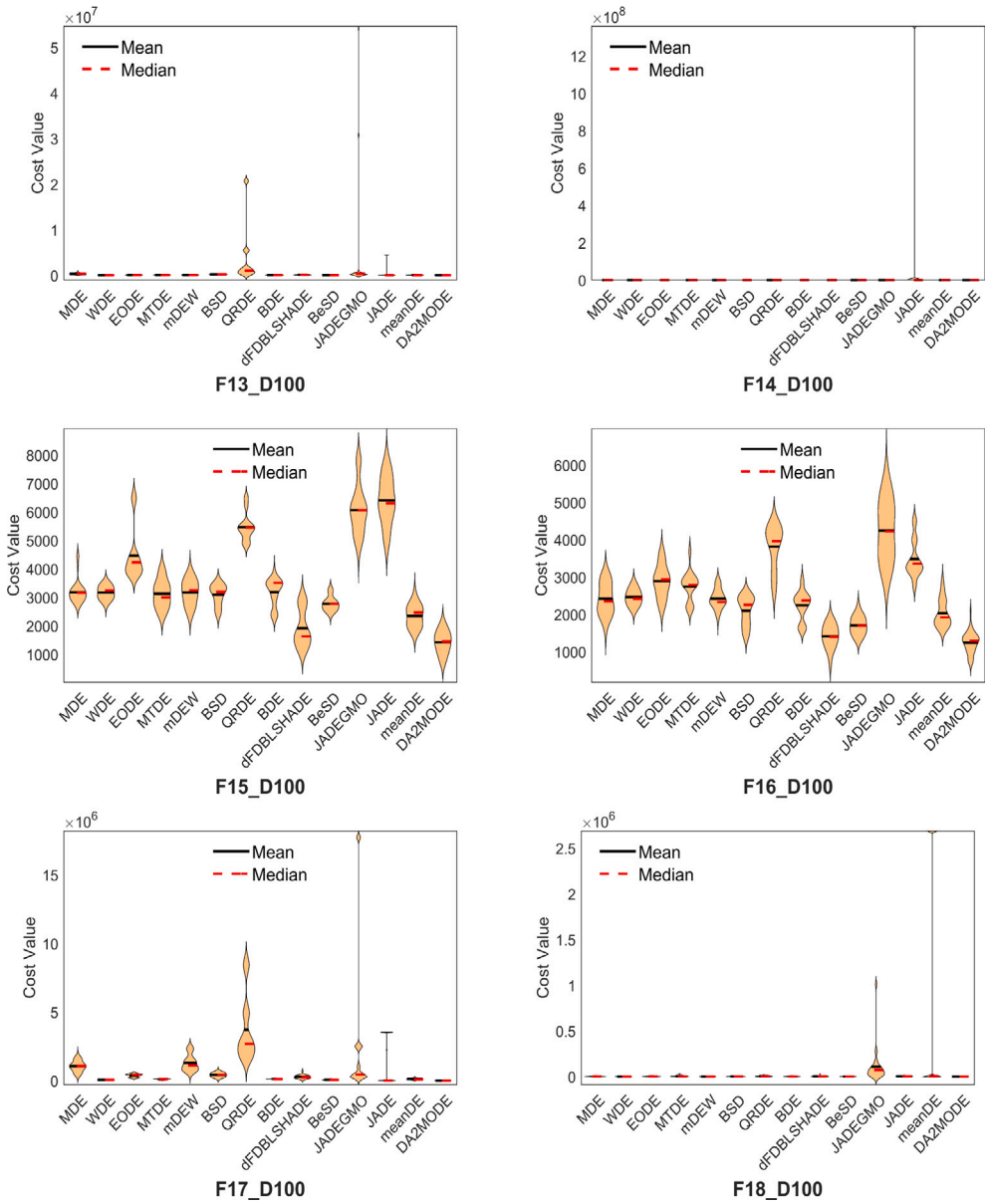



**Fig. F.14c.** Violin plots for the best fitness in 51 runs for 14 DE variants in CEC2017-2018, F13-F18 (100D).

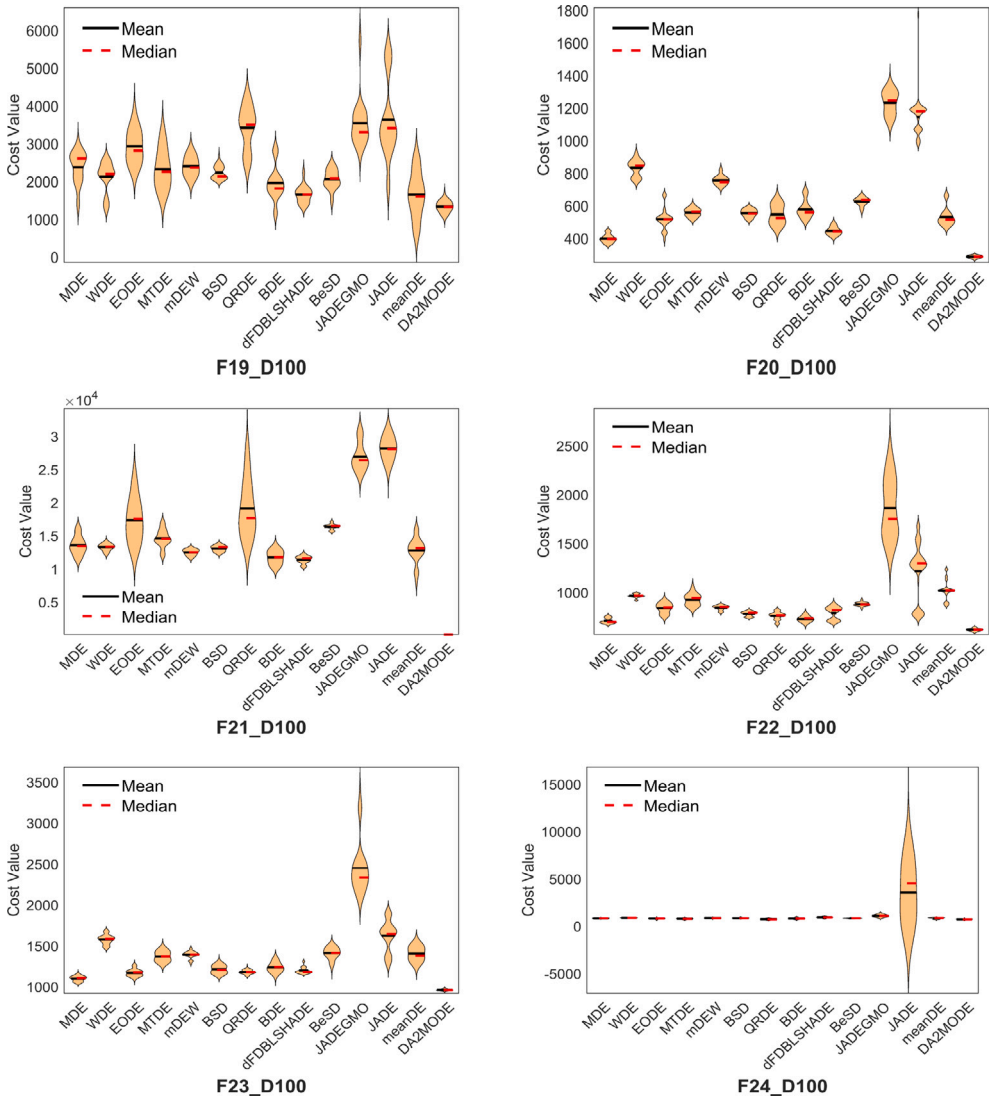



**Fig. F.14d.** Violin plots for the best fitness in 51 runs for 14 DE variants in CEC2017-2018, F19-F24 (100D).

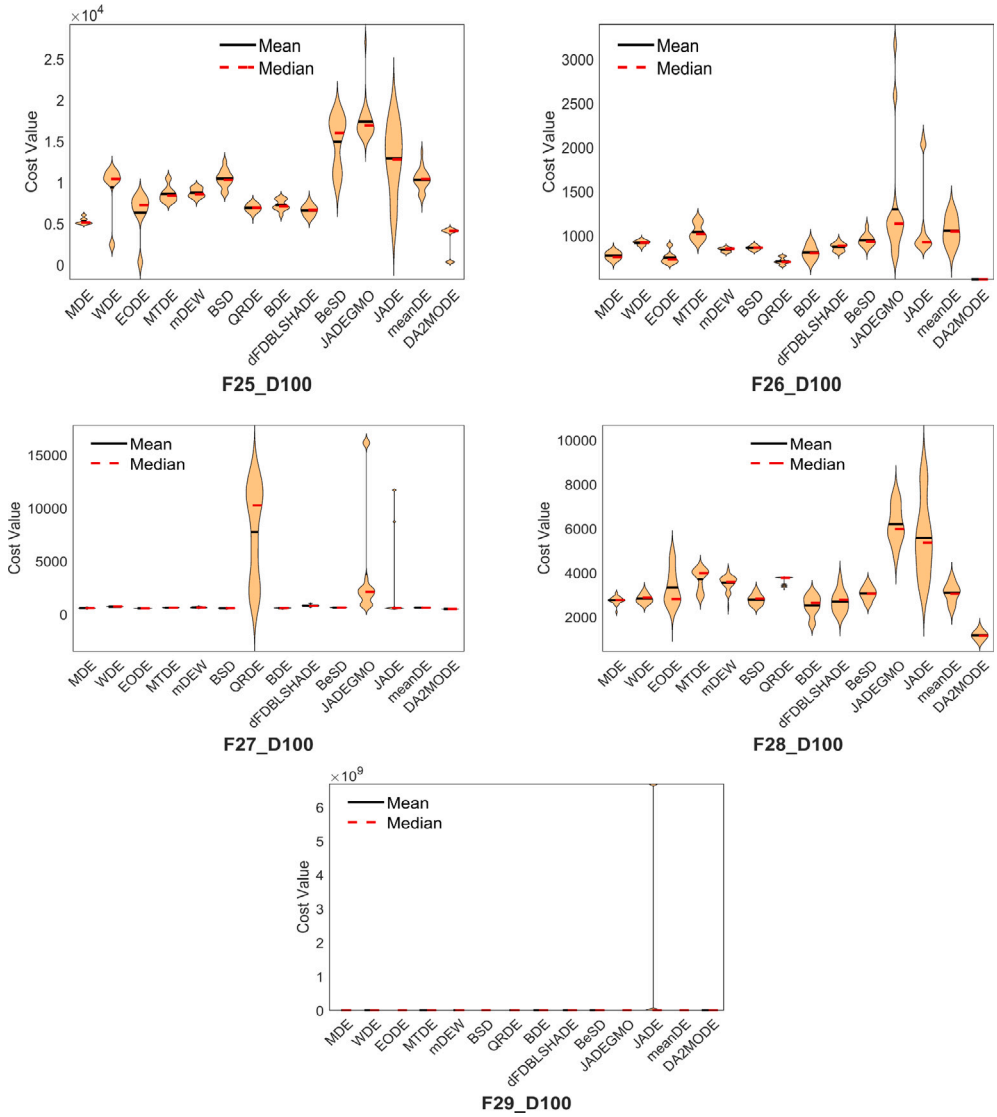



**Fig. F.14e.** Violin plots for the best fitness in 51 runs for 14 DE variants in CEC2017-2018, F25-F29 (100D).

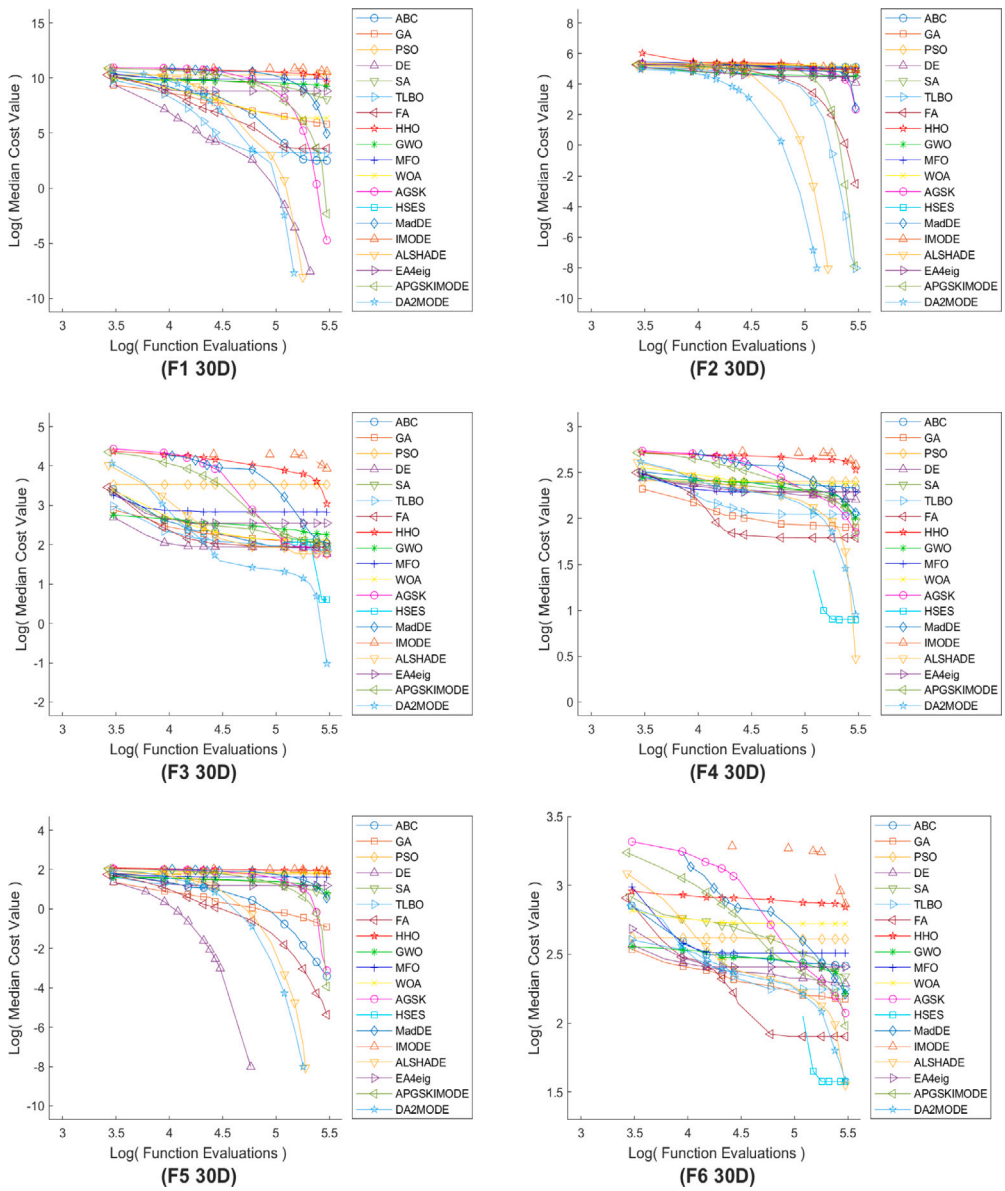



**Fig. G.15a.** Convergence plots for median fitness in 51 runs for all algorithms CEC2017-2018, (F1-F6, 30D).

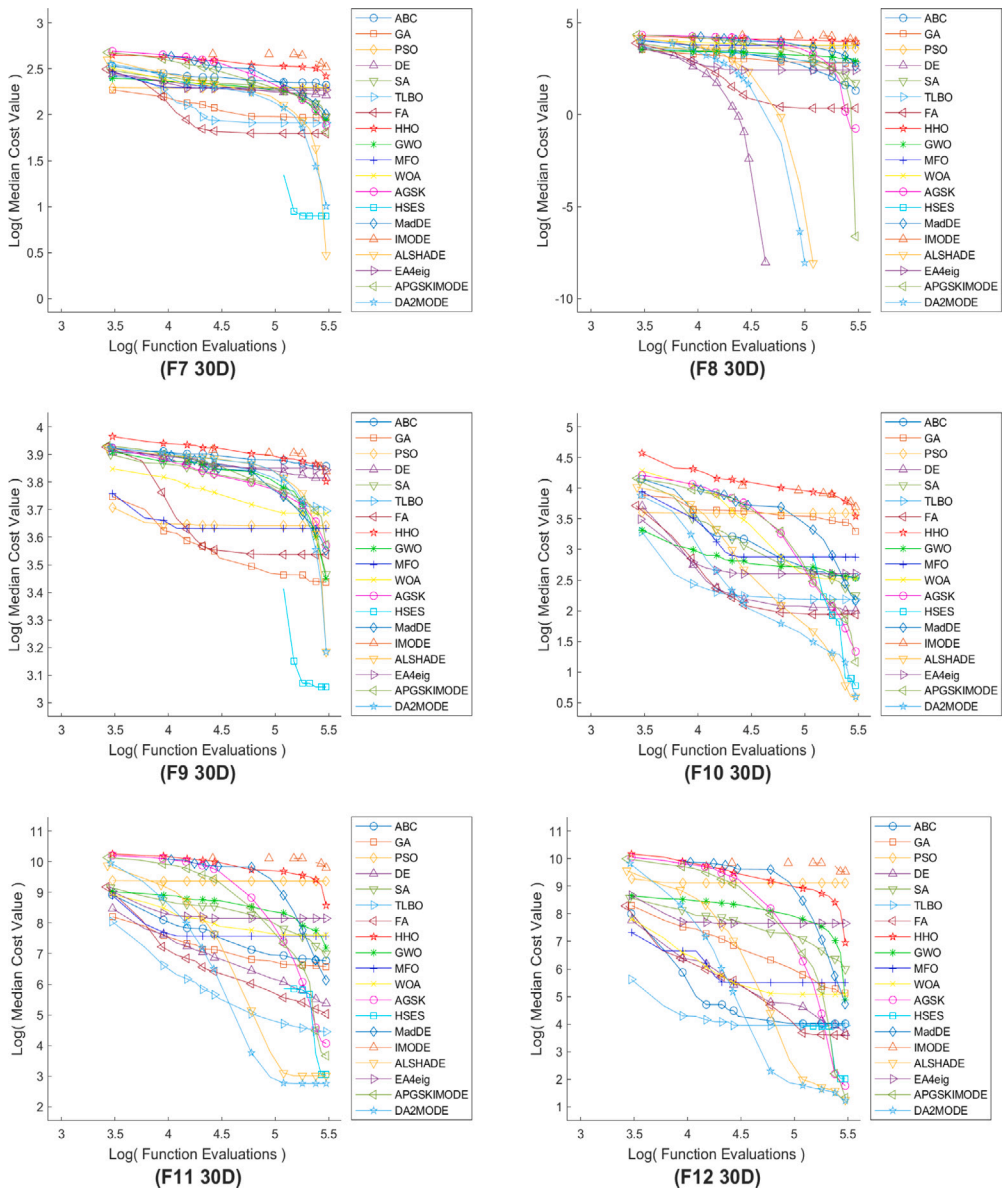



**Fig. G.15b.** Convergence plots for median fitness in 51 runs for all algorithms CEC2017-2018, (F7-F12, 30D).

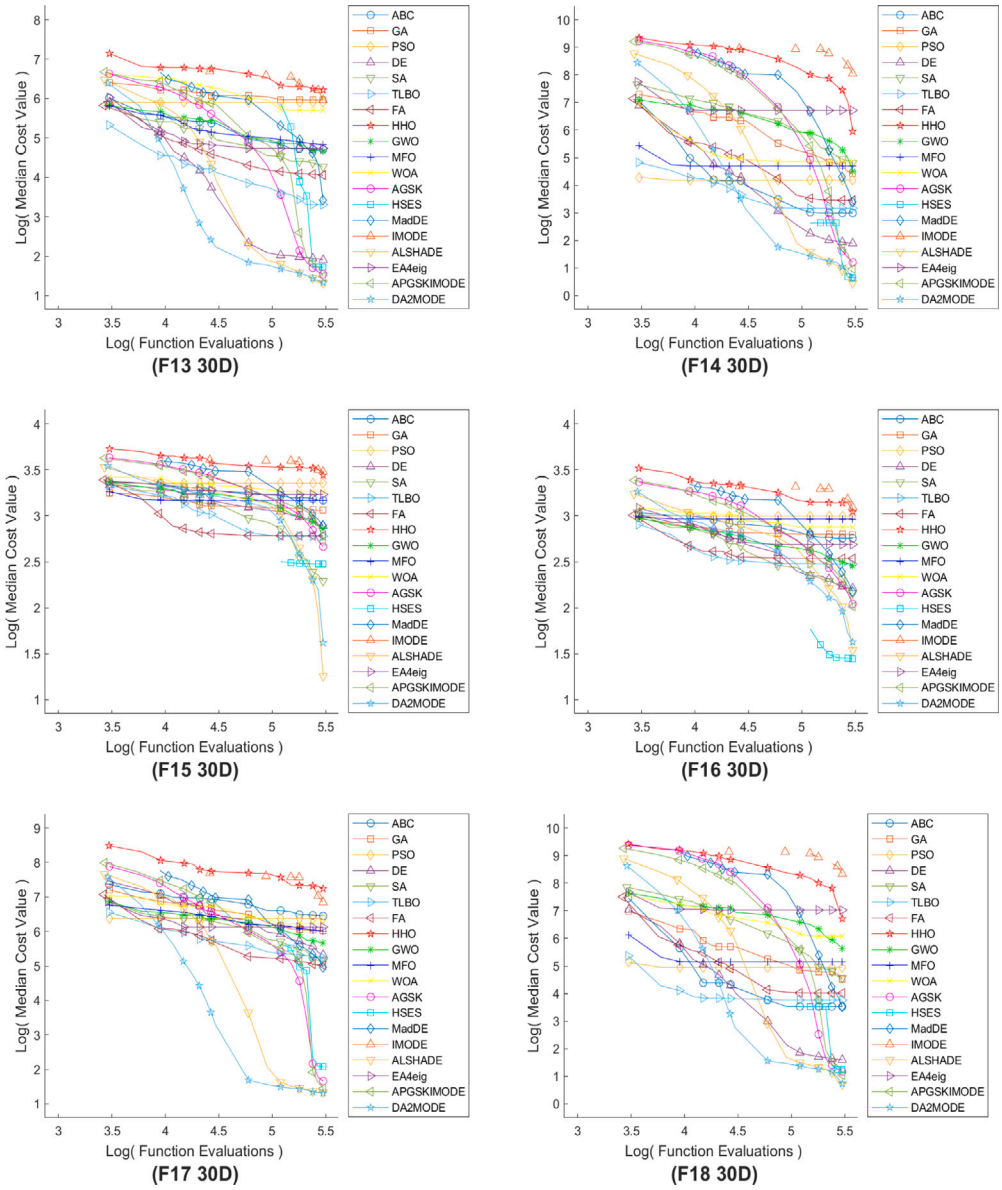



**Fig. G.15c.** Convergence plots for median fitness in 51 runs for all algorithms CEC2017-2018, (F13-F18, 30D).

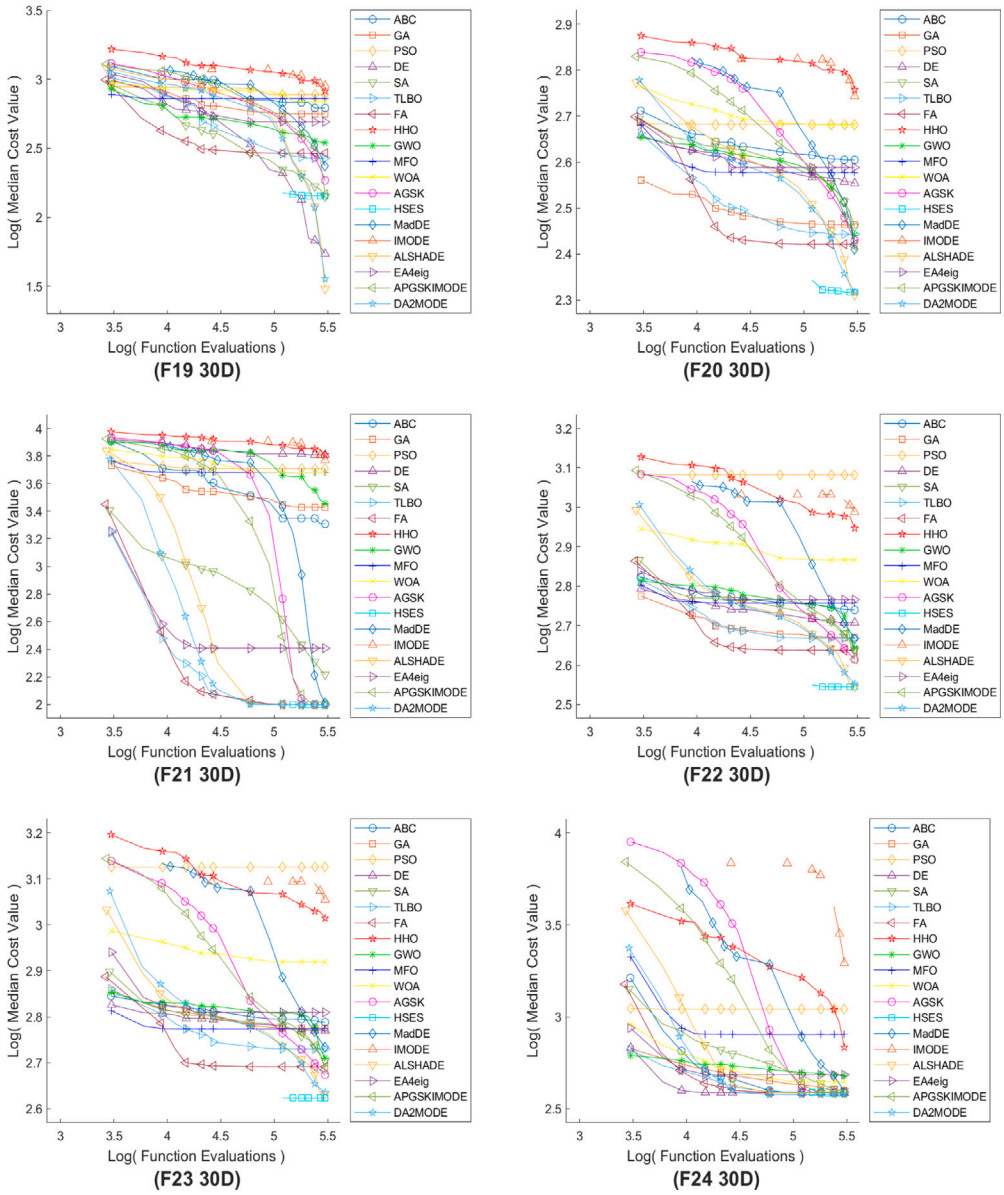



**Fig. G.15d.** Convergence plots for median fitness in 51 runs for all algorithms CEC2017-2018, (F19-F24, 30D).

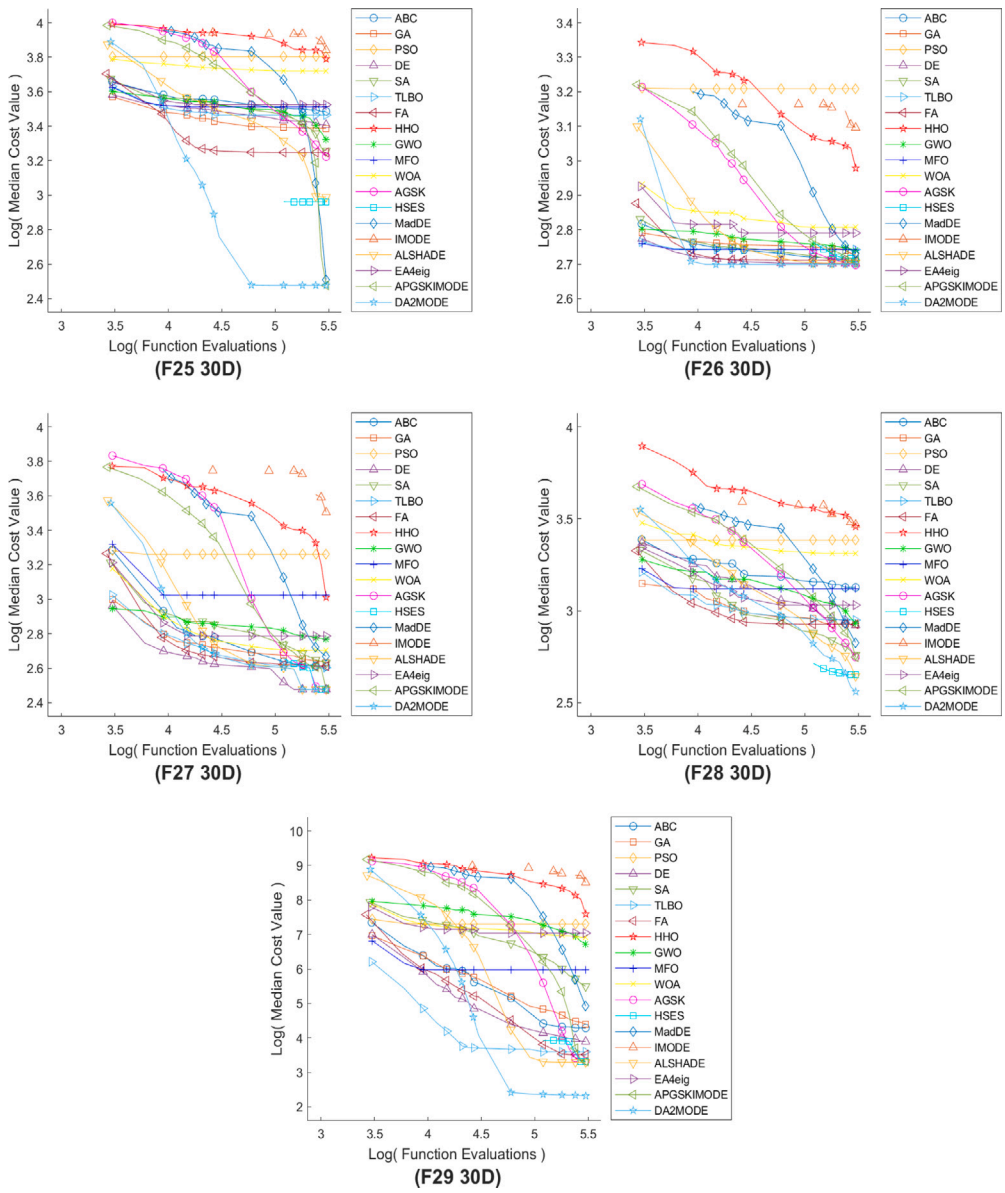



**Fig. G.15e.** Convergence plots for median fitness in 51 runs for all algorithms CEC2017-2018, (F25-F29, 30D).

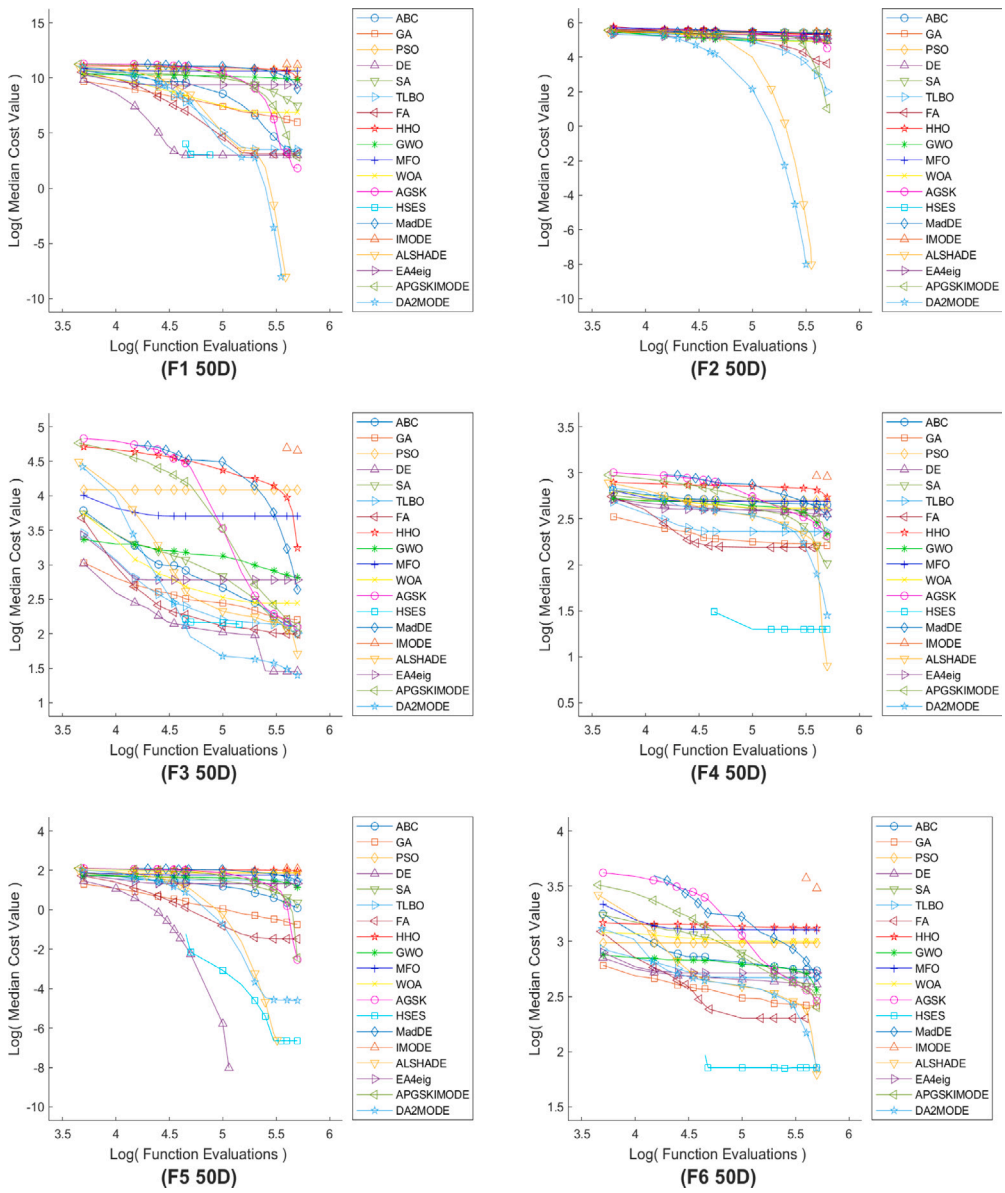



**Fig. G.16a.** Convergence plots for median fitness in 51 runs for all algorithms CEC2017-2018, (F1-F6, 50D).

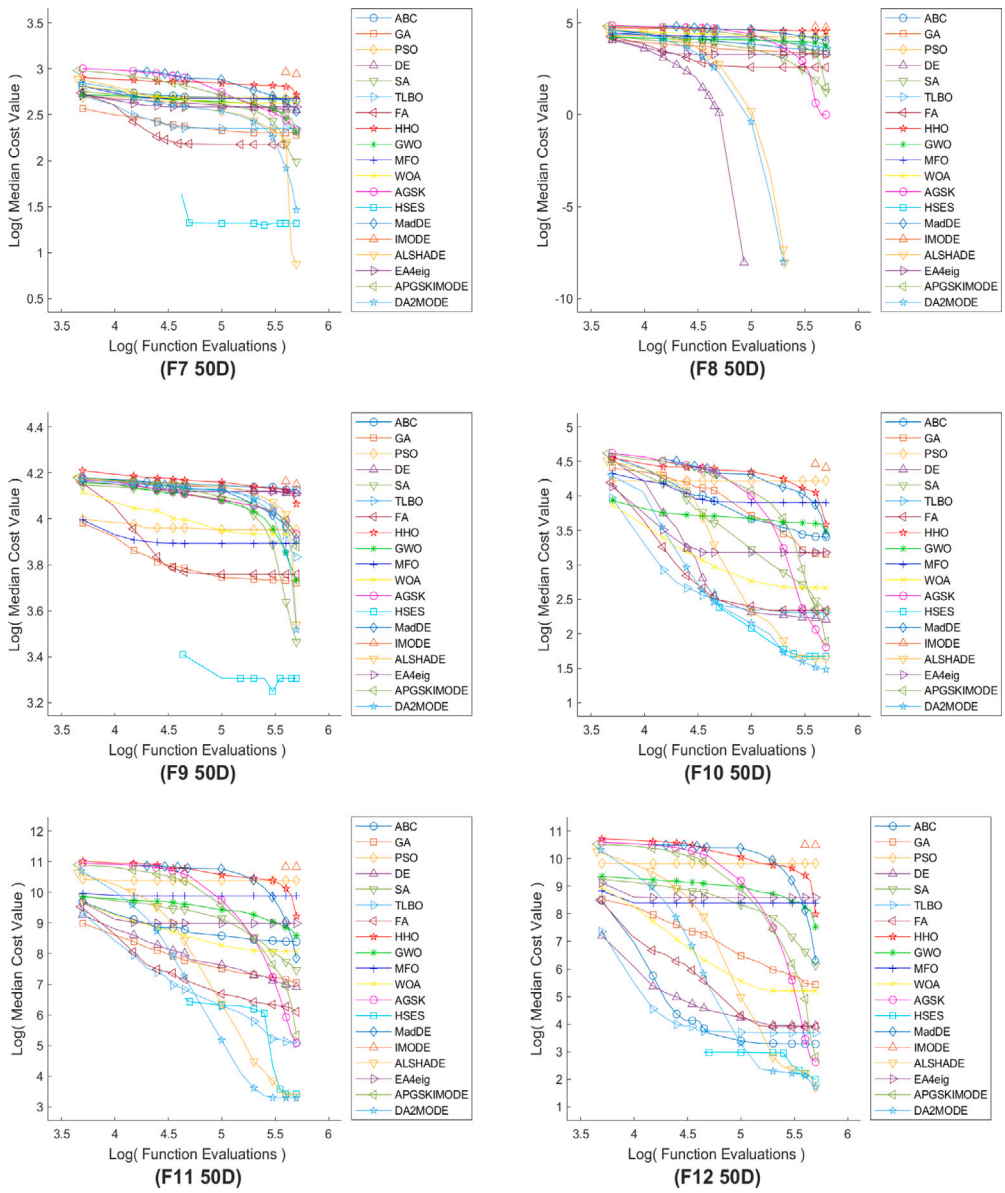



**Fig. G.16b.** Convergence plots for median fitness in 51 runs for all algorithms CEC2017-2018, (F7-F12, 50D).

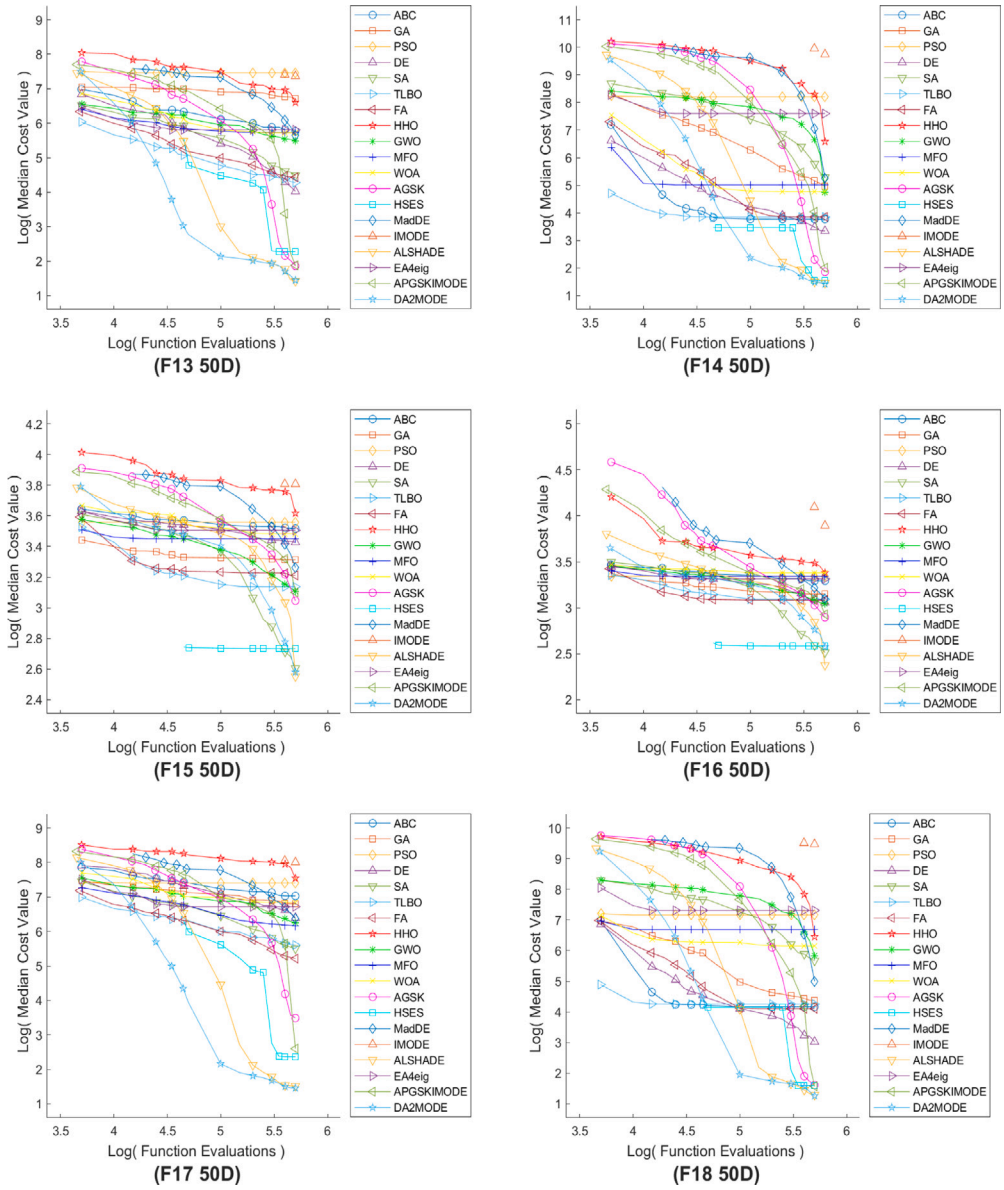



**Fig. G.16c.** Convergence plots for median fitness in 51 runs for all algorithms CEC2017-2018, (F13-F18, 50D).

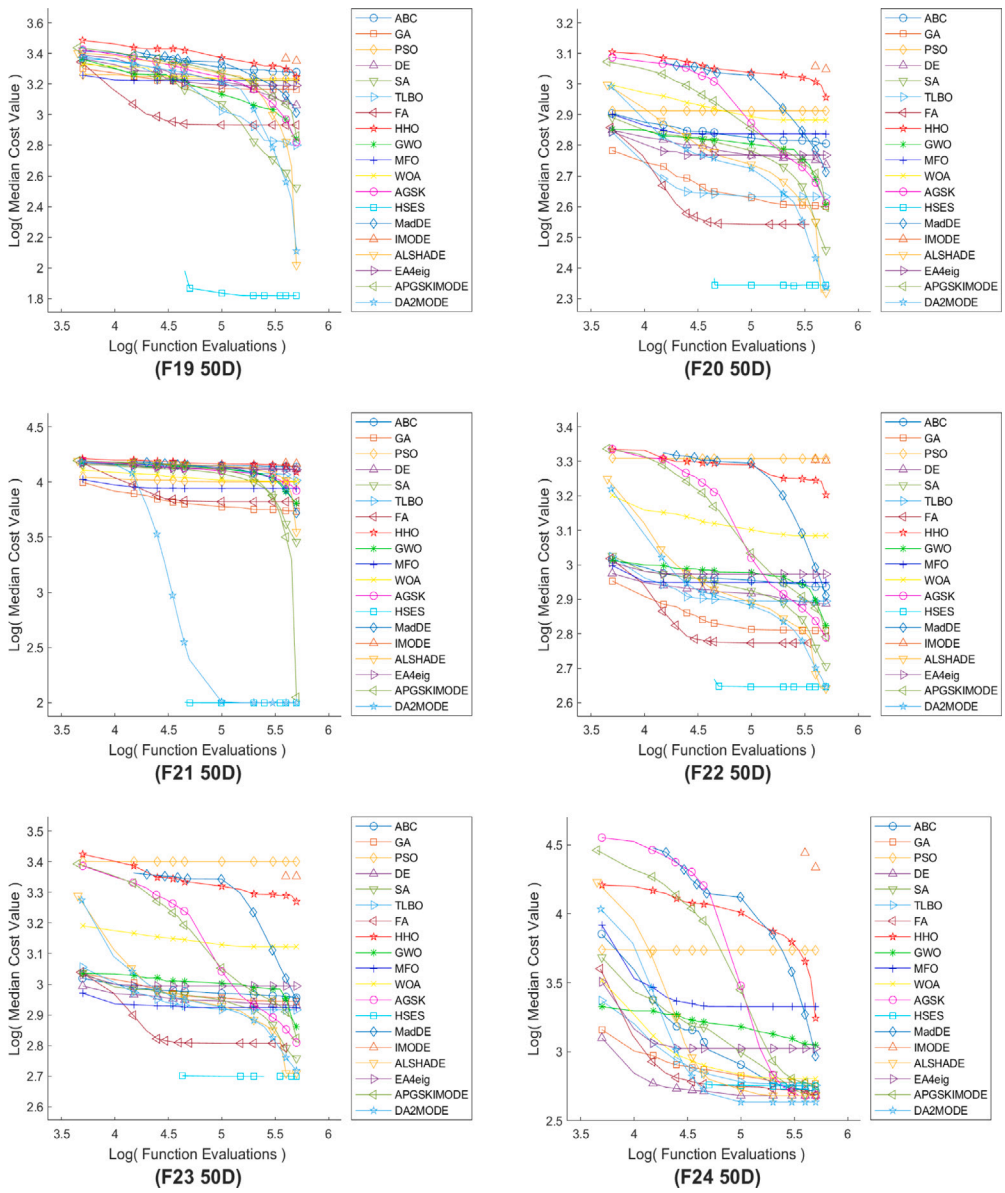



**Fig. G.16d.** Convergence plots for median fitness in 51 runs for all algorithms CEC2017-2018, (F19-F24, 50D).

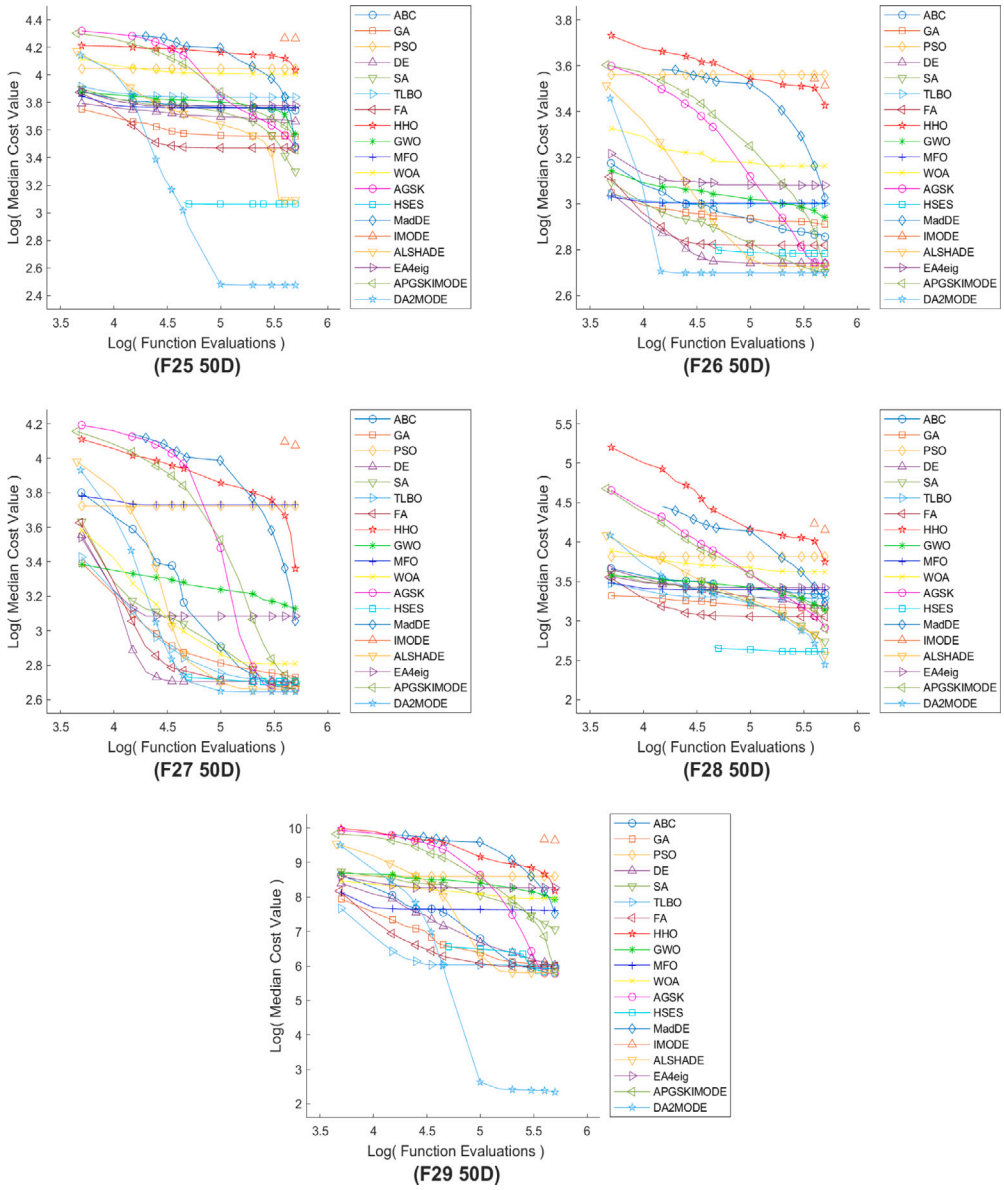



**Fig. G.16e.** Convergence plots for median fitness in 51 runs for all algorithms CEC2017-2018, (F25-F29, 50D).

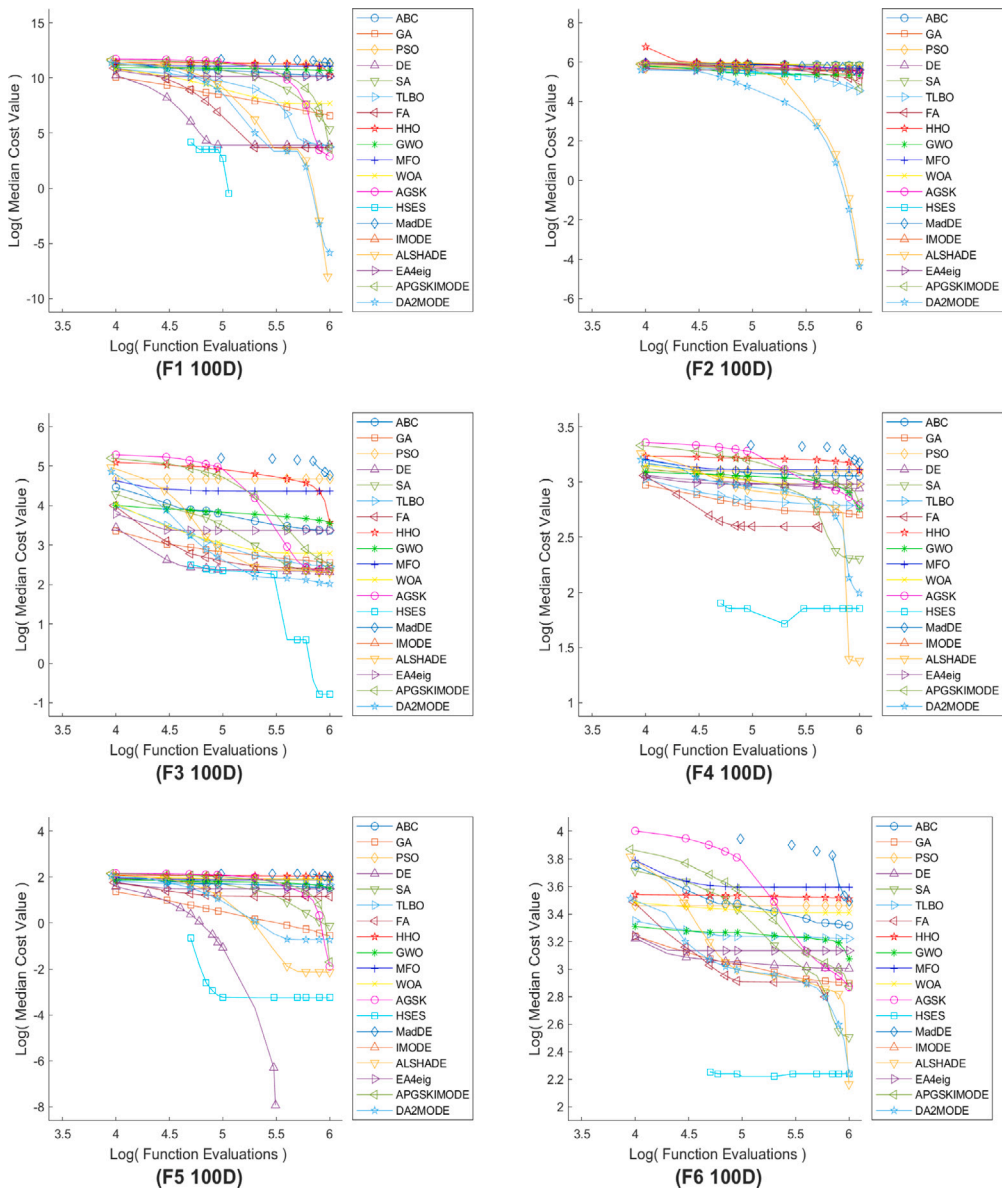



**Fig. G.17a.** Convergence plots for median fitness in 51 runs for all algorithms CEC2017-2018, (F1-F6, 100D).

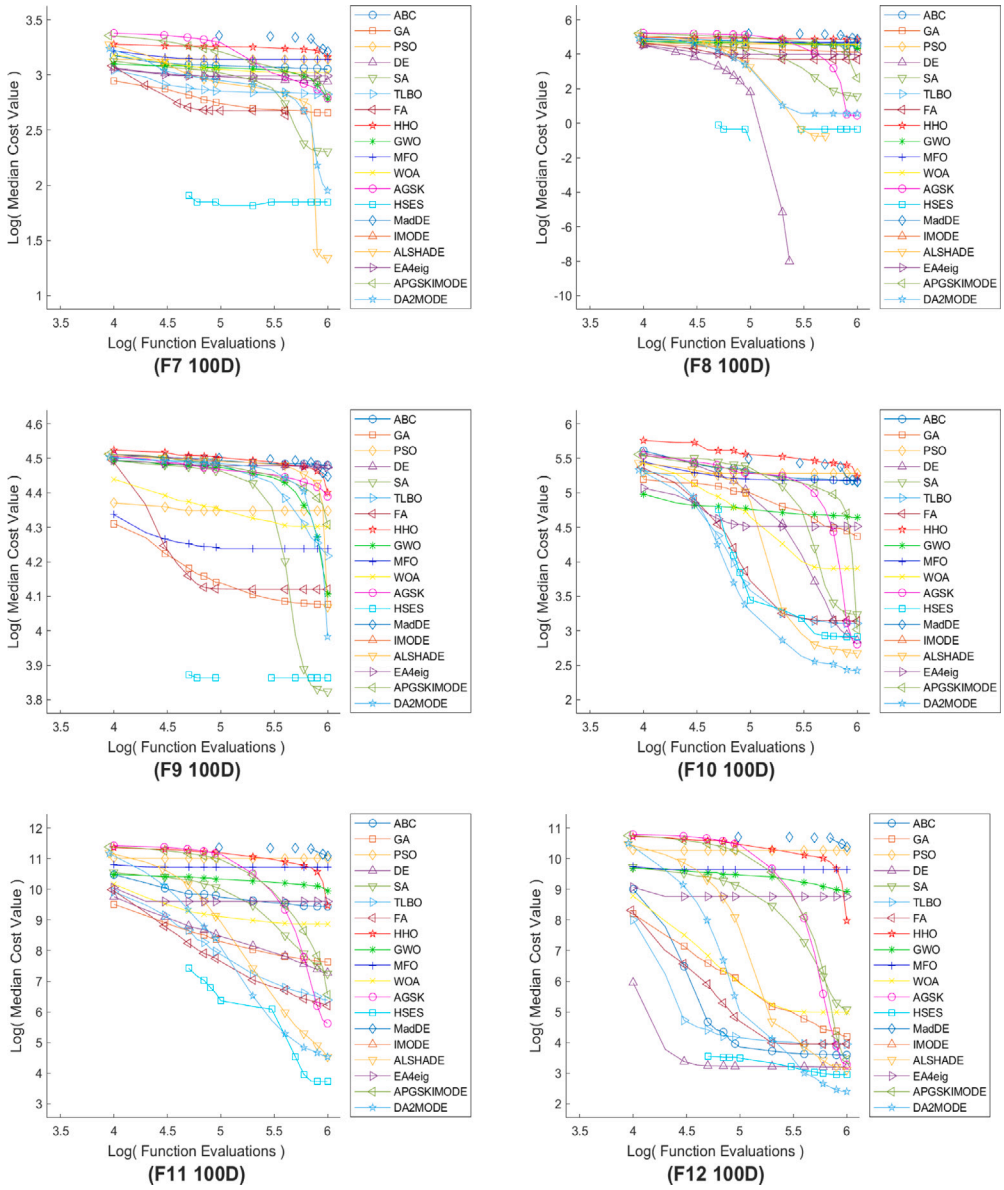



**Fig. G.17b.** Convergence plots for median fitness in 51 runs for all algorithms CEC2017-2018, (F7-F12, 100D).

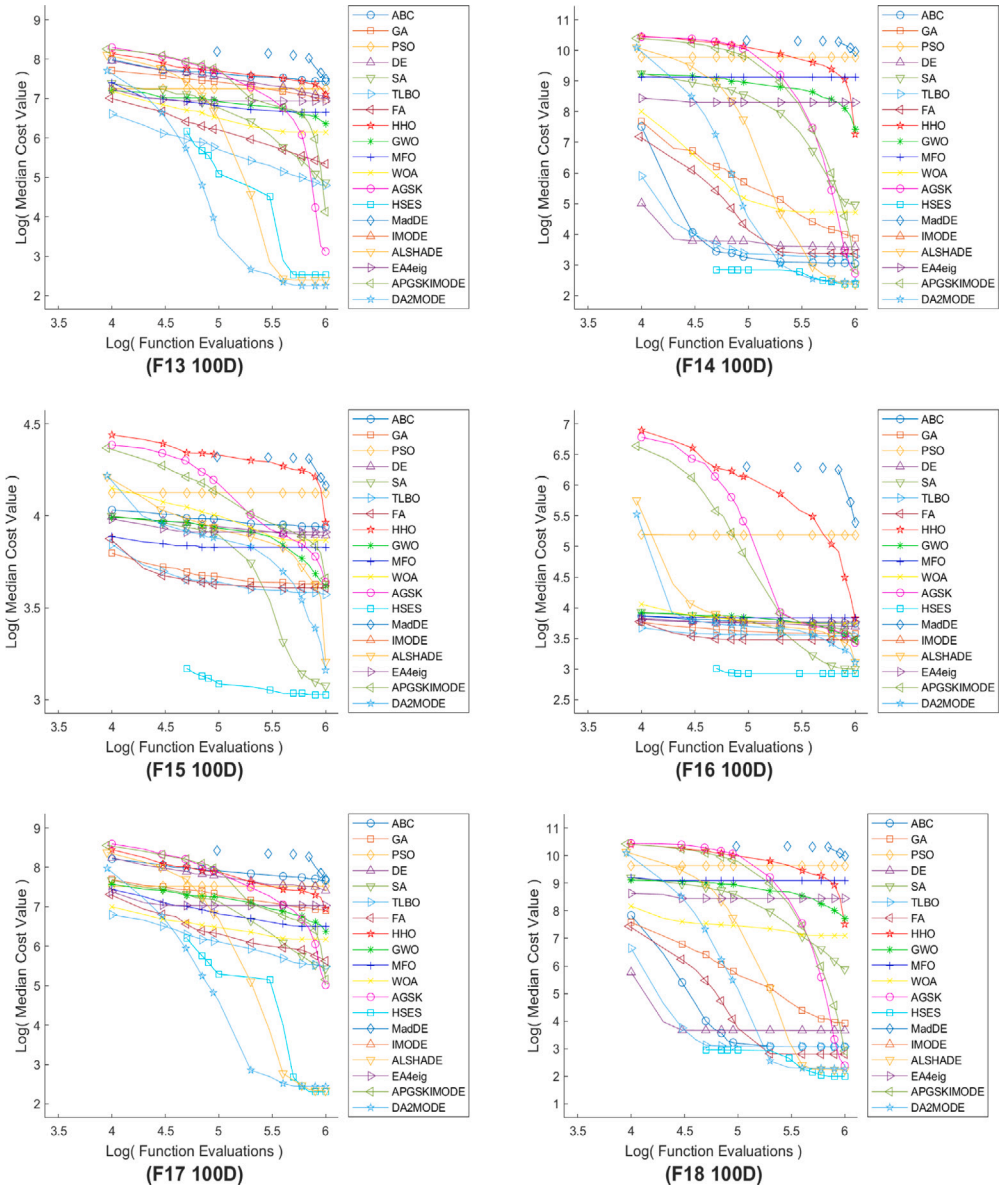



**Fig. G.17c.** Convergence plots for median fitness in 51 runs for all algorithms CEC2017-2018, (F13-F18, 100D).

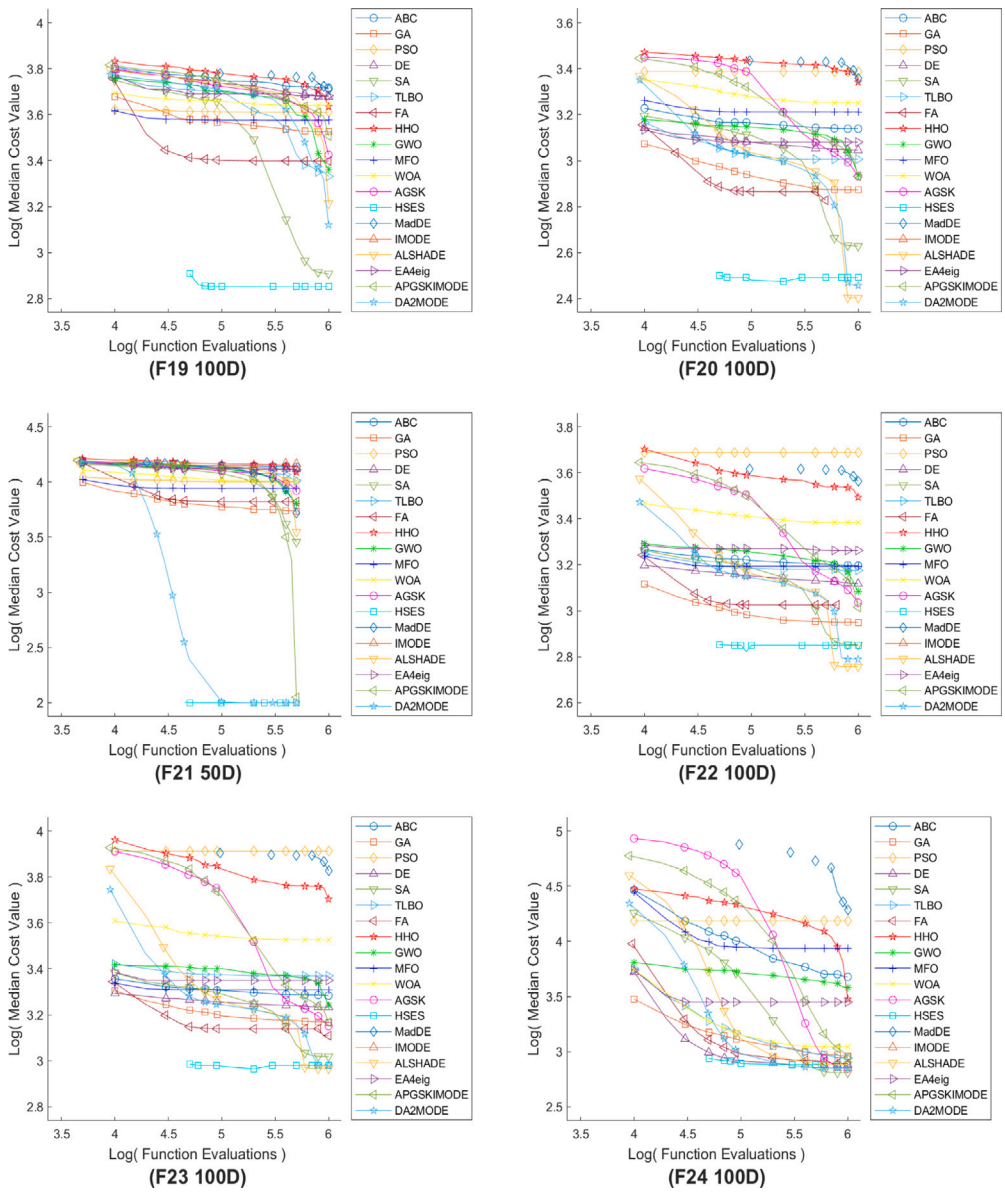



**Fig. G.17d.** Convergence plots for median fitness in 51 runs for all algorithms CEC2017-2018, (F19-F24, 100D).

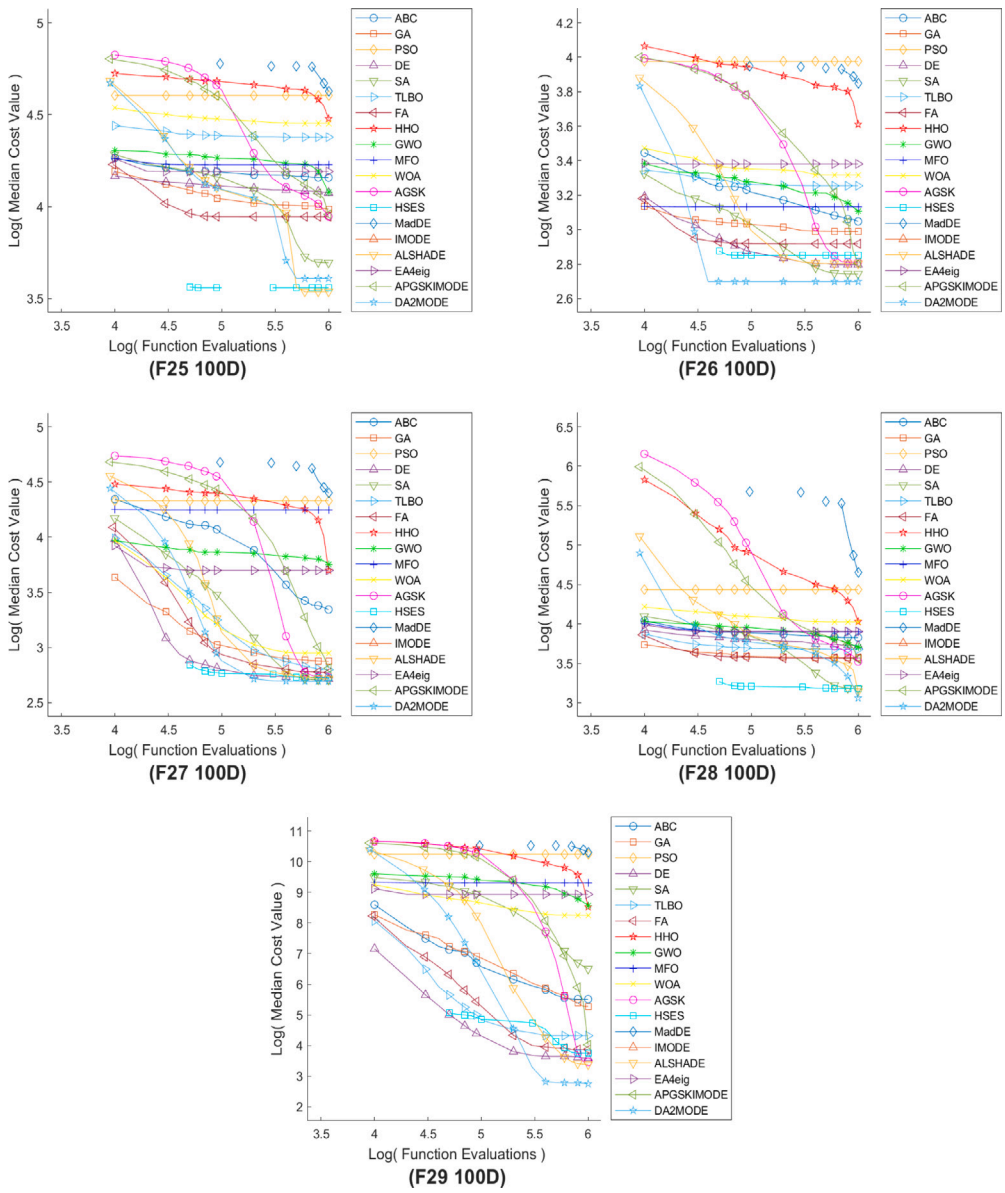



**Fig. G.17e.** Convergence plots for median fitness in 51 runs for all algorithms CEC2017-2018, (F25-F29, 100D).

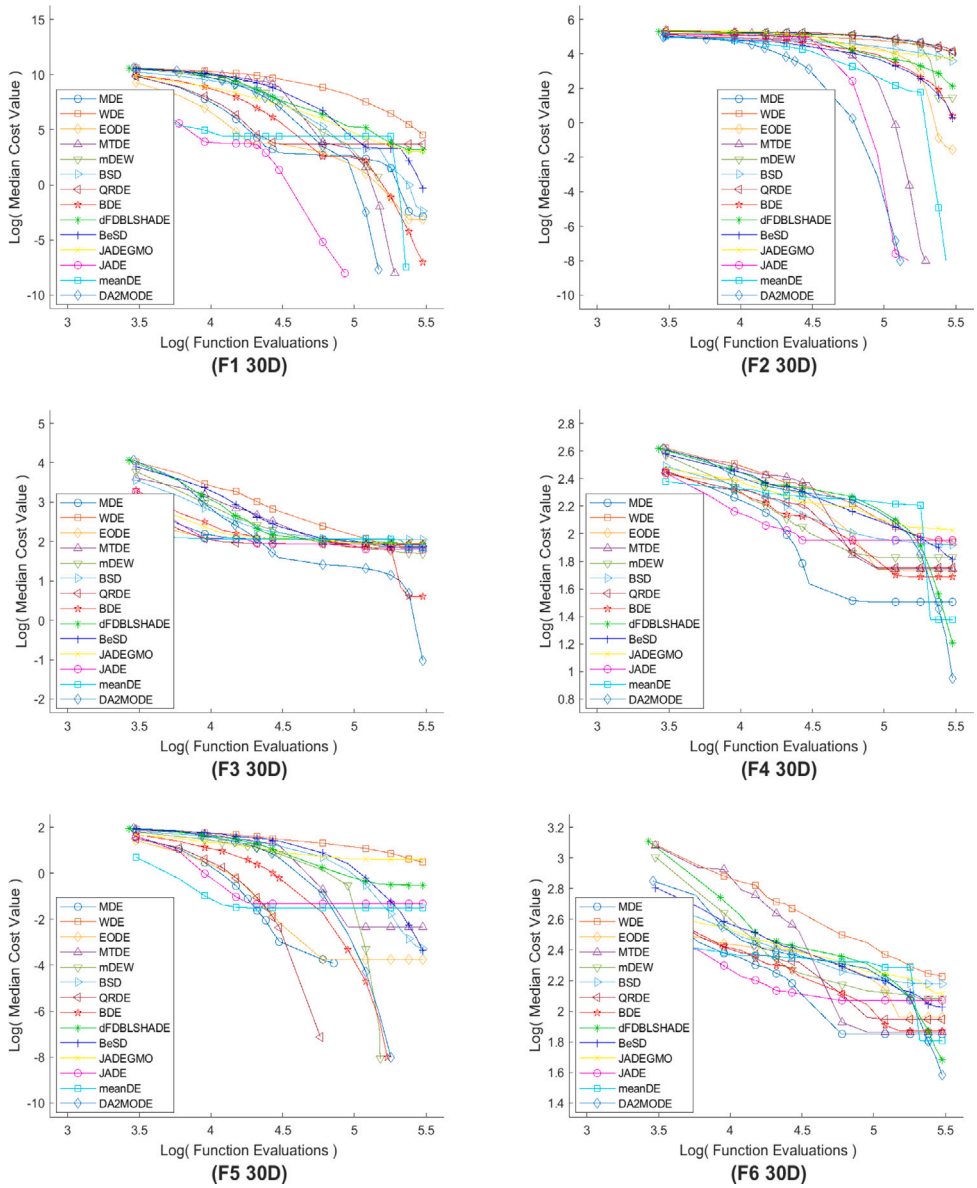



**Fig. G.18a.** Convergence plots for median fitness in 51 runs for 14 DE variants CEC2017-2018, (F1-F6, 30D).

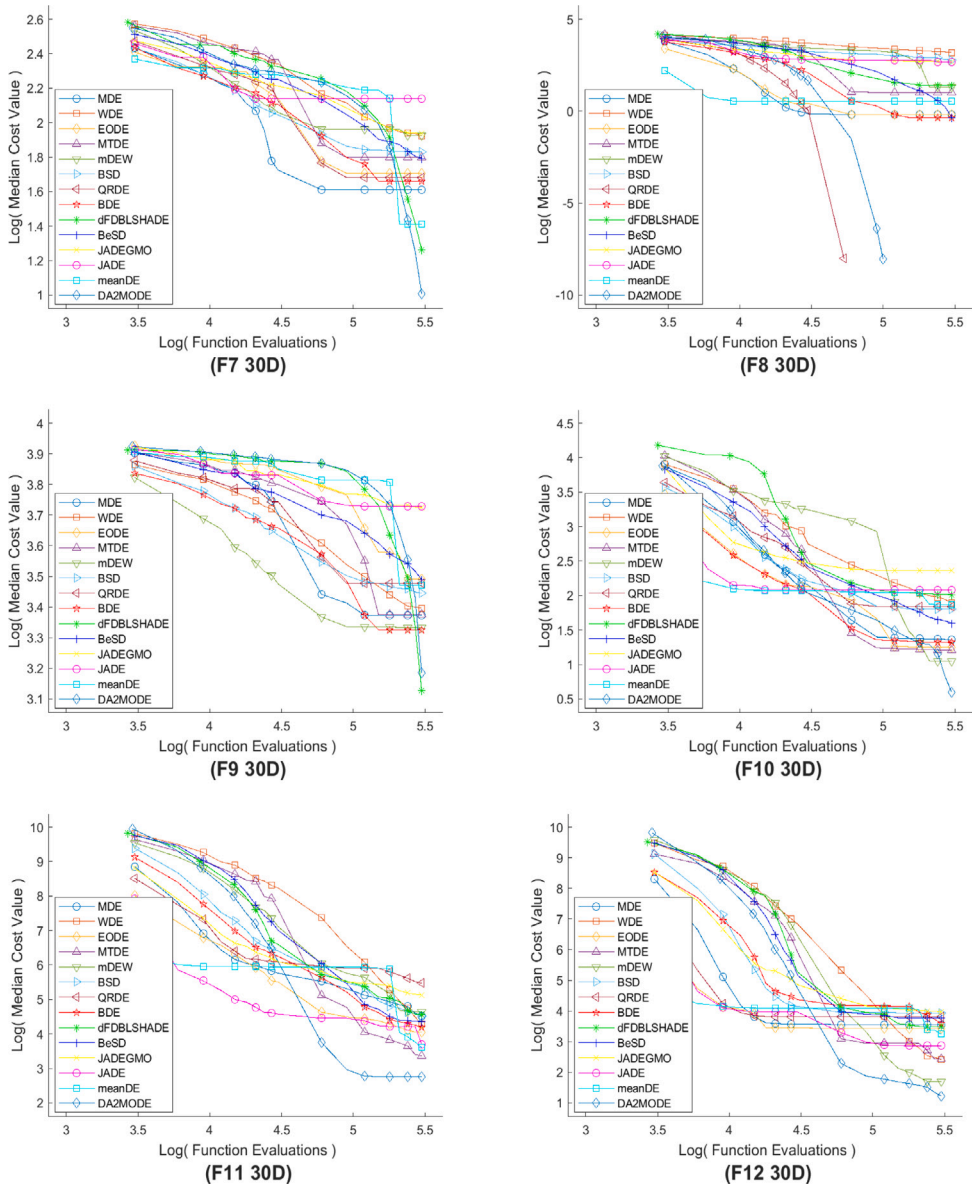



**Fig. G.18b.** Convergence plots for median fitness in 51 runs for 14 DE variants CEC2017-2018, (F7-F12, 30D).

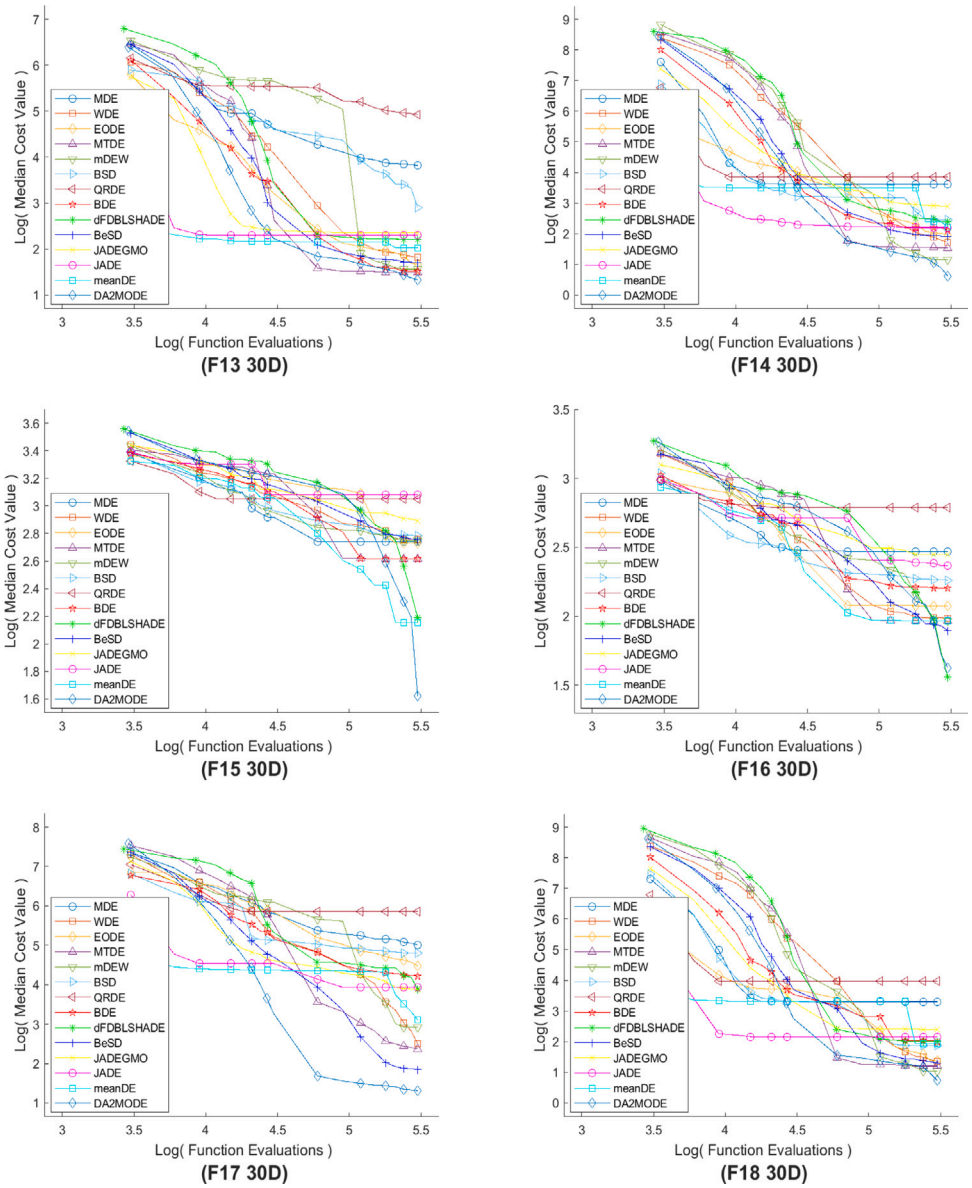



**Fig. G.18c.** Convergence plots for median fitness in 51 runs for 14 DE variants CEC2017-2018, (F13-F18, 30D).

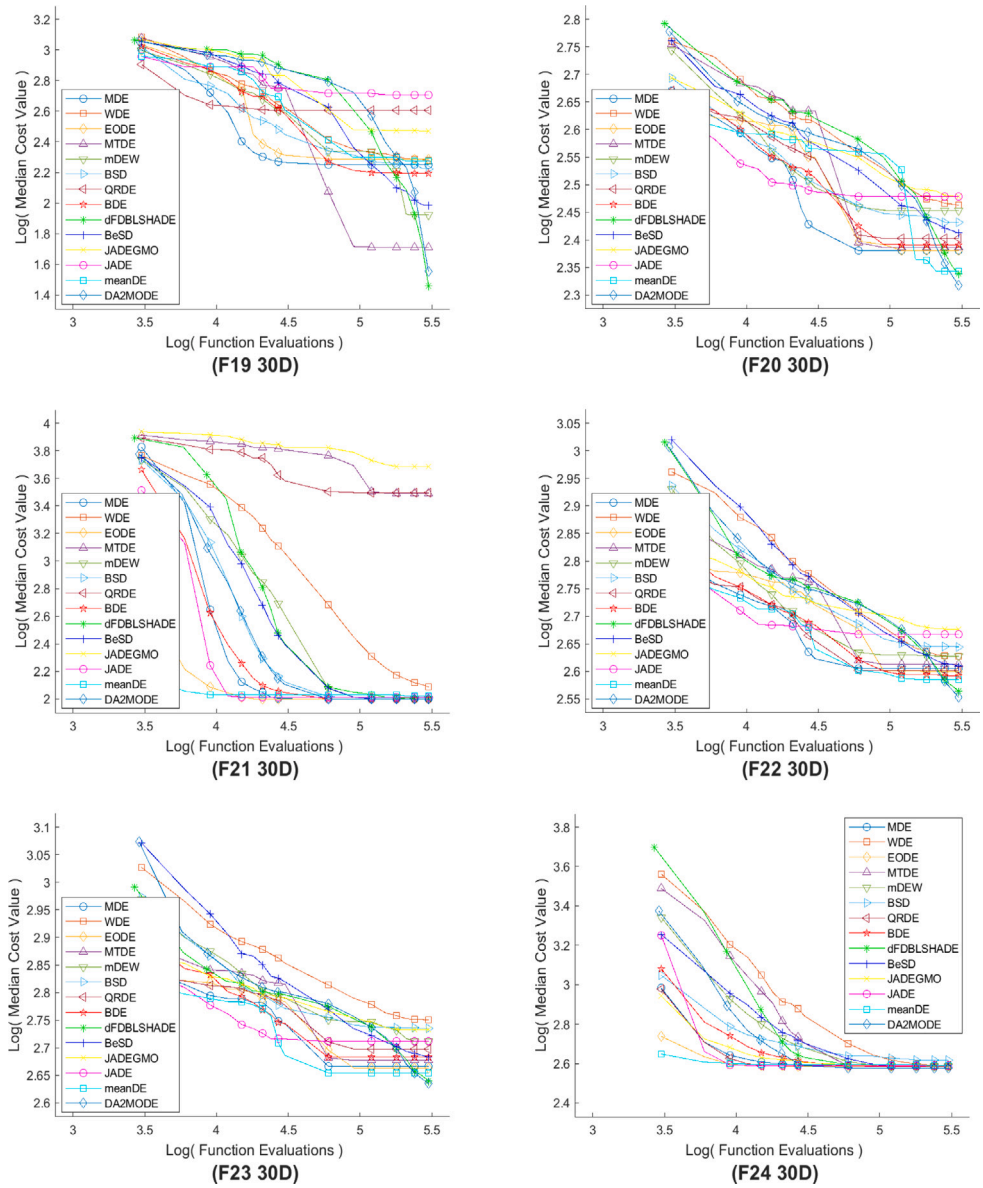



**Fig. G.18d.** Convergence plots for median fitness in 51 runs for 14 DE variants CEC2017-2018, (F19-F24, 30D).

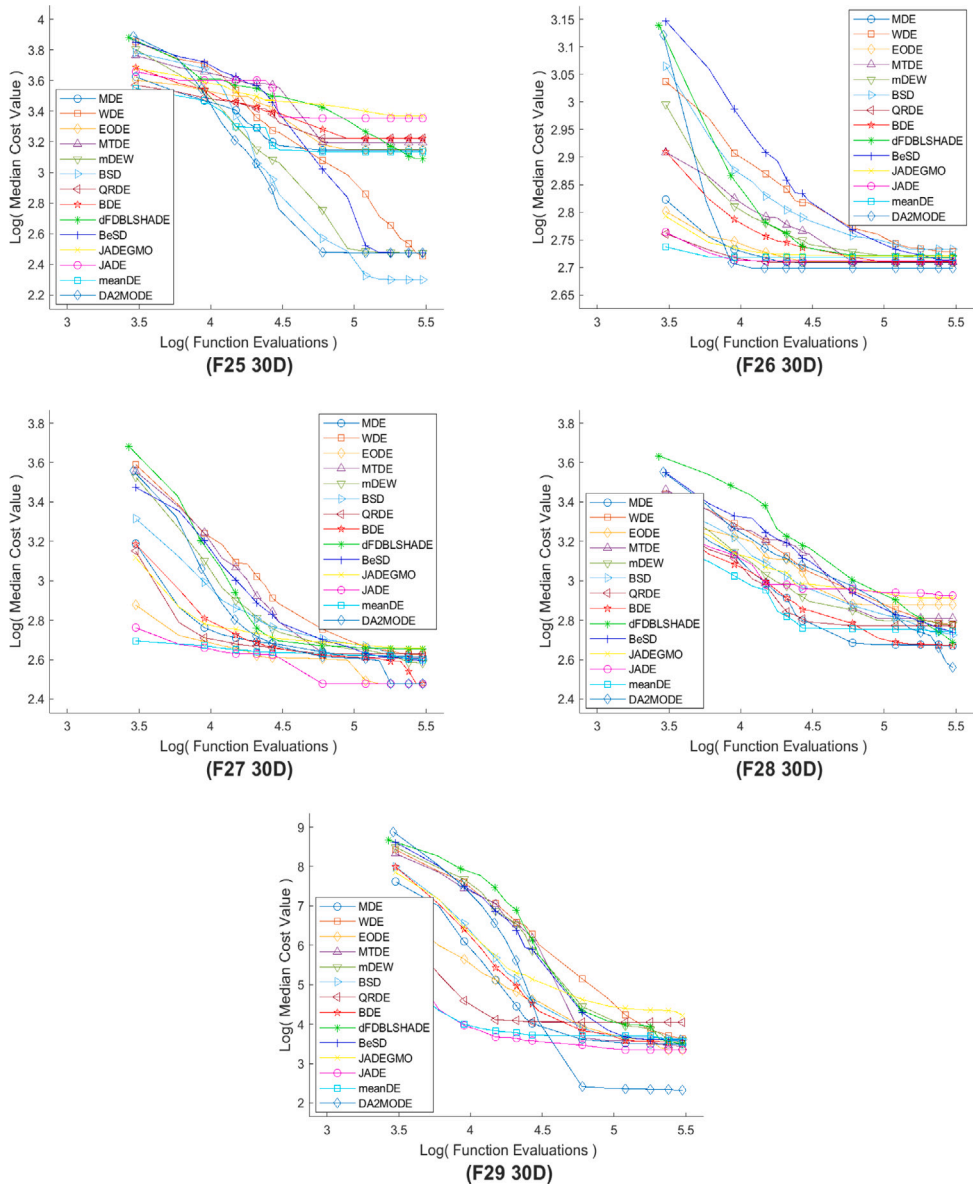



**Fig. G.18e.** Convergence plots for median fitness in 51 runs for 14 DE variants CEC2017-2018, (F25-F29, 30D).

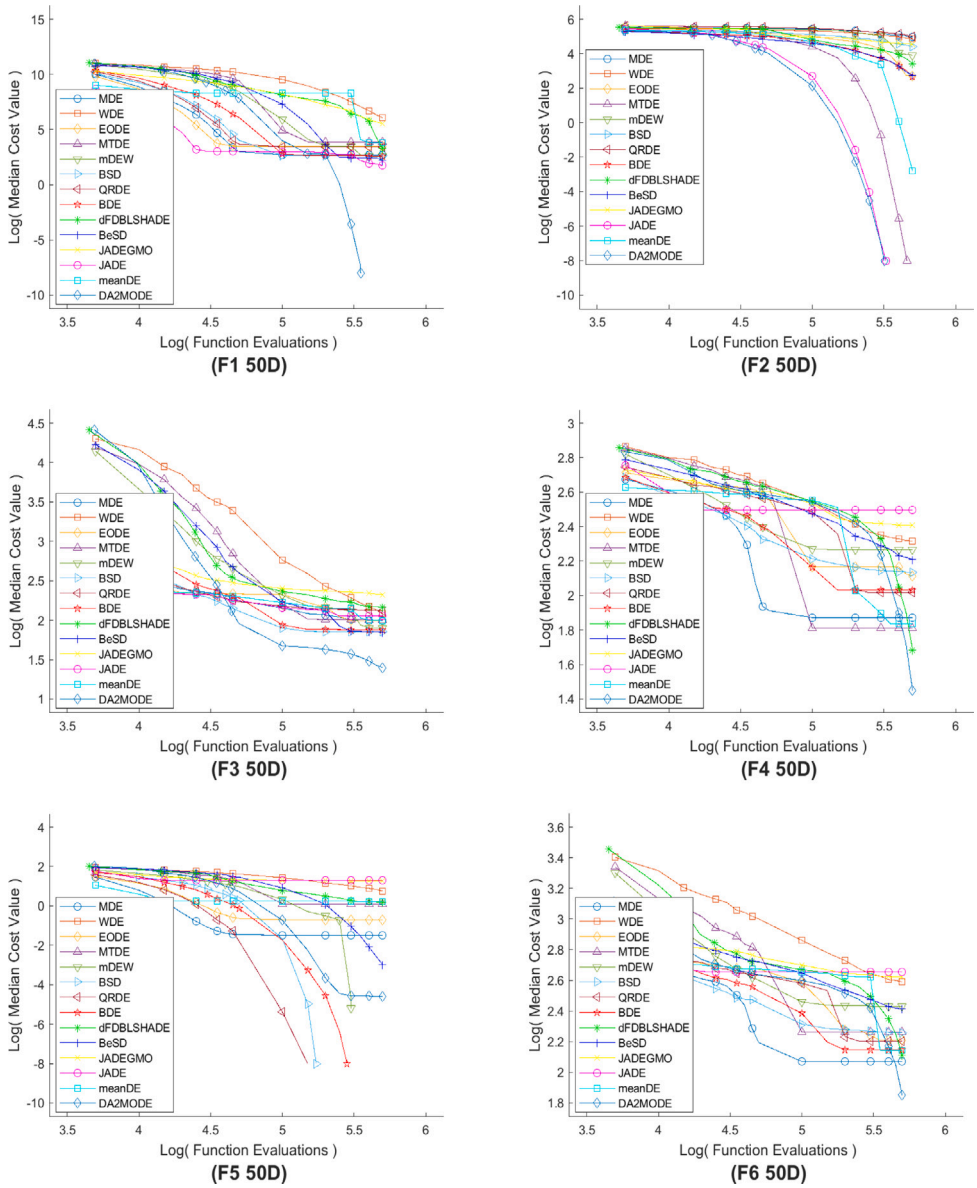



**Fig. G.19a.** Convergence plots for median fitness in 51 runs for 14 DE variants CEC2017-2018, (F1-F6, 50D).

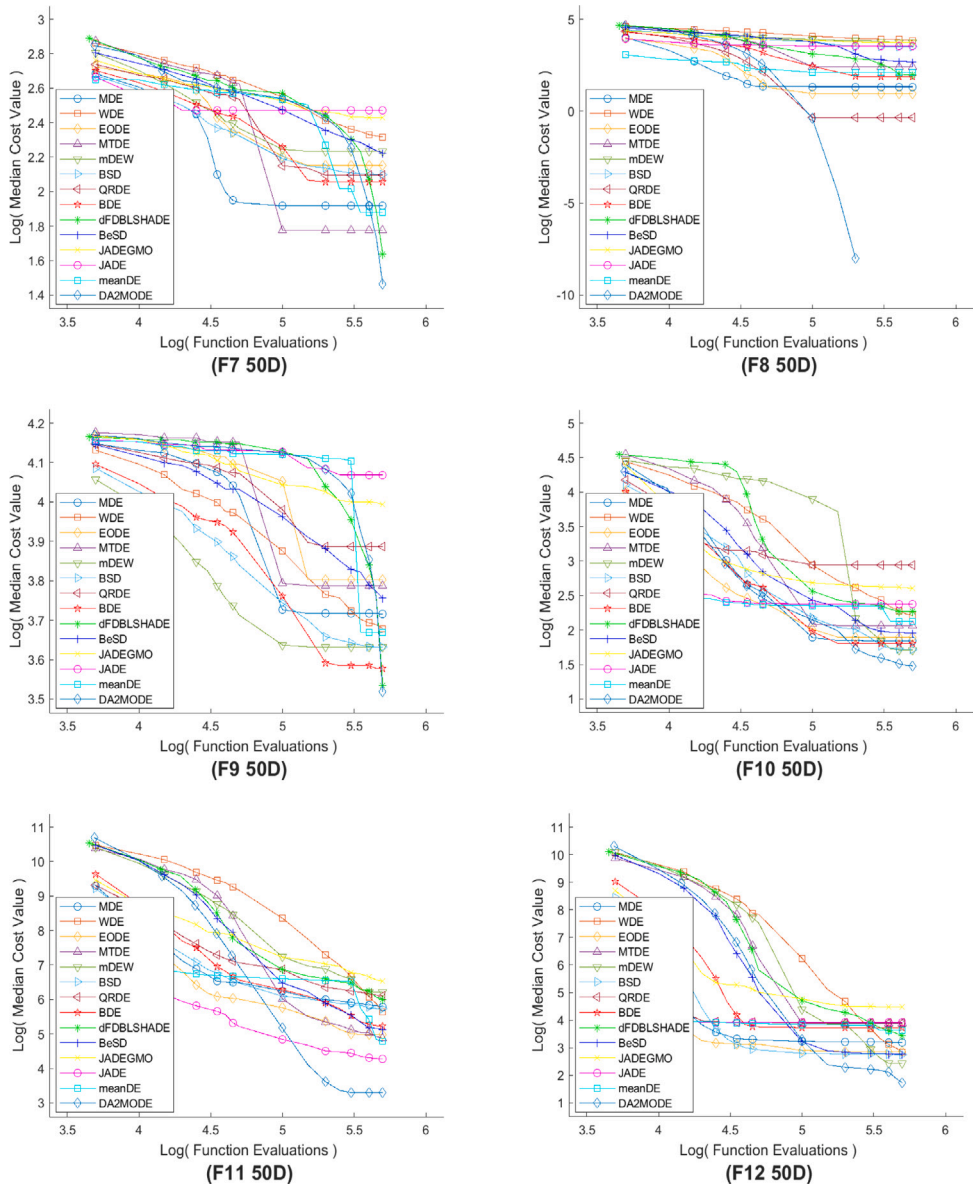



**Fig. G.19b.** Convergence plots for median fitness in 51 runs for 14 DE variants CEC2017-2018, (F7-F12, 50D).

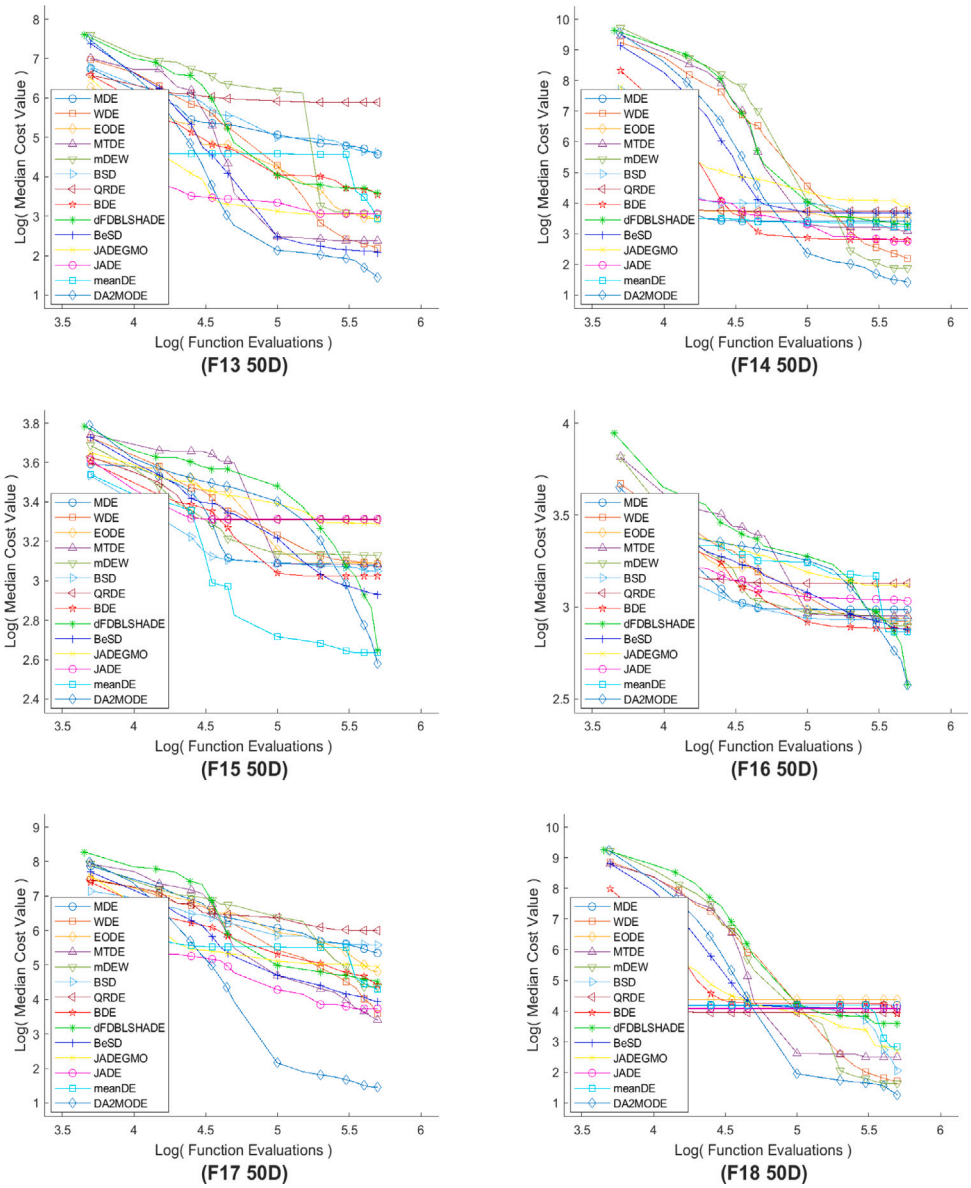



**Fig. G.19c.** Convergence plots for median fitness in 51 runs for 14 DE variants CEC2017-2018, (F13-F18, 50D).

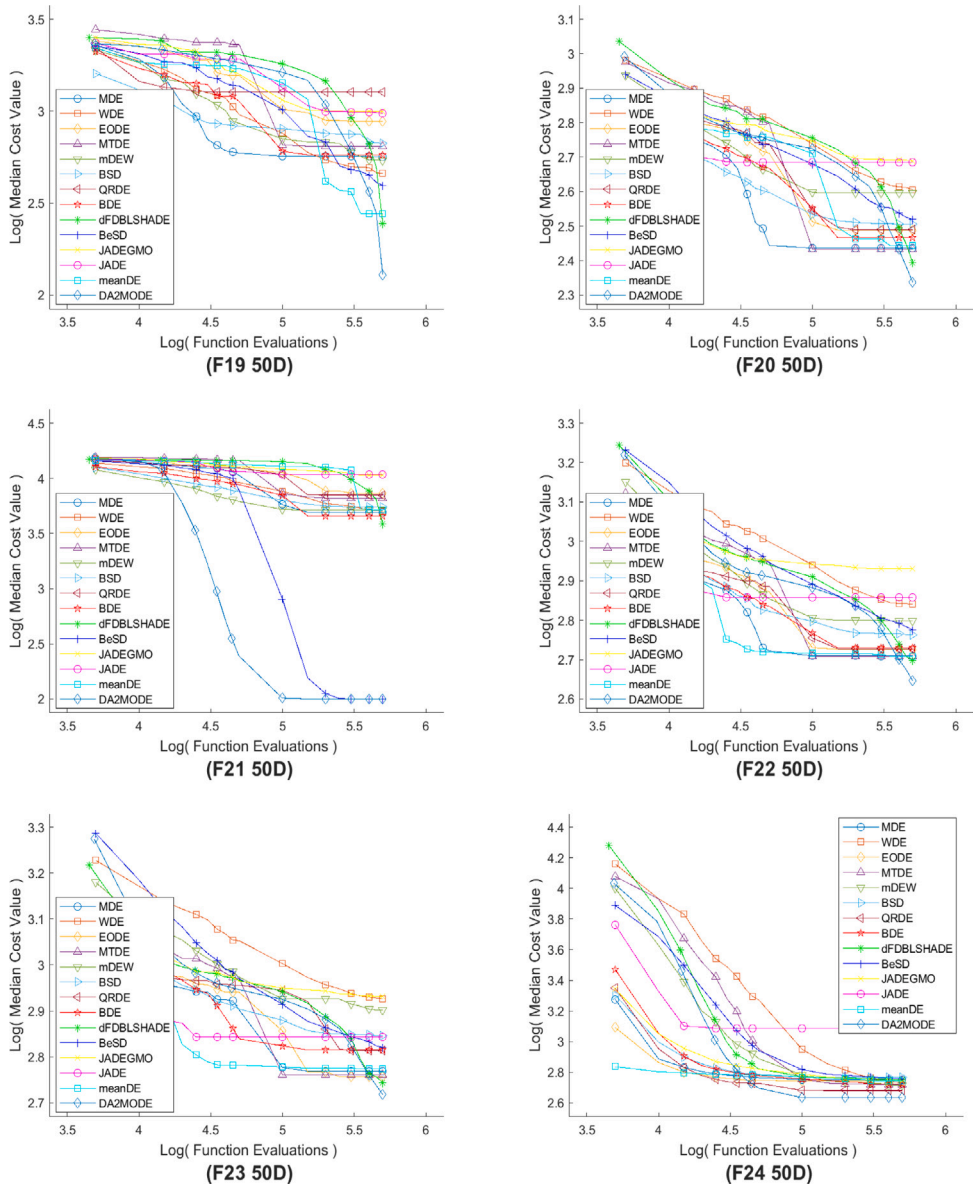



**Fig. G.19d.** Convergence plots for median fitness in 51 runs for 14 DE variants CEC2017-2018, (F19-F24, 50D).

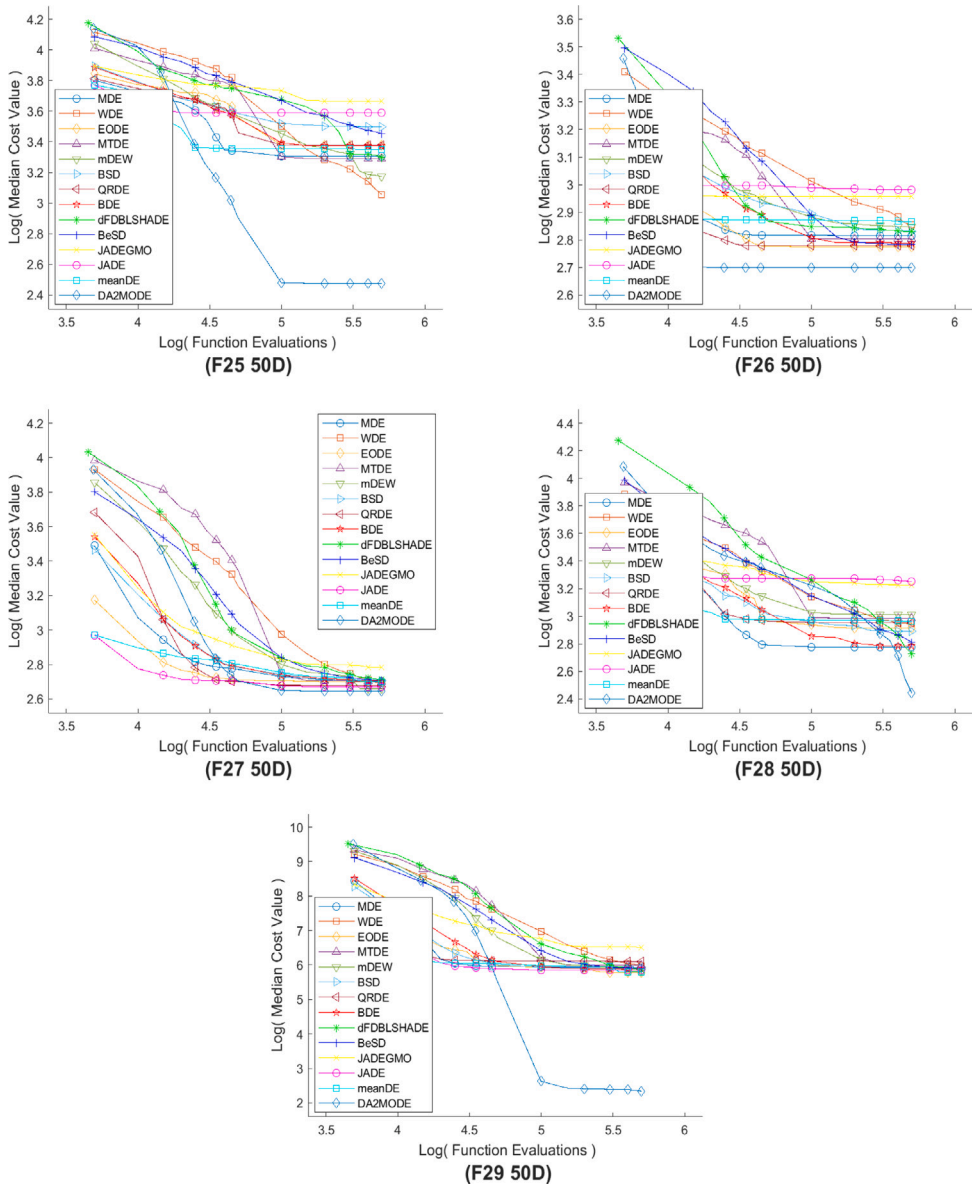



**Fig. G.19e.** Convergence plots for median fitness in 51 runs for 14 DE variants CEC2017-2018, (F25-F29, 50D).

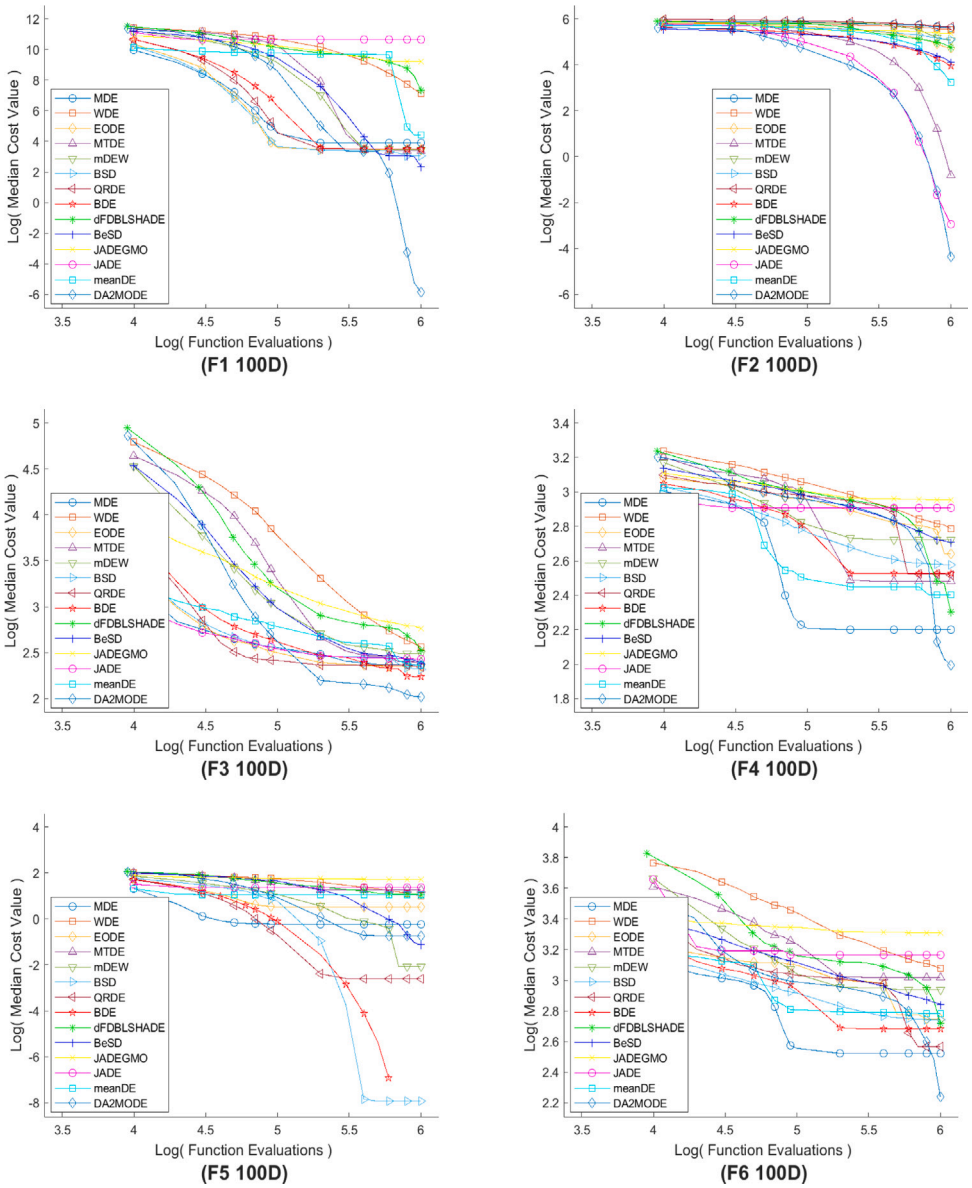



**Fig. G.20a.** Convergence plots for median fitness in 51 runs for 14 DE variants CEC2017-2018, (F1-F6, 100D).

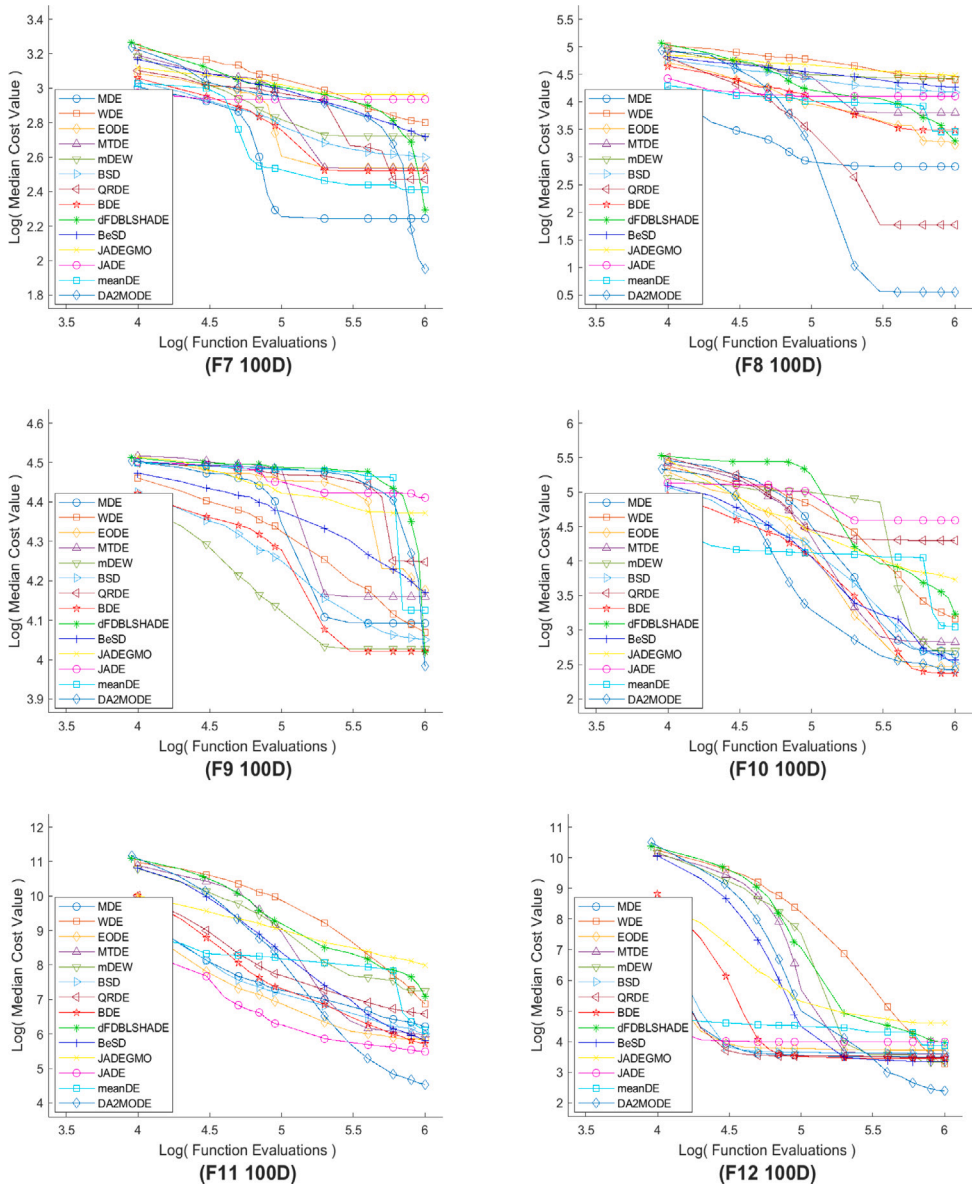



**Fig. G.20b.** Convergence plots for median fitness in 51 runs for 14 DE variants CEC2017-2018, (F7-F12, 100D).

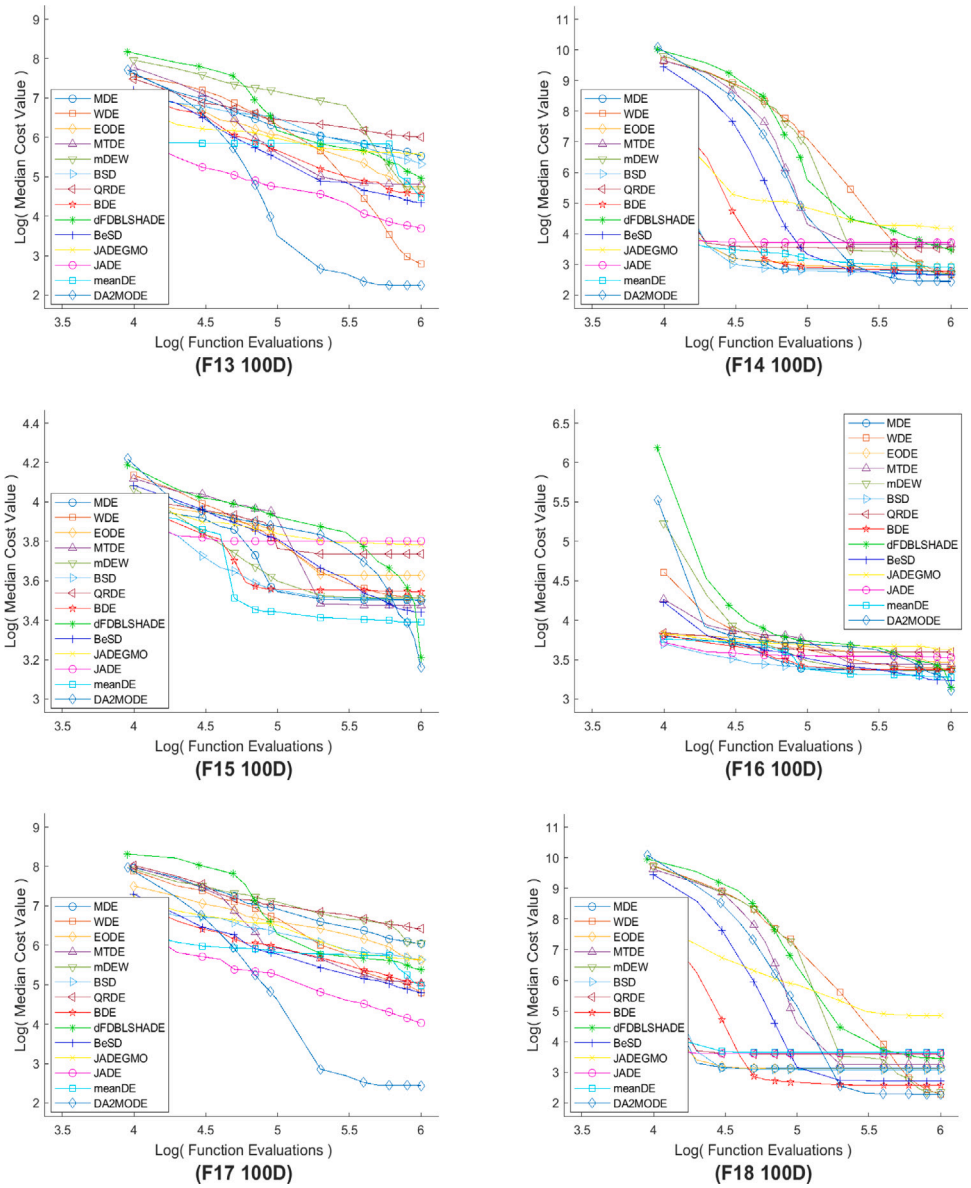



**Fig. G.20c.** Convergence plots for median fitness in 51 runs for 14 DE variants CEC2017-2018, (F13-F18, 100D).

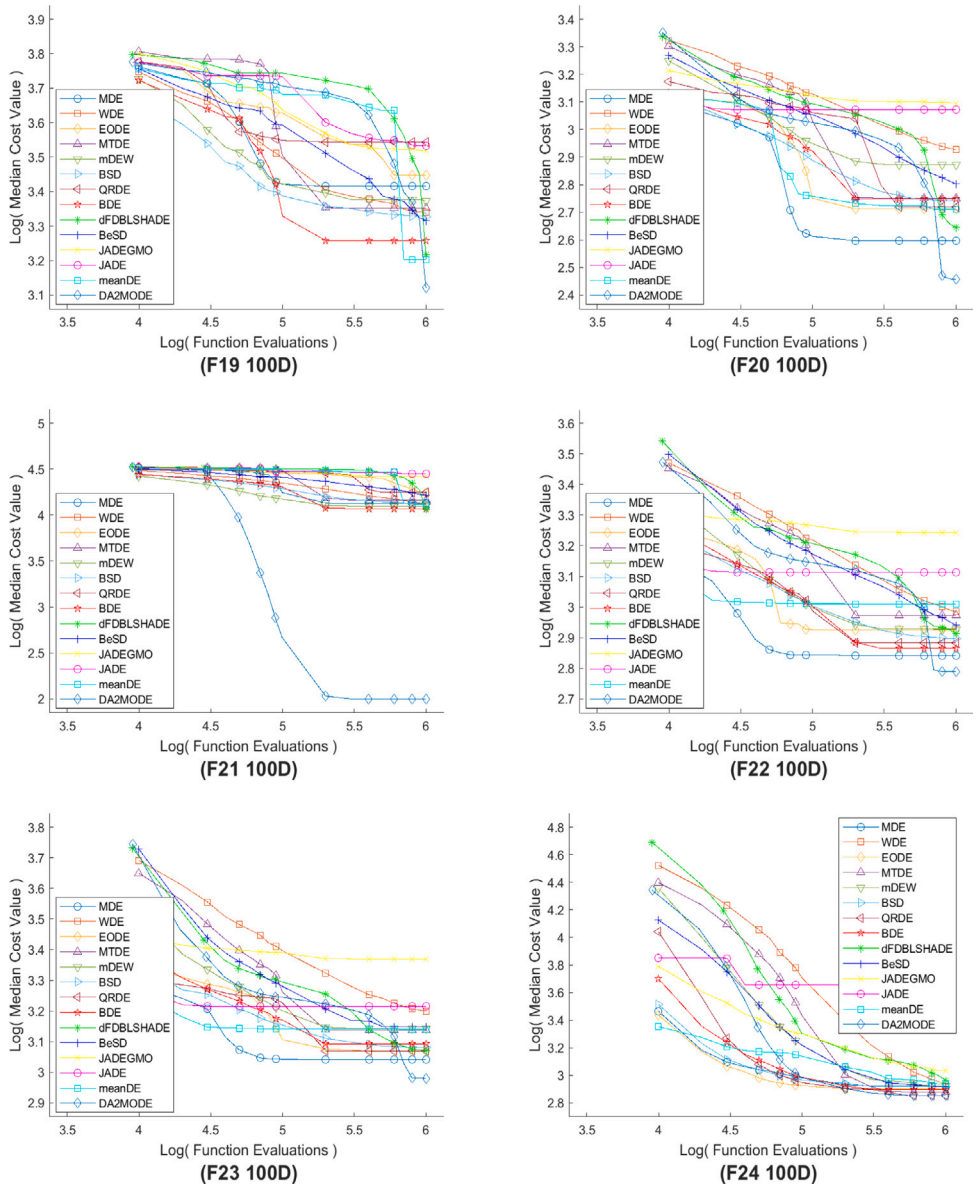



**Fig. G.20d.** Convergence plots for median fitness in 51 runs for 14 DE variants CEC2017-2018, (F19-F24, 100D).

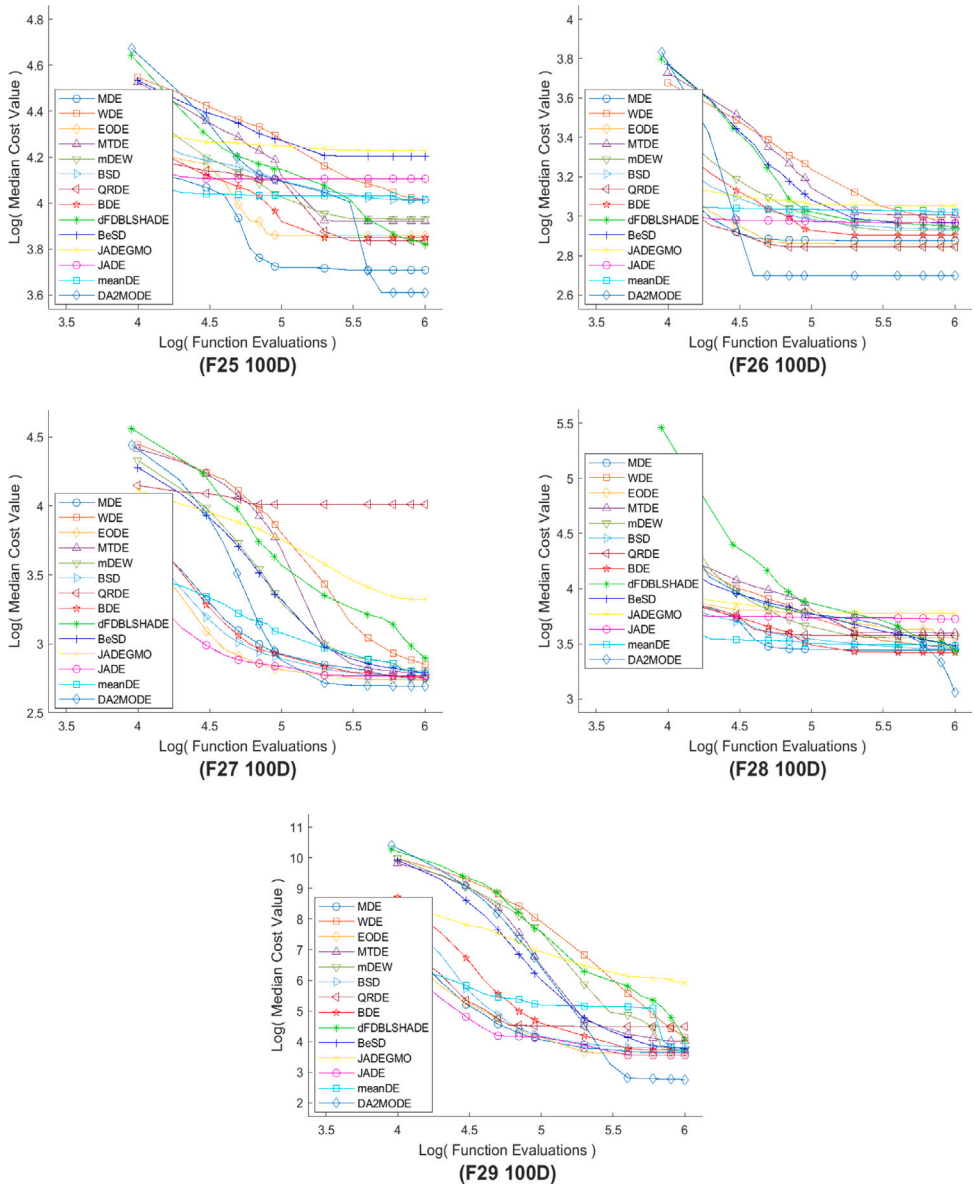



**Fig. G.20e.** Convergence plots for median fitness in 51 runs for 14 DE variants CEC2017-2018, (F25-F29, 100D).

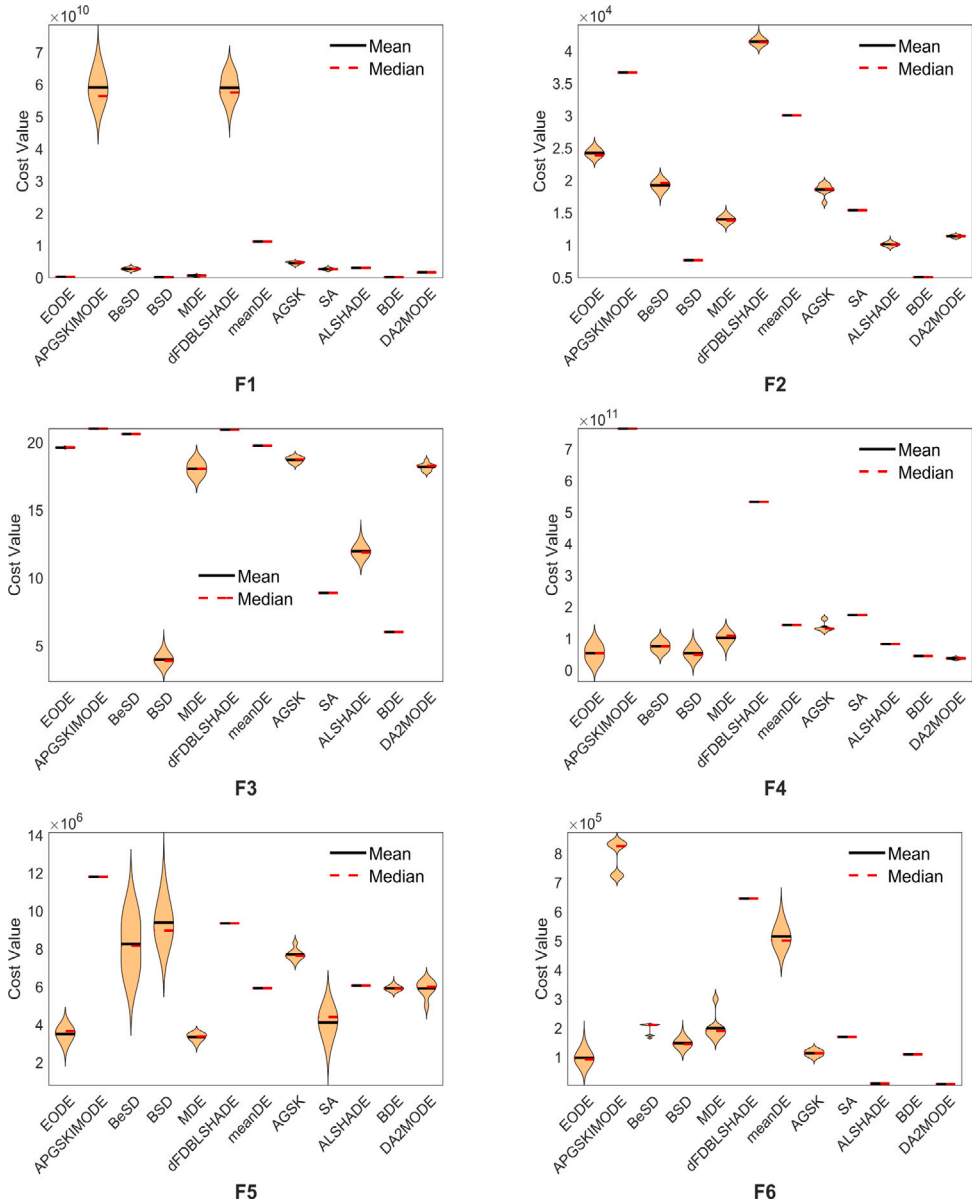



**Fig. I.21a.** Violin plots for the best fitness in 25 runs for all the algorithms in CEC2013-LSGO, F1-F6 (1000D).

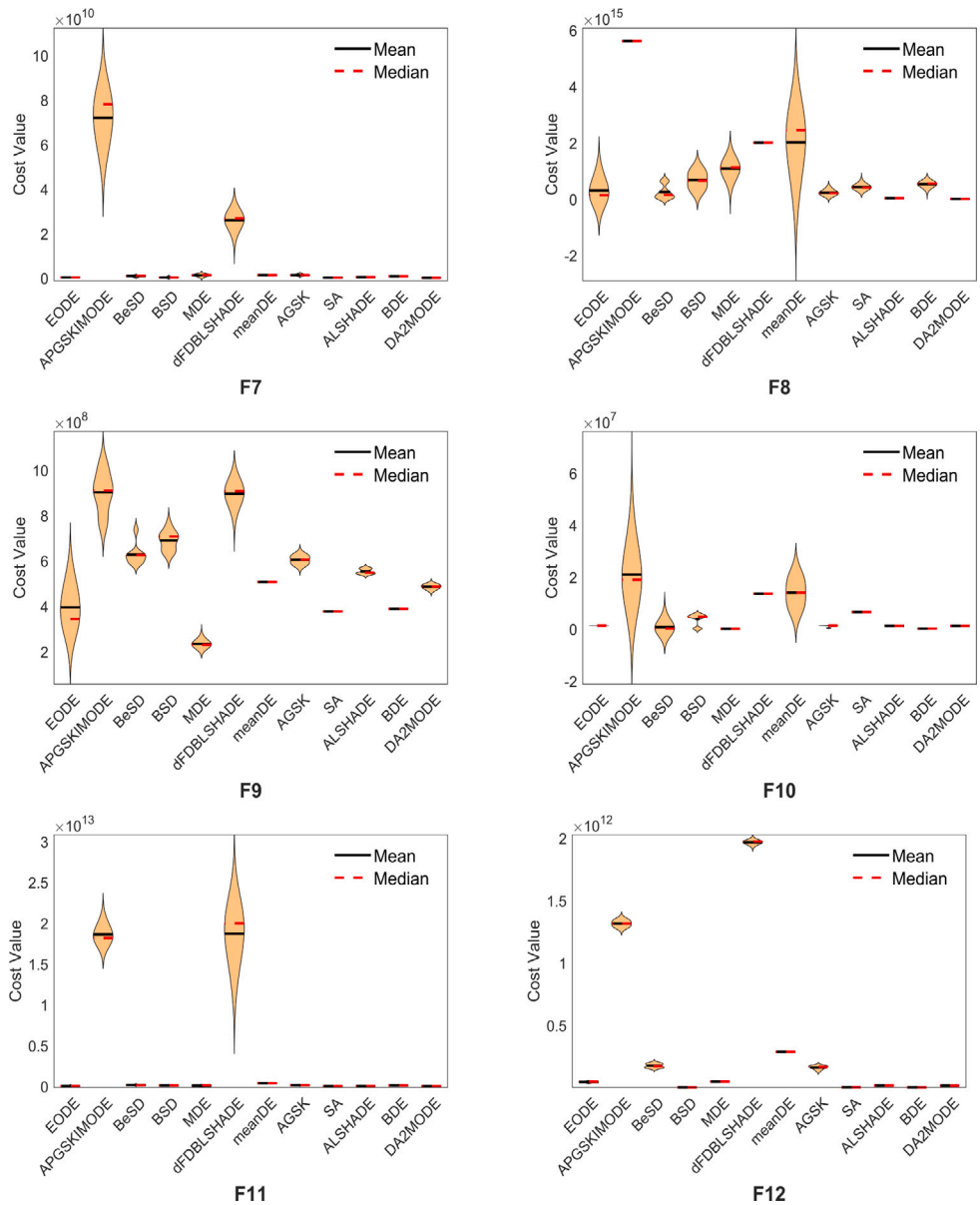



**Fig. I.21b.** Violin plots for the best fitness in 25 runs for all the algorithms in CEC2013-LSGO, F7-F12 (1000D).

**Table H.15**
Table H.15. The results metrics for the error and function evaluation metrics, CEC2013-LSGO (F6–F10, 1000 Dim).

| Fun | Alg. | Error | | | | | Function evaluations | | | | | SR (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No. | Name | Best | Worst | Median | Mean | SD | Best | Worst | Median | Mean | SD | |
| F1 | EODE | 1.12E+08 | 1.12E+08 | 1.12E+08 | 1.12E+08 | 1.59E−08 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0 |
| | APGSKIMODE | 5.63E+10 | 6.34E+10 | 5.63E+10 | 5.89E+10 | 3.69E+09 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0 |
| | BeSD | 2.15E+09 | 3.02E+09 | 2.53E+09 | 2.55E+09 | 3.53E+08 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0 |
| | BSD | 5.04E+04 | 1.06E+05 | 5.04E+04 | **7.14E+04** | 2.90E+04 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0 |
| | MDE | 2.25E+08 | 7.84E+08 | 4.20E+08 | 4.52E+08 | 1.96E+08 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0 |
| | dFDBLSHADE | 5.21E+10 | 6.33E+10 | 5.74E+10 | 5.89E+10 | 4.00E+09 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0 |
| | meanDE | 1.11E+10 | 1.11E+10 | 1.11E+10 | 1.11E+10 | 0.00E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0 |
| | AGSK | 3.58E+09 | 4.83E+09 | 4.56E+09 | 4.38E+09 | 4.48E+08 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0 |
| | SA | 2.45E+09 | 2.89E+09 | 2.45E+09 | 2.51E+09 | 1.53E+08 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0 |
| | ALSHADE | 2.83E+09 | 2.88E+09 | 2.88E+09 | 2.86E+09 | 2.24E+07 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0 |
| | BDE | 8.62E+06 | 8.62E+06 | 8.62E+06 | 8.62E+06 | 0.00E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0 |
| | DA2MODE | 1.39E+09 | 1.66E+09 | 1.49E+09 | 1.51E+09 | 8.95E+07 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0 |
| F2 | EODE | 2.38E+04 | 2.47E+04 | 2.38E+04 | 2.42E+04 | 4.68E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0 |
| | APGSKIMODE | 3.66E+04 | 3.66E+04 | 3.66E+04 | 3.66E+04 | 7.78E−12 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0 |
| | BeSD | 1.84E+04 | 1.95E+04 | 1.95E+04 | 1.92E+04 | 5.25E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0 |
| | BSD | 7.56E+03 | 7.62E+03 | 7.59E+03 | 7.59E+03 | 3.21E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0 |
| | MDE | 1.36E+04 | 1.44E+04 | 1.38E+04 | 1.39E+04 | 3.22E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0 |
| | dFDBLSHADE | 4.13E+04 | 4.21E+04 | 4.13E+04 | 4.14E+04 | 3.04E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0 |
| | meanDE | 3.00E+04 | 3.00E+04 | 3.00E+04 | 3.00E+04 | 0.00E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0 |
| | AGSK | 1.65E+04 | 1.95E+04 | 1.86E+04 | 1.85E+04 | 9.35E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0 |
| | SA | 1.53E+04 | 1.54E+04 | 1.53E+04 | 1.53E+04 | 2.49E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0 |
| | ALSHADE | 1.00E+04 | 1.04E+04 | 1.00E+04 | 1.01E+04 | 1.57E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0 |
| | BDE | 4.96E+03 | 5.00E+03 | 5.00E+03 | **4.99E+03** | 1.34E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0 |
| | DA2MODE | 1.10E+04 | 1.16E+04 | 1.13E+04 | 1.13E+04 | 1.88E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0 |
| F3 | EODE | 1.96E+01 | 1.96E+01 | 1.96E+01 | 1.96E+01 | 2.65E−02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0 |
| | APGSKIMODE | 2.10E+01 | 2.10E+01 | 2.10E+01 | 2.10E+01 | 3.80E−15 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0 |
| | BeSD | 2.06E+01 | 2.06E+01 | 2.06E+01 | 2.06E+01 | 1.24E−03 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0 |
| | BSD | 3.88E+00 | 4.62E+00 | 3.88E+00 | **3.97E+00** | 2.61E−01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0 |
| | MDE | 1.76E+01 | 1.85E+01 | 1.80E+01 | 1.80E+01 | 4.59E−01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0 |
| | dFDBLSHADE | 2.09E+01 | 2.09E+01 | 2.09E+01 | 2.09E+01 | 0.00E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0 |
| | meanDE | 1.97E+01 | 1.97E+01 | 1.97E+01 | 1.97E+01 | 0.00E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0 |
| | AGSK | 1.84E+01 | 1.89E+01 | 1.87E+01 | 1.87E+01 | 2.07E−01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0 |
| | SA | 8.86E+00 | 8.86E+00 | 8.86E+00 | 8.86E+00 | 0.00E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0 |
| | ALSHADE | 1.18E+01 | 1.26E+01 | 1.18E+01 | 1.19E+01 | 2.75E−01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0 |
| | BDE | 5.99E+00 | 5.99E+00 | 5.99E+00 | 5.99E+00 | 9.50E−16 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0 |
| | DA2MODE | 1.78E+01 | 1.86E+01 | 1.82E+01 | 1.82E+01 | 2.70E−01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0 |
| F4 | EODE | 3.01E+10 | 7.39E+10 | 5.20E+10 | 5.20E+10 | 2.34E+10 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0 |
| | APGSKIMODE | 7.63E+11 | 7.63E+11 | 7.63E+11 | 7.63E+11 | 1.30E−04 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0 |
| | BeSD | 5.98E+10 | 8.76E+10 | 7.31E+10 | 7.33E+10 | 1.42E+10 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0 |
| | BSD | 4.13E+10 | 6.96E+10 | 4.71E+10 | 5.20E+10 | 1.11E+10 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0 |
| | MDE | 8.13E+10 | 1.07E+11 | 1.07E+11 | 1.00E+11 | 1.18E+10 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0 |
| | dFDBLSHADE | 5.31E+11 | 5.31E+11 | 5.31E+11 | 5.31E+11 | 6.52E−05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0 |
| | meanDE | 1.41E+11 | 1.41E+11 | 1.41E+11 | 1.41E+11 | 0.00E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0 |
| | AGSK | 1.19E+11 | 1.65E+11 | 1.30E+11 | 1.36E+11 | 1.64E+10 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0 |
| | SA | 1.72E+11 | 1.73E+11 | 1.73E+11 | 1.73E+11 | 5.32E+08 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0 |
| | ALSHADE | 8.06E+10 | 8.06E+10 | 8.06E+10 | 8.06E+10 | 0.00E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0 |
| | BDE | 4.26E+10 | 4.26E+10 | 4.26E+10 | 4.26E+10 | 0.00E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0 |
| | DA2MODE | 3.14E+10 | 3.99E+10 | 3.56E+10 | **3.54E+10** | 2.59E+09 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0 |
| F5 | EODE | 3.03E+06 | 3.63E+06 | 3.63E+06 | 3.48E+06 | 2.79E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0 |
| | APGSKIMODE | 1.18E+07 | 1.18E+07 | 1.18E+07 | 1.18E+07 | 1.99E−09 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0 |
| | BeSD | 6.97E+06 | 9.67E+06 | 8.11E+06 | 8.24E+06 | 1.36E+06 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0 |
| | BSD | 8.95E+06 | 1.06E+07 | 8.95E+06 | 9.37E+06 | 7.73E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0 |
| | MDE | 2.93E+06 | 3.49E+06 | 3.35E+06 | **3.32E+06** | 2.04E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0 |
| | dFDBLSHADE | 9.32E+06 | 9.32E+06 | 9.32E+06 | 9.32E+06 | 0.00E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0 |
| | meanDE | 5.91E+06 | 5.91E+06 | 5.91E+06 | 5.91E+06 | 9.96E−10 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0 |
| | AGSK | 7.27E+06 | 8.30E+06 | 7.62E+06 | 7.68E+06 | 3.04E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0 |
| | SA | 3.22E+06 | 4.38E+06 | 4.38E+06 | 4.09E+06 | 5.40E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0 |
| | ALSHADE | 6.04E+06 | 6.04E+06 | 6.04E+06 | 6.04E+06 | 0.00E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0 |
| | BDE | 5.87E+06 | 6.08E+06 | 5.87E+06 | 5.90E+06 | 7.57E+04 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0 |
| | DA2MODE | 4.97E+06 | 6.29E+06 | 5.97E+06 | 5.89E+06 | 4.33E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0 |
| F6 | EODE | 9.09E+04 | 1.33E+05 | 9.13E+04 | 9.65E+04 | 1.49E+04 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0 |
| | APGSKIMODE | 7.22E+05 | 8.35E+05 | 8.24E+05 | 7.90E+05 | 5.63E+04 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0 |
| | BeSD | 1.65E+05 | 2.11E+05 | 2.09E+05 | 1.95E+05 | 2.09E+04 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0 |
| | BSD | 1.43E+05 | 1.70E+05 | 1.43E+05 | 1.47E+05 | 9.44E+03 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0 |
| | MDE | 1.57E+05 | 2.98E+05 | 1.89E+05 | 1.98E+05 | 4.31E+04 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0 |
| | dFDBLSHADE | 6.44E+05 | 6.44E+05 | 6.44E+05 | 6.44E+05 | 1.24E−10 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0 |
| | meanDE | 4.99E+05 | 5.58E+05 | 4.99E+05 | 5.14E+05 | 2.73E+04 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0 |
| | AGSK | 9.72E+04 | 1.25E+05 | 1.12E+05 | 1.12E+05 | 1.00E+04 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0 |
| | SA | 1.68E+05 | 1.68E+05 | 1.68E+05 | 1.68E+05 | 0.00E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0 |
| | ALSHADE | 7.82E+03 | 7.83E+03 | 7.82E+03 | 7.82E+03 | 4.69E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0 |
| | BDE | 1.08E+05 | 1.08E+05 | 1.08E+05 | 1.08E+05 | 0.00E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0 |
| | DA2MODE | 5.85E+03 | 6.07E+03 | 5.98E+03 | **5.97E+03** | 6.46E+01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0 |
| F7 | EODE | 2.87E+08 | 3.02E+08 | 2.87E+08 | 2.89E+08 | 5.24E+06 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0 |
| | APGSKIMODE | 6.17E+10 | 7.80E+10 | 7.80E+10 | 7.19E+10 | 8.42E+09 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0 |
| | BeSD | 5.54E+08 | 9.79E+08 | 9.79E+08 | 8.58E+08 | 1.88E+08 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0 |
| | BSD | 2.08E+08 | 5.75E+08 | 2.08E+08 | 2.54E+08 | 1.30E+08 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0 |
| | MDE | 4.81E+08 | 1.31E+09 | 1.31E+09 | 1.21E+09 | 2.95E+08 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0 |
| | dFDBLSHADE | 2.01E+10 | 2.67E+10 | 2.67E+10 | 2.59E+10 | 2.32E+09 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0 |
| | meanDE | 1.32E+09 | 1.32E+09 | 1.32E+09 | 1.32E+09 | 0.00E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0 |
| | AGSK | 9.01E+08 | 1.93E+09 | 1.30E+09 | 1.31E+09 | 3.27E+08 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0 |
| | SA | 1.46E+08 | 1.61E+08 | 1.61E+08 | 1.56E+08 | 7.98E+06 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0 |
| | ALSHADE | 4.02E+08 | 4.09E+08 | 4.09E+08 | 4.08E+08 | 3.61E+06 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0 |
| | BDE | 7.39E+08 | 7.39E+08 | 7.39E+08 | 7.39E+08 | 0.00E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0 |
| | DA2MODE | 5.55E+07 | 9.79E+07 | 7.02E+07 | **7.30E+07** | 1.63E+07 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0 |
| F8 | EODE | 1.34E+14 | 8.10E+14 | 1.34E+14 | 3.03E+14 | 3.13E+14 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0 |
| | APGSKIMODE | 5.62E+15 | 5.62E+15 | 5.62E+15 | 5.62E+15 | 0.00E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0 |
| | BeSD | 5.59E+13 | 6.38E+14 | 1.45E+14 | 2.47E+14 | 2.54E+14 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0 |
| | BSD | 4.00E+14 | 9.56E+14 | 6.53E+14 | 6.72E+14 | 2.91E+14 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0 |
| | MDE | 6.61E+14 | 1.23E+15 | 1.12E+15 | 1.08E+15 | 1.72E+14 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0 |
| | dFDBLSHADE | 2.00E+15 | 2.00E+15 | 2.00E+15 | 2.00E+15 | 2.67E−01 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0 |
| | meanDE | 7.15E+14 | 2.44E+15 | 2.44E+15 | 2.01E+15 | 8.00E+14 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0 |
| | AGSK | 1.05E+14 | 4.10E+14 | 2.08E+14 | 2.25E+14 | 1.01E+14 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0 |
| | SA | 4.04E+14 | 5.75E+14 | 4.04E+14 | 4.25E+14 | 6.03E+13 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0 |
| | ALSHADE | 2.40E+13 | 3.15E+13 | 3.15E+13 | 3.06E+13 | 2.68E+12 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0 |
| | BDE | 3.70E+14 | 5.47E+14 | 5.47E+14 | 5.25E+14 | 6.23E+13 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0 |
| | DA2MODE | 9.78E+11 | 1.64E+12 | 1.25E+12 | **1.24E+12** | 2.08E+11 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0 |

(*continued on next page*)

**Table H.15** (*continued*).

| Fun | Alg. | Error | | | | | Function evaluations | | | | | SR (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No. | Name | Best | Worst | Median | Mean | SD | Best | Worst | Median | Mean | SD | |
| F9 | EODE | 3.43E+08 | 4.80E+08 | 3.43E+08 | 3.95E+08 | 7.08E+07 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0 |
| | APGSKIMODE | 7.76E+08 | 1.01E+09 | 9.09E+08 | 9.01E+08 | 8.89E+07 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0 |
| | BeSD | 5.92E+08 | 7.37E+08 | 6.25E+08 | 6.27E+08 | 4.73E+07 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0 |
| | BSD | 6.43E+08 | 7.57E+08 | 7.07E+08 | 6.89E+08 | 4.18E+07 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0 |
| | MDE | 2.30E+08 | 2.59E+08 | 2.30E+08 | **2.34E+08** | 1.01E+07 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0 |
| | dFDBLSHADE | 8.20E+08 | 9.06E+08 | 9.06E+08 | 8.95E+08 | 3.03E+07 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0 |
| | meanDE | 5.07E+08 | 5.07E+08 | 5.07E+08 | 5.07E+08 | 0.00E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0 |
| | AGSK | 5.78E+08 | 6.30E+08 | 6.05E+08 | 6.04E+08 | 1.90E+07 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0 |
| | SA | 3.76E+08 | 3.76E+08 | 3.76E+08 | 3.76E+08 | 6.37E−08 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0 |
| | ALSHADE | 5.41E+08 | 5.66E+08 | 5.48E+08 | 5.52E+08 | 1.20E+07 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0 |
| | BDE | 3.88E+08 | 3.88E+08 | 3.88E+08 | 3.88E+08 | 6.37E−08 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0 |
| | DA2MODE | 4.67E+08 | 4.99E+08 | 4.86E+08 | 4.85E+08 | 1.07E+07 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0 |
| F10 | EODE | 1.27E+06 | 1.29E+06 | 1.27E+06 | 1.28E+06 | 8.73E+03 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0 |
| | APGSKIMODE | 1.80E+07 | 3.67E+07 | 1.90E+07 | 2.09E+07 | 6.39E+06 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0 |
| | BeSD | 5.36E+04 | 4.59E+06 | 1.15E+05 | 6.67E+05 | 1.59E+06 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0 |
| | BSD | 1.16E+05 | 5.67E+06 | 4.68E+06 | 3.79E+06 | 2.31E+06 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0 |
| | MDE | 4.82E+04 | 4.89E+04 | 4.89E+04 | **4.88E+04** | 2.59E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0 |
| | dFDBLSHADE | 1.36E+07 | 1.36E+07 | 1.36E+07 | 1.36E+07 | 1.99E−09 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0 |
| | meanDE | 9.29E+06 | 1.86E+07 | 1.39E+07 | 1.39E+07 | 4.97E+06 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0 |
| | AGSK | 2.58E+05 | 1.32E+06 | 1.27E+06 | 1.06E+06 | 4.37E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0 |
| | SA | 6.51E+06 | 6.51E+06 | 6.51E+06 | 6.51E+06 | 0.00E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0 |
| | ALSHADE | 1.20E+06 | 1.21E+06 | 1.20E+06 | 1.20E+06 | 7.18E+02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0 |
| | BDE | 9.99E+04 | 9.99E+04 | 9.99E+04 | 9.99E+04 | 0.00E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0 |
| | DA2MODE | 1.19E+06 | 1.20E+06 | 1.20E+06 | 1.20E+06 | 4.64E+03 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0 |
| F11 | EODE | 6.81E+09 | 8.28E+10 | 6.81E+09 | 1.63E+10 | 2.69E+10 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0 |
| | APGSKIMODE | 1.82E+13 | 1.99E+13 | 1.82E+13 | 1.86E+13 | 8.22E+11 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0 |
| | BeSD | 1.18E+11 | 1.95E+11 | 1.18E+11 | 1.45E+11 | 3.75E+10 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0 |
| | BSD | 7.42E+10 | 1.00E+11 | 8.71E+10 | 8.71E+10 | 1.38E+10 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0 |
| | MDE | 1.89E+10 | 9.95E+10 | 9.95E+10 | 6.93E+10 | 4.17E+10 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0 |
| | dFDBLSHADE | 1.48E+13 | 2.00E+13 | 2.00E+13 | 1.87E+13 | 2.39E+12 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0 |
| | meanDE | 3.65E+11 | 3.65E+11 | 3.65E+11 | 3.65E+11 | 0.00E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0 |
| | AGSK | 6.47E+10 | 1.75E+11 | 1.17E+11 | 1.18E+11 | 3.92E+10 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0 |
| | SA | 6.43E+09 | 6.66E+09 | 6.43E+09 | 6.49E+09 | 1.06E+08 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0 |
| | ALSHADE | 1.02E+10 | 1.36E+10 | 1.36E+10 | 1.32E+10 | 1.19E+09 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0 |
| | BDE | 9.05E+10 | 9.05E+10 | 9.05E+10 | 9.05E+10 | 1.63E−05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0 |
| | DA2MODE | 2.10E+09 | 3.12E+09 | 2.62E+09 | **2.58E+09** | 3.93E+08 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0 |
| F12 | EODE | 4.01E+10 | 4.60E+10 | 4.60E+10 | 4.37E+10 | 3.06E+09 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0 |
| | APGSKIMODE | 1.29E+12 | 1.34E+12 | 1.31E+12 | 1.31E+12 | 2.43E+10 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0 |
| | BeSD | 1.59E+11 | 1.92E+11 | 1.70E+11 | 1.74E+11 | 1.66E+10 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0 |
| | BSD | 8.12E+05 | 1.18E+06 | 8.12E+05 | **8.77E+05** | 1.33E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0 |
| | MDE | 4.52E+10 | 4.69E+10 | 4.69E+10 | 4.65E+10 | 7.56E+08 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0 |
| | dFDBLSHADE | 1.95E+12 | 1.97E+12 | 1.97E+12 | 1.97E+12 | 1.19E+10 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0 |
| | meanDE | 2.87E+11 | 2.87E+11 | 2.87E+11 | 2.87E+11 | 6.52E−05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0 |
| | AGSK | 1.30E+11 | 1.74E+11 | 1.65E+11 | 1.60E+11 | 1.55E+10 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0 |
| | SA | 6.36E+08 | 6.37E+08 | 6.36E+08 | 6.36E+08 | 3.41E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0 |
| | ALSHADE | 1.53E+10 | 1.53E+10 | 1.53E+10 | 1.53E+10 | 2.04E−06 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0 |
| | BDE | 9.05E+07 | 9.05E+07 | 9.05E+07 | 9.05E+07 | 1.59E−08 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0 |
| | DA2MODE | 1.33E+10 | 1.69E+10 | 1.45E+10 | 1.48E+10 | 1.33E+09 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0 |
| F13 | EODE | 7.07E+09 | 7.07E+09 | 7.07E+09 | 7.07E+09 | 0.00E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0 |
| | APGSKIMODE | 3.52E+12 | 3.44E+13 | 3.52E+12 | 1.12E+13 | 1.43E+13 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0 |
| | BeSD | 1.42E+10 | 2.03E+10 | 1.42E+10 | 1.57E+10 | 2.80E+09 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0 |
| | BSD | 4.53E+09 | 7.47E+09 | 6.26E+09 | 6.07E+09 | 1.36E+09 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0 |
| | MDE | 1.14E+10 | 1.52E+10 | 1.52E+10 | 1.42E+10 | 1.74E+09 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0 |
| | dFDBLSHADE | 3.66E+12 | 4.71E+12 | 4.18E+12 | 4.18E+12 | 5.62E+11 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0 |
| | meanDE | 2.23E+10 | 2.92E+10 | 2.92E+10 | 2.66E+10 | 3.54E+09 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0 |
| | AGSK | 2.19E+10 | 3.11E+10 | 2.54E+10 | 2.60E+10 | 3.26E+09 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0 |
| | SA | 9.33E+09 | 9.33E+09 | 9.33E+09 | 9.33E+09 | 0.00E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0 |
| | ALSHADE | 7.88E+09 | 9.75E+09 | 7.88E+09 | 8.11E+09 | 6.63E+08 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0 |
| | BDE | 7.93E+09 | 1.05E+10 | 1.05E+10 | 9.53E+09 | 1.33E+09 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0 |
| | DA2MODE | 3.11E+09 | 4.50E+09 | 4.26E+09 | **4.02E+09** | 5.21E+08 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0 |
| F14 | EODE | 6.54E+10 | 8.25E+10 | 6.54E+10 | 6.97E+10 | 7.92E+09 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0 |
| | APGSKIMODE | 1.47E+13 | 1.60E+13 | 1.60E+13 | 1.59E+13 | 4.54E+11 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0 |
| | BeSD | 2.15E+11 | 4.40E+11 | 2.63E+11 | 2.79E+11 | 8.01E+10 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0 |
| | BSD | 9.08E+10 | 1.71E+11 | 1.71E+11 | 1.42E+11 | 3.97E+10 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0 |
| | MDE | 1.14E+11 | 1.41E+11 | 1.41E+11 | 1.37E+11 | 9.51E+09 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0 |
| | dFDBLSHADE | 4.78E+12 | 9.25E+12 | 9.25E+12 | 8.14E+12 | 2.07E+12 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0 |
| | meanDE | 4.25E+11 | 4.25E+11 | 4.25E+11 | 4.25E+11 | 0.00E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0 |
| | AGSK | 1.82E+11 | 5.70E+11 | 3.68E+11 | 3.69E+11 | 1.37E+11 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0 |
| | SA | 2.08E+10 | 2.08E+10 | 2.08E+10 | 2.08E+10 | 4.08E−06 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0 |
| | ALSHADE | 6.59E+10 | 6.59E+10 | 6.59E+10 | 6.59E+10 | 0.00E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0 |
| | BDE | 1.55E+11 | 1.55E+11 | 1.55E+11 | 1.55E+11 | 3.26E−05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0 |
| | DA2MODE | 9.09E+09 | 2.42E+10 | 1.46E+10 | **1.59E+10** | 5.44E+09 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0 |
| F15 | EODE | 1.36E+08 | 2.12E+10 | 2.12E+10 | 1.39E+10 | 1.02E+10 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0 |
| | APGSKIMODE | 1.37E+14 | 1.60E+14 | 1.48E+14 | 1.48E+14 | 1.20E+13 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0 |
| | BeSD | 4.19E+08 | 4.36E+08 | 4.19E+08 | 4.25E+08 | 8.44E+06 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0 |
| | BSD | 3.30E+07 | 4.99E+07 | 3.41E+07 | 3.79E+07 | 7.44E+06 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0 |
| | MDE | 6.19E+07 | 7.73E+07 | 7.08E+07 | 6.83E+07 | 5.75E+06 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0 |
| | dFDBLSHADE | 1.20E+14 | 1.20E+14 | 1.20E+14 | 1.20E+14 | 1.67E−02 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0 |
| | meanDE | 2.61E+08 | 2.61E+08 | 2.61E+08 | 2.61E+08 | 6.37E−08 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0 |
| | AGSK | 3.70E+07 | 1.33E+08 | 7.08E+07 | 7.48E+07 | 2.90E+07 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0 |
| | SA | 3.65E+07 | 3.65E+07 | 3.65E+07 | 3.65E+07 | 7.97E−09 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0 |
| | ALSHADE | 2.61E+08 | 3.75E+08 | 3.41E+08 | 3.24E+08 | 5.69E+07 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0 |
| | BDE | 5.56E+07 | 5.56E+07 | 5.56E+07 | 5.56E+07 | 0.00E+00 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0 |
| | DA2MODE | 1.59E+07 | 2.34E+07 | 2.23E+07 | **2.15E+07** | 2.49E+06 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 5.00E+05 | 0.00E+00 | 0 |

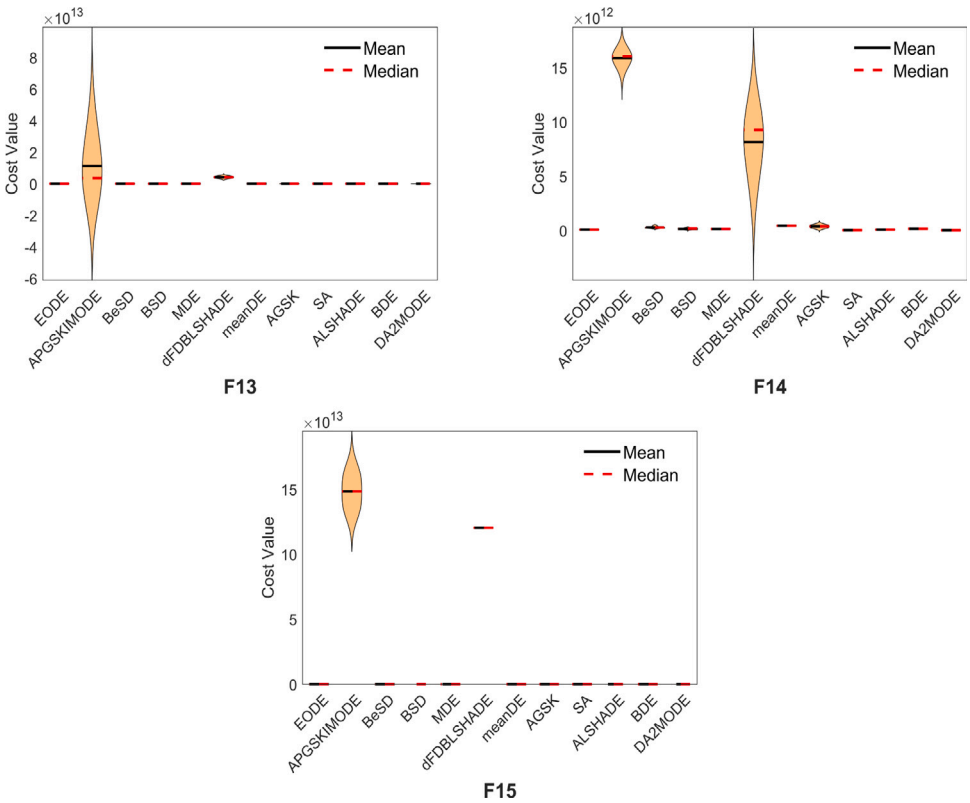



**Fig. I.21c.** Violin plots for the best fitness in 25 runs for all the algorithms in CEC2013-LSGO, F13–F15 (1000D).

## Data availability

Data will be made available on request. The source code of the DA2MODE algorithm is publicly available at: URL https://github.com/MohamedRedaMu/DA2MODE-Algorithm and URL https://uk.mathworks.com/matlabcentral/fileexchange/182019-da2mode-algorithm.

## References

[1] L. Abualigah, M.A. Elaziz, A.M. Khasawneh, M. Alshinwan, R.A. Ibrahim, M.A. Al-Qaness, S. Mirjalili, P. Sumari, A.H. Gandomi, Meta-heuristic optimization algorithms for solving real-world mechanical engineering design problems: a comprehensive survey, applications, comparative analysis, and results, Neural Comput. Appl. (2022) 1–30.

[2] V. Sharma, A.K. Tripathi, A systematic review of meta-heuristic algorithms in IoT based application, Array 14 (2022) 100164.

[3] M. Reda, A. Onsy, A.Y. Haikal, A. Ghanbari, Optimizing the steering of driverless personal mobility pods with a novel differential harris hawks optimization algorithm (DHHO) and encoder modeling, Sensors (Basel Switzerland) 24 (14) (2024) 4650.

[4] M. Kaveh, M.S. Mesgari, Application of meta-heuristic algorithms for training neural networks and deep learning architectures: A comprehensive review, Neural Process. Lett. 55 (4) (2023) 4519–4622.

[5] V.C. SS, A. HS, Nature inspired meta heuristic algorithms for optimization problems, Computing 104 (2) (2022) 251–269.

[6] K. Rajwar, K. Deep, S. Das, An exhaustive review of the metaheuristic algorithms for search and optimization: taxonomy, applications, and open challenges, Artif. Intell. Rev. 56 (11) (2023) 13187–13257.

[7] B. Alhijawi, A. Awajan, Genetic algorithms: Theory, genetic operators, solutions, and applications, Evol. Intell. (2023) 1–12.

[8] M.F. Ahmad, N.A.M. Isa, W.H. Lim, K.M. Ang, Differential evolution: A recent review based on state-of-the-art works, Alex. Eng. J. 61 (5) (2022) 3831–3872.

[9] V.-H. Dang, N.A. Vien, T. Chung, A covariance matrix adaptation evolution strategy in reproducing kernel Hilbert space, Genet. Program. Evolvable Mach. 20 (2019) 479–501.

[10] T. Guilmeau, E. Chouzenoux, V. Elvira, Simulated annealing: A review and a new scheme, in: 2021 IEEE Statistical Signal Processing Workshop, SSP, IEEE, 2021, pp. 101–105.

[11] A.G. Gad, Particle swarm optimization algorithm and its applications: a systematic review, Arch. Comput. Methods Eng. 29 (5) (2022) 2531–2561.

[12] X. Li, K.M. Luk, The grey wolf optimizer and its applications in electromagnetics, IEEE Trans. Antennas and Propagation 68 (3) (2019) 2186–2197.

[13] R. Szczepanski, K. Erwinski, M. Tejer, A. Bereit, T. Tarczewski, Optimal scheduling for palletizing task using robotic arm and artificial bee colony algorithm, Eng. Appl. Artif. Intell. 113 (2022) 104976.

[14] J. Lansky, A.M. Rahmani, M.H. Malik, E. Yousefpoor, M.S. Yousefpoor, M.U. Khan, M. Hosseinzadeh, An energy-aware routing method using firefly algorithm for flying ad hoc networks, Sci. Rep. 13 (1) (2023) 1323.

[15] D. Chen, X. Li, S. Li, A novel convolutional neural network model based on beetle antennae search optimization algorithm for computerized tomography diagnosis, IEEE Trans. Neural Netw. Learn. Syst. 34 (3) (2021) 1418–1429.

[16] K.Y. Gómez Díaz, S.E. De León Aldaco, J. Aguayo Alquicira, M. Ponce-Silva, V.H. Olivares Peregrino, Teaching–learning-based optimization algorithm applied in electronic engineering: A survey, Electronics 11 (21) (2022) 3451.

[17] M. Alazab, R.A. Khurma, A. Awajan, D. Camacho, A new intrusion detection system based on Moth–Flame optimizer algorithm, Expert Syst. Appl. 210 (2022) 118439.

[18] C.T. Yue, K.V. Price, P.N. Suganthan, J.J. Liang, M.Z. Ali, B.Y. Qu, N.H. Awad, P.P. Biswas, Problem Definitions and Evaluation Criteria for the CEC 2020 Special Session and Competition on Single Objective Bound Constrained Numerical Optimization, Technical Report, Nanyang Technological University, Singapore, 2019, URL https://github.com/P-N-Suganthan/2020-Bound-Constrained-Opt-Benchmark.

[19] X. Zhang, Q. Liu, Y. Qu, An adaptive differential evolution algorithm with population size reduction strategy for unconstrained optimization problem, Appl. Soft Comput. 138 (2023) 110209.

[20] K.M. Sallam, S.M. Elsayed, R.K. Chakrabortty, M.J. Ryan, Improved multi-operator differential evolution algorithm for solving unconstrained problems, in: 2020 IEEE Congress on Evolutionary Computation, CEC, IEEE, 2020, pp. 1–8.

[21] Y. Li, T. Han, H. Zhou, S. Tang, H. Zhao, A novel adaptive L-SHADE algorithm and its application in UAV swarm resource configuration problem, Inform. Sci. 606 (2022) 350–367.

[22] Z. Meng, Y. Chen, Differential evolution with exponential crossover can be also competitive on numerical optimization, Appl. Soft Comput. 146 (2023) 110750.

[23] A.W. Mohamed, A.A. Hadi, P. Agrawal, K.M. Sallam, A.K. Mohamed, Gaining-sharing knowledge based algorithm with adaptive parameters hybrid with IMODE algorithm for solving CEC 2021 benchmark problems, in: 2021 IEEE Congress on Evolutionary Computation, CEC, IEEE, 2021, pp. 841–848.

[24] S. Biswas, D. Saha, S. De, A.D. Cobb, S. Das, B.A. Jalaian, Improving differential evolution through Bayesian hyperparameter optimization, in: 2021 IEEE Congress on Evolutionary Computation, CEC, IEEE, 2021, pp. 832–840.

[25] G. Zhang, Y. Shi, Hybrid sampling evolution strategy for solving single objective bound constrained problems, in: 2018 IEEE Congress on Evolutionary Computation, CEC, IEEE, 2018, pp. 1–7.

[26] P. Bujok, P. Kolenovsky, Eigen crossover in cooperative model of evolutionary algorithms applied to CEC 2022 single objective numerical optimisation, in: 2022 IEEE Congress on Evolutionary Computation, CEC, IEEE, 2022, pp. 1–8.

[27] A. Layeb, Differential evolution algorithms with novel mutations, adaptive parameters, and Weibull flight operator, Soft Comput. 28 (11) (2024) 7039–7091.

[28] İ. Yildirim, M.H. Bozkurt, H.T. Kahraman, S. Aras, Dental X-Ray image enhancement using a novel evolutionary optimization algorithm, Eng. Appl. Artif. Intell. 142 (2025) 109879.

[29] J. Zhang, A.C. Sanderson, JADE: adaptive differential evolution with optional external archive, IEEE Trans. Evol. Comput. 13 (5) (2009) 945–958.

[30] Y. Li, T. Han, H. Zhou, S. Tang, H. Zhao, A novel adaptive L-SHADE algorithm and its application in UAV swarm resource configuration problem, Inform. Sci. 606 (2022) 350–367.

[31] A.K. Al Hwaitat, H.N. Fakhouri, Multi-cloud security optimization using novel hybrid JADE-geometric mean optimizer, Symmetry 17 (4) (2025) 503.

[32] S. Mirjalili, S.M. Mirjalili, A. Lewis, Grey wolf optimizer, Adv. Eng. Softw. 69 (2014) 46–61.

[33] M.K. Heris, Simulated annealing in MATLAB, 2015, URL https://yarpiz.com/223/ypea105-simulated-annealing.

[34] R.V. Rao, V.J. Savsani, D. Vakharia, Teaching–learning-based optimization: a novel method for constrained mechanical design optimization problems, Computer-Aided Des. 43 (3) (2011) 303–315.

[35] S. Mirjalili, Moth-flame optimization algorithm: A novel nature-inspired heuristic paradigm, Knowl.-Based Syst. 89 (2015) 228–249.

[36] A.A. Heidari, S. Mirjalili, H. Faris, I. Aljarah, M. Mafarja, H. Chen, Harris hawks optimization: Algorithm and applications, Future Gener. Comput. Syst. 97 (2019) 849–872.

[37] A. Kumar, K.V. Price, A.W. Mohamed, A.A. Hadi, P.N. Suganthan, Problem Definitions and Evaluation Criteria for the CEC 2022 Special Session and Competition on Single Objective Bound Constrained Numerical Optimization, Technical Report, Nanyang Technological University, 2021, URL https://github.com/P-N-Suganthan/2022-SO-BO.

[38] A.W. Mohamed, A.A. Hadi, A.K. Mohamed, N.H. Awad, Evaluating the performance of adaptive gainingsharing knowledge based algorithm on CEC 2020 benchmark problems, in: 2020 IEEE Congress on Evolutionary Computation, CEC, IEEE, 2020, pp. 1–8.

[39] P. Civicioglu, E. Besdok, M.A. Gunen, U.H. Atasever, Weighted differential evolution algorithm for numerical function optimization: a comparative study with cuckoo search, artificial bee colony, adaptive differential evolution, and backtracking search optimization algorithms, Neural Comput. Appl. 32 (2020) 3923–3937.

[40] A. Moharam, A.Y. Haikal, M. Elhosseini, Economically optimized heat exchanger design: a synergistic approach using differential evolution and equilibrium optimizer within an evolutionary algorithm framework, Neural Comput. Appl. 36 (24) (2024) 14999–15026.

[41] A.E. Karkinli, Detection of object boundary from point cloud by using multi-population based differential evolution algorithm, Neural Comput. Appl. 35 (7) (2023) 5193–5206.

[42] M.H. Nadimi-Shahraki, S. Taghian, S. Mirjalili, H. Faris, MTDE: An effective multi-trial vector-based differential evolution algorithm and its applications for engineering design problems, Appl. Soft Comput. 97 (2020) 106761.

[43] P. Civicioglu, E. Besdok, Bernstain-search differential evolution algorithm for numerical function optimization, Expert Syst. Appl. 138 (2019) 112831.

[44] P. Civicioglu, E. Besdok, Bernstein-levy differential evolution algorithm for numerical function optimization, Neural Comput. Appl. 35 (9) (2023) 6603–6621.

[45] P. Civicioglu, E. Besdok, Bezier search differential evolution algorithm for numerical function optimization: A comparative study with CRMLSP, MVO, WA, Shade and Lshade, Expert Syst. Appl. 165 (2021) 113875.

[46] E.H. Haro, D. Oliva, A. Casas-Ordaz, E. Reyes-Davila, O. Avalos, Improving the selection of differential evolution through a quartile-based ranked operator, Int. J. Mach. Learn. Cybern. (2024) 1–36.

[47] R. Storn, K. Price, Differential evolution–a simple and efficient heuristic for global optimization over continuous spaces, J. Global Optim. 11 (4) (1997) 341–359.

[48] K. Price, R.M. Storn, J.A. Lampinen, Differential Evolution: a Practical Approach to Global Optimization, Springer Science & Business Media, 2006.

[49] D. Liu, Z. Hu, Q. Su, M. Liu, A niching differential evolution algorithm for the large-scale combined heat and power economic dispatch problem, Appl. Soft Comput. 113 (2021) 108017.

[50] K.M. Sallam, S.M. Elsayed, R.A. Sarker, D.L. Essam, Landscape-assisted multi-operator differential evolution for solving constrained optimization problems, Expert Syst. Appl. 162 (2020) 113033.

[51] V.-H. Truong, H.M. Hung, P.H. Anh, T.D. Hoc, Optimization of steel moment frames with panel-zone design using an adaptive differential evolution, J. Sci. Technol. Civ. Eng. (STCE)-HUCE 14 (2) (2020) 65–75.

[52] S. Nguyen-Van, Q.X. Lieu, N. Xuan-Mung, T.T.N. Nguyen, A new study on optimization of four-bar mechanisms based on a hybrid-combined differential evolution and Jaya algorithm, Symmetry 14 (2) (2022) 381.

[53] J. Brest, M. Sepesy Maučec, Population size reduction for the differential evolution algorithm, Appl. Intell. 29 (2008) 228–247.

[54] R. Tanabe, A.S. Fukunaga, Improving the search performance of SHADE using linear population size reduction, in: 2014 IEEE Congress on Evolutionary Computation, CEC, IEEE, 2014, pp. 1658–1665.

[55] R. Boks, A.V. Kononova, H. Wang, Quantifying the impact of boundary constraint handling methods on differential evolution, in: Proceedings of the Genetic and Evolutionary Computation Conference Companion, 2021, pp. 1199–1207.

[56] K.M. Sallam, S.M. Elsayed, R.A. Sarker, D.L. Essam, Improved united multi-operator algorithm for solving optimization problems, in: 2018 IEEE Congress on Evolutionary Computation, CEC, IEEE, 2018, pp. 1–8.

[57] N. Awad, M. Ali, J. Liang, B. Qu, P. Suganthan, Problem Definitions and Evaluation Criteria for the CEC 2017 Special Session and Competition on Single Objective Real-Parameter Numerical Optimization, Tech. Rep., 2016.

[58] X. Li, K. Tang, M.N. Omidvar, Z. Yang, K. Qin, H. China, Benchmark functions for the CEC 2013 special session and competition on large-scale global optimization, Gene 7 (33) (2013) 8.

[59] N.H. Awad, M.Z. Ali, P.N. Suganthan, J.J. Liang, B.Y. Qu, Problem Definitions and Evaluation Criteria for the CEC 2017 Special Session and Competition on Single Objective Real-Parameter Numerical Optimization, Technical Report, Nanyang Technological University, Singapore and Jordan University of Science and Technology, Jordan and Zhengzhou University, Zhengzhou, China, 2016, Modified on October 15th 2016. URL https://github.com/P-N-Suganthan/CEC2017-BoundContrained.

[60] S.Z. Koohi, N.A.W.A. Hamid, M. Othman, G. Ibragimov, Raccoon optimization algorithm, IEEE Access 7 (2018) 5383–5399.

[61] D. Simon, Biogeography-based optimization, IEEE Trans. Evol. Comput. 12 (6) (2008) 702–713.

[62] M. Fischetti, M. Stringher, Embedded hyper-parameter tuning by simulated annealing, 2019, arXiv preprint arXiv:1906.01504.

[63] X. Jiang, S. Li, BAS: beetle antennae search algorithm for optimization problems, 2017, arXiv preprint arXiv:1710.10724.

[64] N. Hansen, A. Ostermeier, Completely derandomized self-adaptation in evolution strategies, Evol. Comput. 9 (2) (2001) 159–195.

[65] S. Mirjalili, A. Lewis, The whale optimization algorithm, Adv. Eng. Softw. 95 (2016) 51–67.

[66] J. Carrasco, S. García, M. Rueda, S. Das, F. Herrera, Recent trends in the use of statistical tests for comparing swarm and evolutionary computing algorithms: Practical guidelines and a critical review, Swarm Evol. Comput. 54 (2020) 100665.

[67] H. Bayzidi, Social network search for solving engineering problems, 2024, Available: https://www.mathworks.com/matlabcentral/fileexchange/97577-social-network-search-for-solving-engineering-problems. (Last Accessed 18 November 2024).

[68] H. Bayzidi, S. Talatahari, M. Saraee, C.-P. Lamarche, Social network search for solving engineering optimization problems, Comput. Intell. Neurosci. 2021 (1) (2021) 8548639.