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Shaft surface as a factor affecting lip seal performance

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1. Introduction

Radial lip seals are widely used to provide effective sealing in numerous applications such as automotive transmissions. The seal is placed on the rotating shafts entering/leaving the gearbox to retain the lubricant within the casing while maintaining a thin lubricating film between the contact surfaces. Seal failure not only reduces efficiency of the transmission system but can also cause environment contamination.

Shaft surface roughness is commonly neglected and assumed to be smooth in comparison with the seal surface [1-3]. Nevertheless, it has been shown that surfaces of the same average height (Ra) demonstrate significant variations in tribological performance indicating that real surfaces are not adequately described by this parameter [4]. The research presented in this paper investigates skewness and core parameters in order to provide a more comprehensive understanding of the seal system behavior. The various rough surfaces are compared for the prediction of their sealing capabilities using a numerical Reynolds equation based model.

2. Methodology

Several shaft surface finishes commonly used in industry have been investigated to identify key differences in sealing bed surface topographies. To assess the influence of shaft topography the shaft profiles have been extracted and roughness parameters measured and compared. An optical focus variation technique was used to measure the shaft surface roughness, using x20, x50 and x100 magnification lens with x100 lens chosen for further analysis as giving the most accurate data and corresponding well to seal/shaft area of contact. The vertical resolution of the latest lens was set to 20nm and lateral resolution to 1 μ m. 15 measurement of approximate sample area 145x110 μ m were taken from each surface obtained by different manufacturing processes.

Hydrodynamic numerical model based on Reynold's equation has been developed to predict pressure distribution, hydrodynamic load and side flow (leakage). Swift-Steiber (Reynold's) condition was included to treat cavitation regions. The solver uses a finite difference method. The seal surface has been assumed to be perfectly smooth and flat to isolate the shaft profile effect only on film thickness and side flow rate

obtained. The simulations were carried out based on surface parameters measured from unused shafts and seals.

3. Results and Discussion

When the shaft and seal are considered to be perfectly aligned with only rotational movement about the shaft center there is no observable difference in leakage for shaft profiles with varying skewness. When movement in axial direction is introduced, the Couette flow arisen distinguishes between the profiles examined by causing very high local pressure rise and/or cavitation regions. Positively skewed surfaces are shown to create larger pressure perturbations while negatively skewed surfaces tend to form more cavitated regions.

The effect of shaft surface roughness highly depends on roughness of the seal material. The smoother the seal becomes during the operation, the more significant shaft surface profile becomes in providing hydrodynamic load support. It might be pointed out that shaft surface is frequently observed to polish during operation. Therefore, future investigations will consider the evolution of both shaft and seal surfaces that take place during the initial breaking-in period to obtain the characteristics of the run surfaces.

4. References

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