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PUBLISHER

Loughborough University

VERSION

VoR (Version of Record)

PUBLISHER STATEMENT

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Paouris, Leonidas I., Stephanos Theodossiades, Miguel De la Cruz, Homer Rahnejat, Adam Kidson, Gregory Hunt, and William Barton. 2019. “Isothermal Elastohydrodynamic Lubrication Analysis of Heavily Loaded Hypoid Gear Pairs”. figshare. https://hdl.handle.net/2134/17730.

Isothermal Elastohydrodynamic Lubrication Analysis of Heavily Loaded Hypoid Gear Pairs

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A numerical model able to predict the pressure distribution and the film thickness in heavily loaded elliptical EHL contacts is developed and presented in this study. The operating conditions, such as the contact load and the velocities of the mating surfaces, are representative of the corresponding conditions present in automotive differential hypoid gear pair units. The EHL solver presented is able to predict the minimum and central film thickness of the lubricating oil as well as the pressure distribution assuming isothermal and Newtonian conditions. Results are presented for a full quasi-static meshing cycle. A comparison between the numerically calculated values of the central and the minimum film thickness is performed against the corresponding values produced using the Chittenden-Dowson formula. A very good agreement is observed between the values of the central film thickness. However, it is shown that the minimum film thickness values using the Chittenden-Dowson formula can deviate up to 40% compared with the corresponding values which are calculated numerically.

1. Introduction

The automotive differential unit is one of the most heavily loaded components of the powertrain of the vehicle. Its main purpose is to transfer the rotational motion and the torque from the main driveshaft coming out of the gearbox to the wheels. In order to do so a hypoid gear pair is used. Hypoid gear pairs used in differential units operate under extreme pressure and sliding conditions making the efficient lubrication of the gear teeth a demanding task. The high contact load, combined with the intense shear heating of the lubricant, contribute to a reduced film thickness between the mating surfaces. The knowledge of the film thickness at every instant of the gear meshing cycle is hence an important parameter that should be accounted for when selecting the lubricant grade or the gear pair geometry. The present study presents a methodology which is deemed appropriate for such kind of calculations.

2. Methodology/Results/Discussion

In order to determine the pressure distribution in the EHL contact, knowing the lubricant properties and the operating conditions, the 2D Reynolds equation with side leakage terms is used. The lubricant is assumed to behave as a Newtonian fluid in isothermal flow. The elastic deflection of the mating surfaces due to the high pressure of the lubricant are calculated using the theory of elastic potentials for semi-infinite elastic half spaces [1]. Equation (1) is used for that purpose. The pressure-viscosity equation used (2) is based on the one recommended by Roelands [2] and later modified by Houpert [3].

$$\delta(x,y) = \frac{1}{\pi E^*} \iint_A \frac{p d x_1 d x_2}{\sqrt{(x-x_1)^2 + (y-y_1)^2}} \qquad (1)$$

$$\eta = \eta_0 e^{\{[ln(\eta_0)+9.67][-1+(1+5.1\cdot 10^{-9}P)]\}} \qquad (2)$$

Results of the film thickness for a full meshing cycle are presented in figure (1) and compared against the values calculated using the Chittenden-Dowson equations [4].

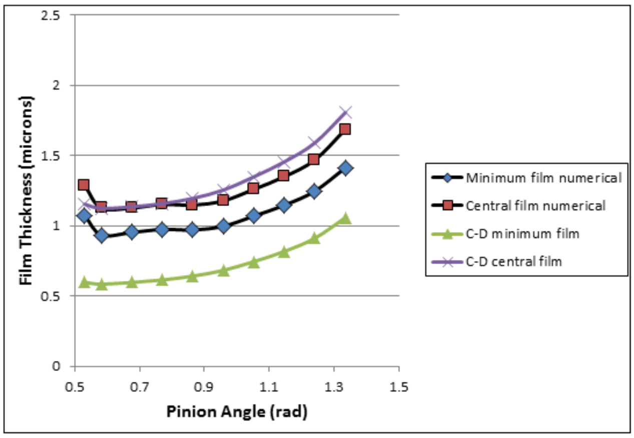

Figure 1: Minimum and central lubricant film thickness for a full meshing cycle using the Chittenden-Dowson as well as the numerical results.

As seen in figure (1), the predictions of the numerical EHL solver exhibit a good agreement with the predictions of the Chittenden-Dowson formula throughout the meshing cycle. However, differences up to 40% for those two approaches are apparent in terms of the minimum film thickness.

3. References

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