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TEHL simulation of low-loss gears considering loaded tooth contact analysis

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Low-loss gears can minimize load-dependent gear power losses significantly. The related gear design results in a very short path of contact. Hence, sliding during gear meshing and load-dependent gear losses are reduced. By means of numerical calculations of the thermal elastohydrodynamically lubricated (TEHL) contact considering mixed lubrication, the area of contact during gear meshing of low-loss gears is analyzed. Required local gear mesh quantities are determined by a detailed loaded tooth contact analysis (LTCA). Results show that the thermal regime of friction across the area of gear contact is not pronounced like in typical involute gears. This affects the relevance of thermophysical properties of lubricants and coatings.

Keywords: elastohydrodynamic lubrication, mixed lubrication, gear, efficiency

1. Introduction

The increasing demand on improving the efficiency of drive systems implies the requirement for power loss minimized gearboxes. Power losses can be divided into no-load and load-dependent. No-load gear losses occur due to interaction of rotating gears with lubricant and ambient medium. Load-dependent gear losses P_{LGP} are driven by the transmitted power and often represent a large proportion of the total power loss. Influencing quantities are sliding speed v_g, normal force F_N and coefficient of friction μ across the area of contact:

$$P_{LGP} = \frac{1}{p_{et}} \int_0^b \int_A^E F_N(x,y) \cdot v_g(x,y) \cdot \mu(x,y)\, dxdy$$

The load-dependent gear losses of involute gears can be minimized by low-loss gears, which concentrate the gear mesh around the pitch point area. These gears are characterized by a reduced module m_n, an increased pressure angle $\propto_n$ and a reduced transverse contact ratio of $\varepsilon_\propto$ even below one. To meet the same load capacity at constant gear ratio, the tooth width b is typically increased. Figure 1 shows exemplarily two low-loss gear designs based on a reference.

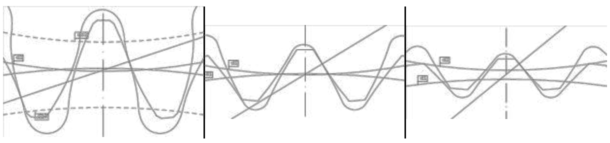

Figure 1: Geometry of a reference (left), moderate low-loss (mid) and extreme low-loss (right) gear design [1]

The very short path of contact of low-loss gears leads to significantly changed sliding portions and load distributions. For the extreme low-loss design in Figure 1, the length of path of contact is reduced by 81 % compared to the reference.
Its influence on the tribological behavior of the lubricated low-loss gear contact has not been investigated so far. Hence, the aim of this numerical study is to analyze the effect of geometrical characteristics of low-loss gears on the tribological conditions across the area of gear contact.

2. Methods

In order to analyze the tribological contact of low loss gears numerically, the local load distribution and surface velocities must be computed across the area of contact in a first step. Therefore, a LTCA is performed considering gear, bearing and shaft deformations. In a second step, the contact is analyzed by transient TEHL gear contact simulation considering mixed lubrication. The numerical model is based on a fully-coupled 3D finite element formulation according to the full-system approach of Habchi [2] and on the work of Ziegltrum et al. [3]. The considered operating conditions are aligned to experimental investigations at a gear efficiency back-to-back test rig with a typical mineral oil. Non-Newtonian fluid behavior is considered. The ground and superfinished gear surfaces are measured optically. Based on the surface topography, characteristic solid contact pressure curves and flow factors are derived to determine the solid contact ratio and the influence of the surface roughness on fluid flow.

3. Discussion

The geometrical characteristics of low-loss gears reduce load-dependent gear power losses strongly due to the concentration of gear meshing around the pitch point area. The shortened path of contact results in small sliding portions reducing local heat generation and affecting the local coefficient of friction. The thermal regime of friction across the area of gear contact is not pronounced like in typical involute gears. This is discussed in terms of the considered operating conditions and compared to measured load-dependent gear power losses in [1]. The characteristic tribological conditions of low-loss gear reduce the relevance of thermophysical properties of lubricants and coatings on the load-dependent gear power loss.

4. References

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