Simulation of Thermal Elastohydrodynamic Lubricated (TEHL) Gear Contacts

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Abstract

Thermal elastohydrodynamically lubricated (TEHL) contacts occur very frequently in drive technology and thus in gear drives. Surface stresses and lubrication regimes have significant influence on friction and damage behavior of gears. Due to the very small scales in space and time in TEHL contacts, numerical simulations are required to capture the involved tribological processes in detail. Particularly, the continuous increase of power density and energy efficiency in gear drives reveal the limits of conventional empirical design approaches. Hence, physically based simulation approaches are required to understand the friction and damage behavior of gears in more detail.
Due to the elastic deformation of the rolling elements induced by hydrodynamic pressure, the simulation of TEHL contacts requires the coupling of the areas of fluid dynamics and contact mechanics. Lohner et al. [1] show the implementation of a TEHL simulation model in COMSOL Multiphysics® based on the full-system approach suggested by Habchi [2]. Thereby, the transient generalized Reynolds equation (Weak Form Boundary PDE interface), the linear elasticity equation (Solid Mechanics interface) and the energy equations (Heat Transfer in Fluids and Heat Transfer in Solids interfaces) form the basic relations from a physical point of view. The calculation procedure is based on two setups of finite element models FEM-model(P,H) and FEM-model(T). The hydrodynamic pressure and lubricant film thickness distributions are solved within the FEM-model(P,H). Temperature distributions in lubricant and solid bodies is calculated within the FEM-model(T). An iterative procedure is established between the FEM-model(P,H) and FEM-model(T) until the maximum absolute difference of two consecutive solutions of dimensionless pressure and temperature distributions is smaller than a convergence limit. The communication between the two FEM models is achieved by MATLAB® via the LiveLink™ for MATLAB®.
This study focuses, based on Lohner et al. [1], on the implementation of a TEHL simulation model for gear contacts in COMSOL. As load, velocity and radius of curvature varies along the path of contact of gears, transient operating behavior has to be considered. Hence, two consecutive time steps are coupled by an implicit backward differentiation formula (BDE) scheme of the first order. Exemplary, results obtained from the TEHL simulation approach for gear contacts include the local hydrodynamic pressure, lubricant film thickness and temperature distribution along the path of contact of gears. Furthermore, the stress distribution on and into the depth of the gear flanks as well as the coefficient of friction along the path of contact can be obtained, which serve as starting point for detailed evaluation of the friction and damage behavior of gear contacts.
To conclude, the implementation of a finite element based TEHL simulation approach for

gear contacts in commercial COMSOL Multiphysics® software is shown. This is different compared to most of the existing TEHL simulation approaches capable of considering gear contacts, which are usually based on self-developed simulation approaches and numerical solvers. Hence, research in computational tribology can be shifted even more on physical modelling instead of numerical modelling. Further modeling will be focused on rough gear surfaces and mixed lubrication regime.

Reference

[1] T. Lohner et al., Engineering software solution for thermal elastohydrodynamic lubrication using multiphysics software, Advances in Tribology, Vol. 2016, Article ID 6507203 (2016)
[2] W. Habchi et al., Stabilized fully-coupled finite elements for elastohydrodynamic lubrication problems, Advances in Engineering Software, Vol. 46, pp. 4-18 (2012)