CONTACTLUB: Computational Modelling of TEHL in Bearing and Gears

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Motivation

Powertrains and drivetrains consist of multiple high-precision components, such as bearings, gears, seals, cams, etc.. which determine the global performance, reliability and durability of the entire machine. These components largely affect the Total Cost-of-Ownership (TCO), due to primary hardware costs, secondary costs related to performance decrease over lifetime, maintenance, repair, downtime, outage and failure and to power consumption. Lubrication of these components is vital to improve their performance and durability, and reduce TCO.

The primary role of lubrication is to separate (fully or partially) the opposing surfaces of interacting machine elements via a thin lubricant film through which the load can be transferred, while minimizing damage and wear, noise and vibration, and friction. In addition, the lubricant film must be able to transport heat away from the contact area and to evacuate contaminants and wear debris.

CONTACTLUB focusses on the Thermo-Elastohydrodynamic lubrication (TEHL) regime, which typically occurs in non-conformal contact pairs under rolling-sliding conditions.

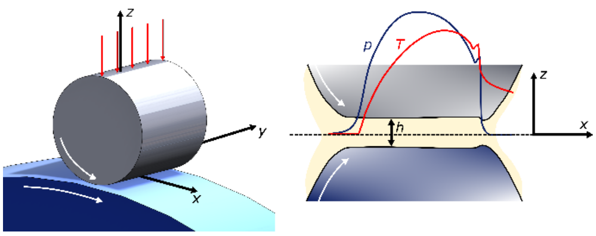

Figure 1 Elastohydrodynamic lubrication in a cylindrical roller bearing: roller element and raceway deform due to high hydrodynamic pressure

(T)EHL is characterized by very thin films (0.05–1 μm) and locally extreme hydrodynamic pressures (1–4 GPa), resulting in a significant local elastic deformation of the solid surfaces as illustrated in **Error! Reference source not found.**Figure 1.

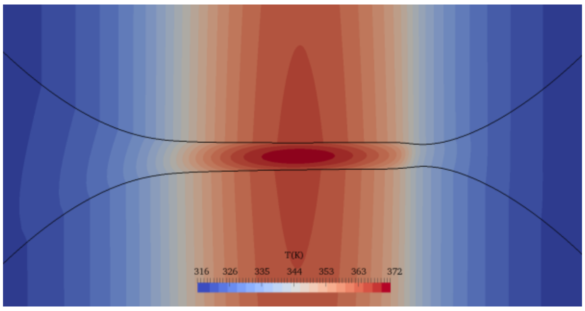

Figure 2 Temperature distribution in TEHL line contacts.

Objectives

This thesis consist of two goals:

1. **Computational modelling of Thermo-Elastohydrodynamic contacts**, with a 3D CFD-FSI model, including thermal effects, compressibility and lubricant rheology.
2. Parametric analysis & **meta-modelling of TEHL contact dynamics** for an extensive parameter space and based on full FSI calculations of the previously developed TEHL model. Here, variable loads and rolling/sliding velocities, as well as their combination will be assessed.

Within the ContactLub project, the outputs of these simulations and models will be used in the multi-body simulation of lubricated components with reducedorder models. Conversely, the global deformation obtained from the multi-body models serves as input for the local contact problem. Moreover, experiments are performed for the validation of the obtained models.

Approach

For the accurate physical description of the lubricant flow under various conditions in TEHL contacts, a comprehensive 3D **CFD model** is constructed in the open-source software OpenFOAM. This CFD model involves the Navier-Stokes equations in combination with an energy equation and is enriched with existing models for the thermo-mechanical lubricant properties, comprising non-Newtonian rheology, piezo-viscosity, compressibility and thermal dependencies using Equations of State (EOS) as a function of pressure, shear rate, and temperature. Moreover, gaseous and vaporous cavitation is taken into account using an adequate cavitation model.

For the linear elastic deformation of the contacting bodies, a structural solver is developed in both OpenFOAM and the commercial FEA-solver Abaqus.

The **2-way FSI-coupling** between the flow and structure solver is realized with a partitioned approach and an advanced Quasi-Newton coupling algorithm implemented in the open-source Python code CoCoNuT. This code, developed at UGent, allows for a modular and flexible approach towards the different coupling components, such as mappers, solver wrappers, and coupling algorithms.

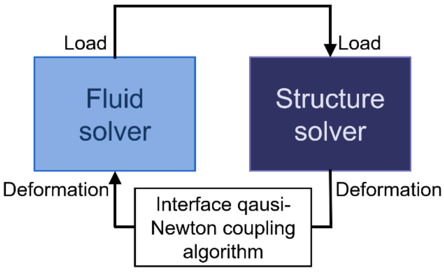

Figure 3 Schematic of partitioned FSI approach, accelerated and stabilized with an interface quasi-Newton coupling algorithm

The developed 3D CFD-FSI model for TEHL is used to analyze the effect of surface waviness and roughness on TEHL, as well as for studying the dynamic response of 2- and 3-dimensional TEHL contacts subject to dynamic loading conditions in combination with accelerating, decelerating, and oscillating motions. Thereto the pressure, temperature distributions will be investigated as well as the variability of the film thickness, the contact stiffness and damping over time. To obtain the correct geometrical contact conditions and corresponding dynamic response, the global contact deformation – obtained from macro-scale flexible multi-body models of the consortium partners at KULeuven – are superimposed to the local elastic deformation of the bodies.

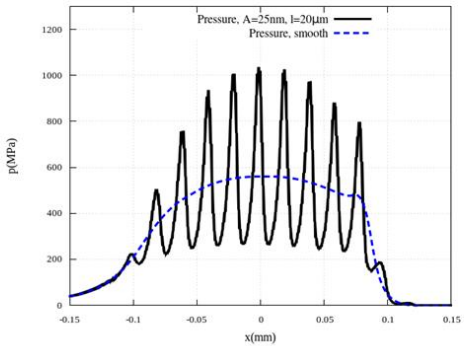

Figure 4 Pressure profile for a smooth and a rough TEHL contact

The transient response – in terms of normal and tangential stiffness and damping – will be evaluated as a function of the excitation frequency. Due to the non-linear lubricant physics, its response to an artificial broadband excitation will not be identical to that obtained by the superposition of the single modes. The degree of nonlinearity comparing a well-defined broadband response to the estimated response obtained by superposition of individual excitation frequencies in the spectrum.

In order to couple TEHL contact dynamics into multi-body simulations with the aim to assess drivetrain systems for performance and NVH, **meta-models** are constructed in this project. Such meta-models can be either data-driven or physics-based models such as non-linear serial/parallel spring-damper models in which the stiffness and damping is a non-linear function of the local TEHL conditions.. Stiffness and damping can be determined for an entire TEHL region, e.g., point-contacts, but also at different axial positions in, e.g., line contacts, taking into account side-leakage effects.

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