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A modelling framework for the simulation of lubricated and dry line contacts

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Abstract

Complex contact interactions, which typically occur in machine elements, such as gears and bearings, require a manifold analysis methodology. This has led to the development of a large number of different simulation models throughout the last decade. The presented framework aims to incorporate the thermoelastohydrodynamic (TEHD) approach and numerical contact mechanics (NCM) into one simulation model. No analytic function of the lubrication gap is necessary, since arbitrary surfaces can be imported into the model. This leads to the possibility to analyse a wide range of different contact scenarios, considering fluid lubrication or dry contact mechanics. Example results, including a literature comparison with other models and an experimental validation of traction curves considering surface roughness, are presented to elucidate the functionalities of the developed simulation framework.

Keywords: elastohydrodynamics; TEHD; contact mechanics; friction

1. Introduction

Research efforts towards understanding phenomena, which take place when solid bodies contact each other, have been carried out in the last two centuries, starting with the fundamental work of *Hertz* in 1881 [1]. The formulas derived in this essential work are still in wide use today, on the one hand due to their simplicity, and therefore straightforward applicability, and as well because of their accuracy for certain scenarios. Originally intended for the analysis of dry contacts, *Hertzian* formulas have been used also for the calculation of lubricated machine elements, due to the lack of knowledge of hydrodynamic phenomena taking place in such systems. However, in 1949 *Ertel* and *Grubin* showed, that the pressure distribution between two non-conformal lubricated bodies is very similar to the *Hertzian* pressure profile [2]. Ever since then continuous improvements, such as consideration of thermal effects, or non-*Newtonian* fluid behaviour, have been achieved in the field of elastohydrodynamics (EHD). *Venner* introduced in 1991 a multigrid method based on a finite-difference scheme, capable of achieving quick convergence for high pressures [3]. In 2008 *Habchi* presented a fully coupled TEHD solver, which was implemented in a commercial multiphysics software [4, 5]. In the subsequent years similar endeavours followed. *Krampl* for instance introduced an EHD model for the consideration of heterogeneous materials [6]. Also numerous proprietary software for the TEHD calculation of gears has been developed, such as for instance [7]. The enumeration of significant work is far from complete, for a detailed review of the state of the art in *Elastohydrodynamics* the reader is referred to respective publications [8, 9]. A challenge still present in tribology is the modelling of mixed friction phenomena. While it has been shown experimentally, that surface irregularities, such as grooves, indentations or ridges, typically lead to a decreasing film-thickness [10] the reason for the rupture of the fluid-film still remains unknown [8]. Many mixed-friction models employ a special formulation of the *Reynolds* equation in which terms, stemming from the motion of surfaces, are switched of, as soon as the film thickness

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