A numerical investigation of surface waviness effects on TEHL in line contacts

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Comprehensive knowledge of the effects of surface roughness on Thermal Elastohydrodynamic Lubrication (TEHL) in e.g. bearing and gear contacts allows us to predict the precise lubrication conditions, stress distributions and consequently the service life of these mechanical components more accurately. For typical TEHL conditions, where the film thickness is only a few times the surface roughness, it is expected that the surface roughness topology and changes therein - even of the order of a few tens of nanometers - may significantly alter the lubrication in the contact.

In comparison with the classical Reynolds-Boussinesq approach, CFD-FSI modelling of TEHL contacts reduces the number of assumptions and hence offers increased accuracy in cases where inertial and thermal effects are important, e.g. at high slide-to-roll ratios, despite its higher computational cost. Indeed, CFD-FSI modelling better describes potential inertial effects at the inlet and outlet zones of TEHL contacts. Furthermore, the gradient of fluid variables across the film thickness is taken into account directly in CFD-FSI without requiring additional averaging over the film thickness as is the case for e.g. the modified Reynolds equation. This is not only important in the central core region but also in inlet and outlet zones where thermal convection can play a role. Moreover, based on our experience, variations across the film thickness are witnessed to be more pronounced when considering surface waviness or roughness.

In this study, the influence of the amplitude of waviness of surfaces on the lubrication condition in TEHL line contacts is examined through Computational Fluid Dynamics and Fluid-Structure Interaction (CFD-FSI) modelling. The effects of waviness amplitude on the pressure, temperature, friction, and solid stresses are investigated in detail.

The results show that the sinusoidal profile of nominal surfaces causes considerable oscillations in film thickness, hydrodynamic pressure, wall shear stress, and temperature, which is consistent with previous studies in the literature. Furthermore, significant pressure peaks that can reach twice the maximum Hertzian contact pressure cause von Mises stresses in solid materials that can be up to 16% - 108% higher than in smooth surfaces. Even in the absence of direct contact, these maximum stresses were observed to be very close to the surface, exceeding the typical Hertzian maximum shear stresses in the sub-surface.

Keywords: Thermo-Elastohydrodynamic Lubrication (TEHL), Computational Fluid Dynamics (CFD), Fluid-Structure Interaction (FSI), Surface micro-texturing

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