Simulation of Microstructured Rolling-Sliding Contacts

M. Weschta[1], S. Tremmel[1], S. Wartzack[1]

[1]Engineering Design, Friedrich-Alexander-University Erlangen-Nürnberg (FAU), Erlangen, Bavaria, Germany

Abstract

Introduction: In this presentation the impact of microstructures on highly loaded rolling-sliding contacts - like cam tappet or gear tooth contacts - is investigated. In such contacts elastohydrodynamic lubrication theory applies i.e. lubricating film and elastic deformation are of similar size. For lower loaded contacts - such as piston liner contacts - different authors showed that microstructures can improve lubricant film formation and reduce friction. For highly loaded contacts this question is in basic research. Friction reduction itself is a main research promoter with the goal of increased energy efficiency. The valve train for example is a major contributor to combustion engine losses at low crankshaft rotation speeds. Therefore, the cam tappet line-contact, see Figure 1, dominating these losses, is chosen as a demonstrator. The presentation will focus on the simulation of microstructured contacts using a COMSOL Multiphysics® model but also show an outlook on experimental results.

COMSOL Multiphysics: To simulate the elastohydrodynamic contact the elastic deformation and the hydrodynamic fluid film - using Reynolds differential equation - have to be computed simultaneously. Additionally the time dependent motion of microstructures through the contact must be considered. Therefore a fully coupled system using a structural mechanics model (deformation) and weak PDE on boundary model (hydrodynamics) is used. The microstructures are accounted for by a time dependent description of the undeformed lubricating gap.

Results: Due to high pressure in the contact area elastic deformation of contacting bodies plays an important role. Microstructures influence this deformation resulting in a local change of lubricating film. Two-dimensional computations were performed to analyze the influence of slide-to-roll-ratio (SRR) on film formation and pressure distribution. A rectangular microstructure shape was used therefor. One passage of the microstructure through the contact is shown in Figure 2. It can be seen, that for the highest SRR (negative SRR indicates structured surface moves faster than smooth one) the reduction of the central film thickness is the smallest and an increased thickness results after the microstructure passed the central position. This is due to an entrapped lubricant following the microstructure. A three-dimensional line contact in the case of sliding was studied to account for lateral effects. The rotation-symmetric microstructure has a Gaussian-like cross section. Figure 3 shows a plot of the fluid film thickness of the contact area. Also in this case a trailing effect (yellow) can be observed. Nevertheless, it has to be noted that a film reduction occurs (blue) at the side boundaries and in front of the microstructure. Moreover

different microstructure shapes and arrangements were tested in a cam-tappet test rig and friction forces could significantly be reduced and microstructures are preserved during running-in. Similarities to simulation results can be seen.

Conclusion: Simulation results underline positive effects of microstructures in the case of sliding, not in the case of pure rolling. A friction reduction effect is possibly due to a reduced amount of areas with mixed friction due to the cavity of the microstructure itself and a sliding induced trailing effect. On a component test rig friction reduction effects are achieved.

Figures used in the abstract

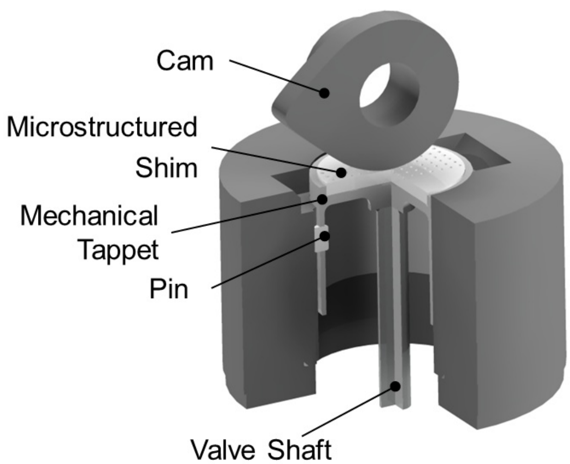

Figure 1: Figure 1: Cam follower line-contact with microstructured shim as used in experimental investigations.

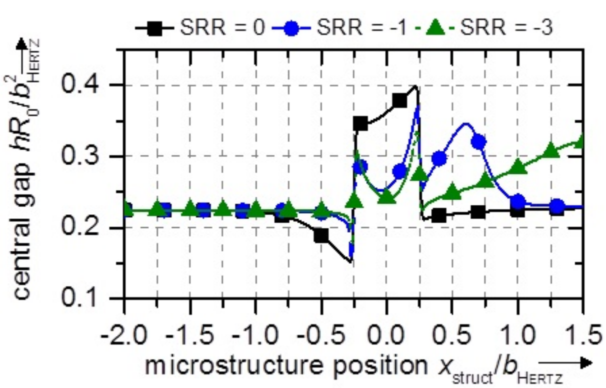

Figure 2: Microstructured two-dimensional line contact and influence of slide-to-roll ratio (SRR) on central film thickness (negative SRR indicates that structured surface moves faster than smooth one).

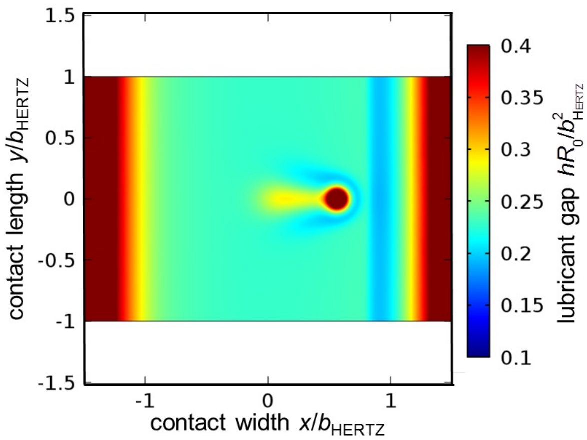

Figure 4: Microstructured three-dimensional line-contact in case of sliding, microstructures moves from left to right: development of a trailing effect, i.e. yellow increased film thickness behind microstructure.