NUMERICAL AND EXPERIMENTAL STUDIES ON FRICTION REDUCTION BY SURFACE MODIFICATION IN TEHL CONTACTS

TRACK OR CATEGORY

Surface Engineering III (7J)

AUTHORS AND INSTITUTIONS

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KEYWORDS

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INTRODUCTION

According to Holmberg et al. [1], around one fifth of the fuel energy in passenger cars is used to overcome friction in the engine, of which, for example, approximately 15 % is consumed in the valve train. Total friction losses could be reduced by taking advantage of new technologies such as surface modifications. The latter can, for instance, be done by applying micro-textures (Gachot et al. [2]) or amorphous carbon coatings (Donnet and Erdemir [3]) onto the rubbing surfaces of lubricated tribological contacts. Both approaches have been studied intensively in literature. For example Marian et al. [4], Tremmel et. al. [5] and Dobrenizki et al. [6] studied the fabrication and tribological performance of micro-textures and diamond-like carbon (DLC) coatings applied onto bucket tappets in the thermo-elastohydrodynamically lubricated (TEHL) cam/tappet contact. Although the basic idea of micro-texturing and applying DLC-coatings is very similar, i. e. to improve the energy efficiency of the tribological contact without affecting other components by, for example, design changes, the two approaches are often considered separately. In addition, many studies are limited to specific contact and lubrication conditions. However, dynamic conditions and thus different friction mechanisms are present in real applications.

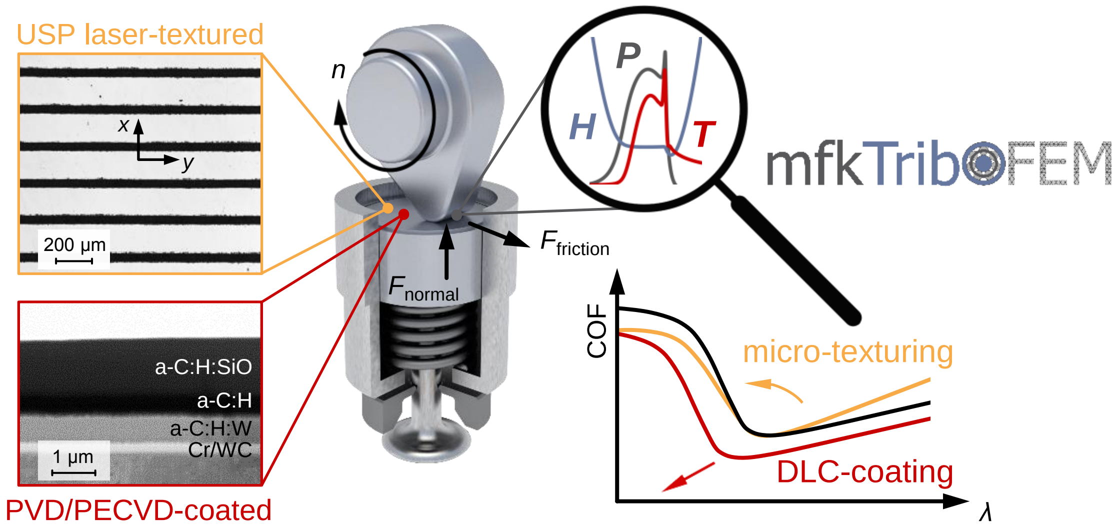

Figure 1: Numerical and experimental studies on the effects of micro-texturing and DLC-coating on the frictional behavior

MATERIALS AND METHODS

In this context, tribo-simulations offer the great potential to explore the effects of aforementioned surface modifications on the tribological performance and to facilitate design optimization while reducing time consuming and costly experimental work. To elucidate the underlying mechanisms during the contact of a cam and a micro-textured or DLC-coated bucket tappet, numerical TEHL simulations were performed. Therefore, a full-system finite element modelling (FEM) approach, as first presented by HABCHI [7], was employed. The calculation model is part of the computation software *mfkTriboFEM*. Further information about FEM of TEHL contacts [8], the implementation [9–11] as well as the consideration of micro-textures [4,12] and tribological coatings [13] can be found elsewhere. Input data, like material and fluid parameters, geometries and load cases, were chosen according to the setup of a component test-rig, on which experimental tests were carried out. Therefore, top adjusting shims (16MnCr5) of mechanical bucket tappets were either textured or coated. For texturing, ultrashort pulse Nd:YVO_4 laser ablation (35 µm width in and 2 mm perpendicular to direction of motion, 2 µm depth, 180 µm distance in and 1 mm perpendicular to direction of motion) was utilized. Furthermore, a silicon-doped amorphous carbon coating (Cr/WC/a-C:H:W/ a-C:H/a-C:H:SiO, 2 µm thick), was deposited by an industrial scale PVD/PECVD coating machine (H-O-T TT 300). The friction behavior of samples with surface modifications were compared to polished references. Tribological characterization was carried out on a single cam/single tappet test-rig utilizing series production valve train parts (valve, spring and 100Cr6 cam). For lubrication, pure mineral oil (FVA 3) was used and heated to 90 °C. The experimental procedure was orientated on MARIAN et al. [4], to which the interested reader is referred to for further information. Moreover, aforementioned surface modifications were characterized by laser scanning microscopy (LSM), focused ion beam (FIB) preparation and ball-on-disk tribometer-tests under dry conditions.

RESULTS AND DISCUSSION

TEHL tribo-simulations acted as a '*numerical zoom*' into the contact area and allowed the numerical prediction of the tribological behavior in terms of properties such as pressure, lubricant gap and temperature distribution as well as solid and fluid friction force in dependency of the load case and contact conditions. Within the scope of this contribution, it was shown that micro-texturing could reduce the fraction of solid friction. This can be explained by lubricant drawing out of the texture due to elastic deformation and velocity differences of the rubbing surfaces, which increased the viscosity and built an additional hydrodynamic pressure. However, this also meant an increase of the fraction of fluid friction. Thus, micro-texturing resembled a counterclockwise tilt of the STRIBECK curve. Contrary, tribological DLC-coatings could reduce solid and fluid friction in all lubrication regimes. This was due to a lower solid friction coefficient of the coated surface as well as the so-called thermal insulation effect. Thereby, the viscosity of the lubricant was reduced due to a temperature increase, which was the result of a lower thermal diffusivity of the coating. Thus, DLC-coating corresponded to a shift of the STRIBECK curve to the lower left. In general, the effects from micro-texturing and DLC-coating on the STRIBECK-curve were supported by performed one cam/one bucket tappet component tests. Moreover, aforementioned explanatory approaches were supplemented by lubrication conditions measurements [4] using an electrical resistivity circuit, ball-on-disk tests for the determination of the friction coefficients of polished and DLC-coated surfaces under dry conditions.

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