Influence of a single asperity on stresses during lubricated sliding contact on DLC-coated system

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1. Introduction

Extreme low wear rates of Diamond-Like Carbon (DLC) coatings are one the properties that makes them particularly interesting for numerous applications, like automotive ones. This property is often observed during characterisation tests under basic sollicitations like fretting, sliding, rolling-sliding, etc... However, tests on cam-tappet systems show the coating lifetime can be highly reduced under specific coupled conditions, such as the presence of an asperity breaking through the lubrication film into the contact area. Experimentally observed, its influence on surface and subsurface stresses has to be quantified to eventually obtain a predictive model of the coating lifetime. The purpose of this study is to develop a simplified numerical model consistent with elasto-hydrodynamic lubrication (EHD) approximations to estimate the stress perturbation due to such an asperity.

2. Coupled wear mechanisms

Contact kinematics of the cam-tappet system is a complex combinaison of impact loading, rolling-sliding and sliding contact under lubricated conditions, resulting in different sollicitations on the tappet surface. Observations on worn coated surfaces revealed six characteristic facies and hightlighted four wear mechanisms. The worst one, relative to coating delamination, was systematically found to initiate around circular scratch networks. It is then assumed that those two wear mechanisms are strongly coupled. Circular scratch networks may be created either by asperity existing on the initial cam surface, or by hard particules (coming from a highly contaminated lubricant) incrusted into the cam surface.

3. Single asperity contact

Regardless its source, it is necessary to assess the damage caused by such a defect on the coating lifetime. It has been shown that, under pure rolling conditions, DLC coatings are more sensitive to hard particules trapped into the contact than uncoated surfaces [1]. The numerical model on which the study is based on is however limited to 2D plain strain with no lubrication and no sliding.

Under sliding conditions, observations suggest the damage is similar to the one caused by scratch tests. The induced damage mechanism was highlighted by Holmberg [2], using both experimental and numerical results and focusing on local stress fields and first crack location.

Based on ongoing research and following the work of Hannes [3], a simplified 3D numerical model consistent with EHD lubrication approximations will be developped, using joint elements with defined compression and shear behavior to model the lubricant. It can estimate the load carried by an asperity as well as the induced perturbation on surface and subsurface stress. As a simplified model, it can be run quickly on multiples configurations. Analytical functions can then be fitted upon specific variables in order to be used as input datas in a more general iterative processus.

6. References

[1] F. He et al., "Wear properties of DLC-coated steel rollers running with highly contaminated lubrication", Tribology International, 43(5-6), 2010, 990–996.

[2] K. Holmberg et al., "Tribological analysis of fracture conditions in thin surface coatings by 3D FEM modelling and stress simulations", Tribology International, 38(11-12), 2006, 1035–1049.

[3] D. Hannes et al., "Rolling contact fatigue crack path prediction by the asperity point load mechanism", Engineering Fracture Mechanics, 78(17), 2011, 2848–2869.