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Experimental approach for investigating critical loading conditions leading to delamination of DLC coatings

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Diamond-Like Carbon (DLC) coatings protect surfaces from wear, however delamination is still a critical issue as observed in industrial applications. Tribometer experiments were carried out to isolate and determine the critical loading conditions, and due to application of a continuous wear measurement method the driving force for DLC delamination in the engine application was identified.

Keywords: Diamond-Like Carbon (DLC), Radio-Isotope Concentration (RIC) method, wear particles, delamination

1. Introduction

DLC coatings are engineered to prevent surfaces from wear and thus to extend the lifetime of engine parts and components. Nevertheless, delamination of the DLC coatings is sometimes observed from engine components without apparent reasons. To scientifically analyze the influence of extrinsic loading conditions on such a delamination process, we carried out detailed experiments at tribometer level [1].

2. Methods

Crucial parameters of influence are investigated in the style of a tribosystem analysis:

- A stress, that causes overloading of the interfaces, can often lead to delamination of the coating. Thus, this influence factor is investigated by different load levels during oscillating tests (UMT) with a ball against plate geometry.
- Additionally, also the influence of heat was investigated by a temperature variation between room temperature (RT) and 100 °C (which is a typical for such an industrial application).
- As a third main tribological parameter, critical friction conditions were simulated with a journal bearing tribometer by varying the relative velocity leading to boundary and mixed lubricated conditions.

The coating and substrate wear was measured continuously and in situ during all experiments using the Radio-Isotope Concentration (RIC) method [2].

3. Results and Discussion

The tribometer experiments revealed that the critical conditions for the DLC coating delamination are more severe than the engine components are exposed to during real applications. Consequently, other parameters need to be responsible for the sometimes observed delamination process. However, during different lubricating conditions (as obtained by velocity ramps, which simulate start-up movements, resulting in changes from boundary to mixed lubrication regimes) no delamination was observed during our experiments.

Luckily, during one experiment the moving sample was in contact with the stationary holder generating wear debris and particles. After this experiment, we observed that the DLC coating showed delamination, although the contact pressure was below the critical one. Based on this "failure"-experiment, we systematically studied the role of added abrasive particles (smaller than 1 μm) on wear and delamination of the DLC coatings (Figure 1).

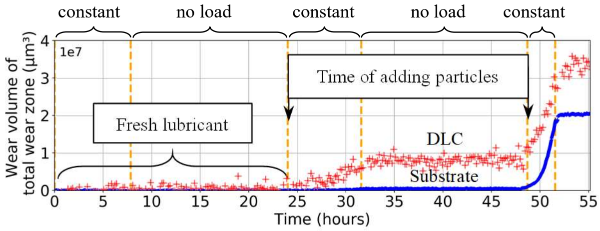

Figure 1: Example of a wear curve while adding particles to the lubricant during the experiments.

Additionally, wear of the co-activated substrate was measurable, which is a clear indication that the DLC coating is rubbed off at certain spots. This is confirmed by optical topography analyses of the wear zone (Figure 2).

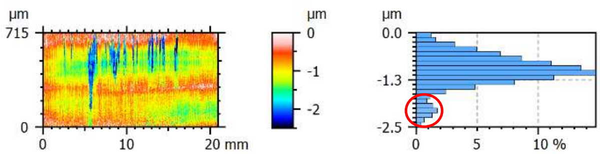

Figure 2: Example of a topographic image (left) and height distribution (right) of the wear zone.

4. Acknowledgments

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5. References

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