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Friction of component coatings in lubricated contact

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Abstract: The use of low friction wear resistant coatings for machine components is rapidly increasing. These components may operate in any lubrication regime, and less frequently even unlubricated. When run unlubricated it is easy to see the beneficial effect of a low friction coating. However, it has frequently been shown that the coating may also be very beneficial under boundary and mixed lubrication conditions.

The present digest briefly presents a few interesting aspects of the use of low friction coatings in lubricated contact illustrated by selected experimental results.

Keywords: friction, low-friction coatings, boundary lubrication, components

1. INTRODUCTION

The use of low friction wear resistant coatings for machine components is rapidly increasing. These components may operate in any lubrication regime, and less frequently even unlubricated. When run unlubricated it is easy to see the beneficial effect of a low friction coating. However, it has frequently been shown that the coating may also be very beneficial under boundary and mixed lubrication conditions [1].

This is explained by that also if normally separated by at least a boundary layer of lubricant molecules, both boundary lubricated and mixed lubricated conditions involve some direct contact between the mating surfaces.

This paper introduces and briefly discusses a number of key issues for lubricated components with low friction coatings. These issues include how and why the friction is modified, if one or both contacting surfaces should preferably be coated [2] and modifications to the running-in and tribofilm formation behaviour when using low friction coatings.

How and why is the friction modified?

Addition of a low friction coating on a boundary lubricated component surface may modify the friction by

- help reducing the friction between the spots of direct contact,
- produce a tribofilm on uncoated surfaces by transfer of coating material. This tribofilm may also promote friction reductions,
- reduce the wear of the coated parts
- facilitate efficient smoothening of uncoated parts
- influence the shape, number and size of the contact spots.

The latter four points may affect the time for running-in as well as the wear rate and the life time. Efficient smoothening and shape adaptation during running-in may shift the conditions from boundary to mixed regime, with substantial reduction of both friction level and wear rate.

2. EXPERIMENTAL

Boundary lubricated friction tests were performed in the Uppsala Load-Scanner in a configuration that involves two crossed, elongated cylinders (ø 10 mm), submerged in oil and forced to slide reciprocally against each other under a constant speed [3]. During forward sliding, the normal load gradually increases from a low to a high level, while it correspondingly decreases during the reversed sliding. A pure poly-alpha-olefin oil (PAO) PAO with a commercial sulfur-based EP additive of typical concentration (PAO+EP) was used as lubricant.

Tests were run with both steel cylinders coated (DLC/DLC), with one cylinder DLC-coated (DLC/steel), and a Steel/Steel combination as reference [4]. The coefficient of friction was monitored as a function of time and normal load. The DLC coating was a 2 μm, 1200 HV W-alloyed, hydrogenated diamond like carbon coating of Me-C:H type, produced by reactive sputtering at about 230 °C. The substrates and the uncoated bars were made of high-speed steel (0.9 C, 4 Cr, 5 Mo, 1.0 V, 2.0 W, 2.5wt% Co) hardened and tempered to 850 HV.

3. RESULTS AND DISCUSSION

Should one or both sides be coated?

From mapping of the friction coefficient versus number of test cycles and load it becomes clear that DLC coating facilitates running-in, see Fig. 1. For all three combinations, a friction level of 0.1 is gradually approached for increasing load and number of cycles. The DLC/Steel gave a low friction already from the first stroke, which then stayed on a low and smooth. level, see Fig. 1c. The reason is that the relatively hard DLC coating of the DLC/Steel combination effectively smoothens the surface of the steel counterface. With two wear resistant coatings run against each other (DLC/DLC), running-in takes longer and requires higher load, see Fig. 1b.

Modifications to the running-in and tribofilm formation behaviour

During the running-in phase, the friction of DLC/DLC and DLC/Steel falls from around 0.1 to close to 0.05 (after about 200 – 400 cycles), see Fig. 2. During these cycles, the surfaces are smoothened and tribofilms are forming on the steel surfaces, as evident from EDS analysis in the SEM. After about 5000 cycles the fritionc coefficient levels out at about 0.08 for all three material combiations. At this stage, EDS analysis shows that this coinsides with removal of the DLC coating by gradual wear.. Hence, also the DLC combinations approach the situatiuon of Steel/Steel.

Obviously, the sliding of tribofilm against DLCoccuring during the stage between running-in and wear through, gives a lower friction level than the tribofilm against tribofilm prevailing after this stage for the DLC combinations and all the test for the steel/steel combination.

No premature failure by fracture or fatigue of the coatings could be observed in any test.

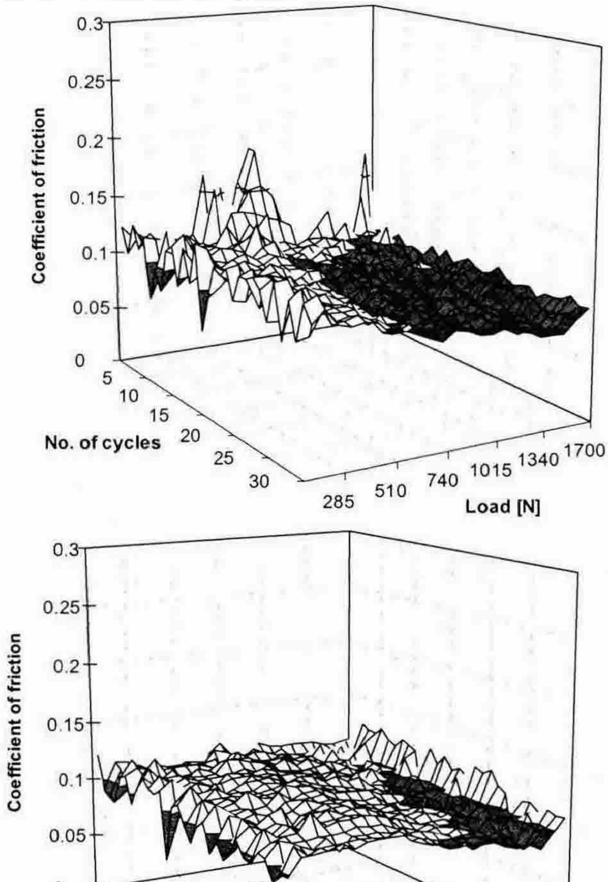

Fig. 1 Friction maps of the first 30 cycles of contact, lubricated with EP additivated PAO (μ levels < 0.1 shaded). a) Steel/steel, b) DLC / DLC, c) DLC coated steel / Steel.

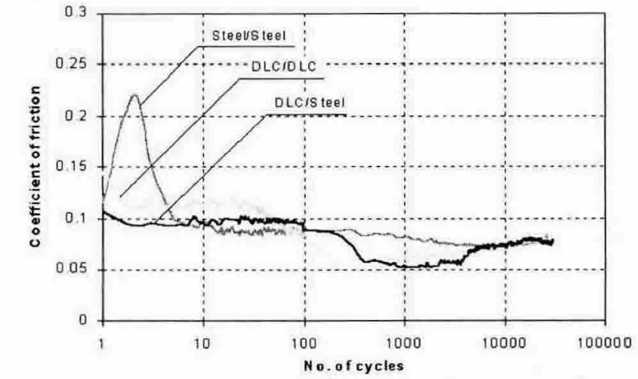

Fig. 2 Coefficient of friction at 700 N load for the first 20.000 cycles of contact, for the three material combinations lubricated by EP additivated PAO.

CONCLUSIONS

Low friction component coatings may be very beneficial for the friction behaviour also in boundary lubricated contact. The coating may facilitate a very rapid running-in, totally lacking high friction peaks.

DLC coating against uncoated steel seems to be more beneficial than coating both sides, due to more efficient running-in and a somewhat lower friction during the steady state at "mid-life".

During the boundary lubricated steady state the steel/DLC combination shows some 25% lower friction than the steel/steel combination

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REFERENCES

1. Jacobson, S. and Hogmark, S., On the tribological character of boundary lubricated DLC coated components, Proc. 28th Leeds-Lyon Symposium, 2001
2. Podgornik, B., Jacobson, S. and Hogmark, S., Advantages of DLC coating of one part, as compared to both or none in boundary lubricated steel components, Proc. Nordtrib 2002, Stockholm, Sweden, 2002
3. Hogmark, S., Jacobson, S. and Podgornik, B., Evaluation of surface treatment and coatings for mechanical components - Recent results from the Uppsala Load-Scanner, Proc. IRG-OECD, Coimbra, Spain, 2002
4. Podgornik, B., Jacobson, S. and Hogmark, S., Influence of EP and AW additives on the tribological behaviour of hard low friction coatings, Proc. ICMCTF, San Diego, USA, 2002