Thermal Damage in EHL Rolling/Sliding Contacts with Micro-Geometry

Guillermo E. Morales-Espejel[1,2)*

[1)]SKF Research and Technology Development, Houten, The Netherlands
[2)]Laboratory of Contacts and Structures Mechanics, INSA de Lyon, France.
*Corresponding author: guillermo.morales@skf.com

A previously developed model for heavily loaded Elastohydrodynamically lubricated (EHL) contacts with surface micro-geometry for the calculation of surface distress (micropitting), based on high-cycle fatigue and mild wear competition, is herewith further extended. It now includes the effects of frictional heating with a sharp temperature rise developed in the rolling contact. For this, a new surface damage model, based on the creep mechanism, is included.

Keywords (from 3 to 5 max): mixed-lubrication, flash temperatures, smearing, scuffing, creep

1. Introduction

Tribological processes involving thermal cyclic damage are, frictional heating, metal softening by bulk heating in the rolling contact. These phenomena happen in combination with rolling contact fatigue and mild wear and, all of them, enter in competition to determine the life expectancy of the rolling contact. Herewith, a temperature-driven, durability model based on the creep-damage accumulation on the contact surfaces is presented. The model is incorporated into the existing micropitting model [1], comprising surface fatigue and mild wear in mixed-lubrication conditions. The thermal damage model is compared with experimentally obtained failure cases in a tribometer. This, in turn, is used to explore the behaviour of thermal damage under different operating conditions and also to study the interaction between surface fatigue, mild wear and thermal damage.

2. Methods

To model thermal damage creep mechanism is used. One of the first damage models related to creep in metals is introduced by Kachanov and Rabotnov. Lemaitre and Desmorat [2] present a refined version and they call it the Kachanov law, describing the damage evolution in cyclic loading with creep, summarised in the following model for the damage (D).

2.1. Basic equation

$$D = 1 - \left[1 - \frac{2a(m+1)(\Delta T)^m N}{C^m U}\right]^{\frac{1}{m+1}} \qquad (1)$$

2.2. Ball-on-Disc Experimental validation
Ball-on-disc experiments were carried out with constant rolling speed and increasing sliding speed until failure. Table 3 shows the calculated results with the model.

Table 3. Calculated results for the ball-on-disc experiments.

No	h_c $[\mu m]$	p_h $[GPa]$	Λ [-]	Max. Temp. [^{0}C]	Result	Test
1	0.23	1.33	0.75	352	may fail	failed
2	0.21	1.91	0.70	385	failed	failed
3	0.024	1.91	0.080	390	failed	failed
4	0.027	1.33	0.088	320	non	non

2.3. Combination with the Micropitting Model
The above thermal damage model was combined with the previously developed micropitting model [1] in order to be able to model cases where there is a gradual passage from surface fatigue to actual seizure or massive adhesive wear like in the case of high speed rolling bearings. This allows engineers to calculate transition diagrams for mixed-EHL contacts.

2.4. Results
Figure 1 shows the calculated results for the case of a measured raceway bearing topography with Rq=23.8 nm. The figure shows the thermally damaged areas in combination with surface fatigue.

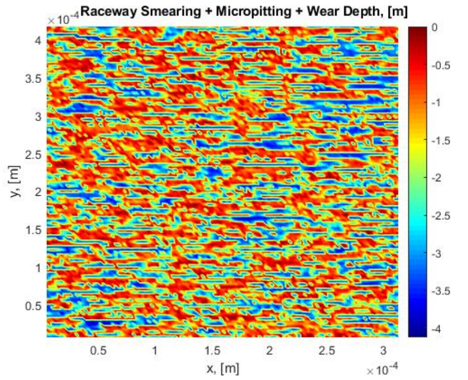

Figure 1: Bearing raceway calculated combined micropitting-smearing damage on the raceway (blue).

3. Discussion

A thermal damage model for tribological contacts has been presented. It is based on the use of creep theory combined with EHL. The model is adapted to be used in combination with a previously developed surface distress (or micropitting) damage model. The combined model can show the competition of thermal damage, surface fatigue and mild wear together

4. References

[1] Morales-Espejel G.E., Brizmer V. "Micropitting Modelling in Rolling–Sliding Contacts: Application to Rolling Bearings". Tribol Trans, vol. 54, 2011, pp. 625–643.

[2] Lemaitre, J., Desmorat, R., "Engineering Damage Mechanics", ISBN 3-540-21503-4 Springer Berlin Heidelberg New York. 2005.