PREDICTION MODEL OF SURFACE TOPOGRAPHY EVOLUTION DUE TO MICROPITTING

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ABSTRACT
Micropitting is often observed on hardened materials that are involved with rolling/sliding contact. Even though micropitting is not a catastrophic failure, it may lead to excessive wear or macroscopic pitting. Field experiences and lab testing results have demonstrated that micropitting has a strong correlation to surface topography. Surface asperity contact induces elevated stresses that in turn cause near surface material distress. In this study a micropitting prediction model, based on the contact stresses of rough surfaces, is proposed. Surface topography is modified due to micropitting. The modification of the surface topography causes a redistribution of the contact stresses. Consequently, the intervention between surface topography and the stress field may form a course of surface degradation, or the contact surface may reach steady state without generating any further micropits. The evolution of surface topography is demonstrated for different surface finishes. The comparative micropitting wear volumes and depths are summarized for these finishes.

ANALYTICAL MODEL
By identifying the stress field of contacting components, the prediction of micropitting occurrence and micropitting wear becomes possible. To accomplish this the following micropitting criterion, is proposed,

\[ \sigma_c \left( \gamma + \gamma_0 \right)^n \frac{H_0}{\gamma} > W_{cr} \]

where \( W_{cr} \) is a stress-based micropitting criterion; \( H_0 \) is the reference surface hardness; \( \gamma_0 \) is the reference slide-to-roll ratio; \( \gamma \) is the slide-to-roll ratio; \( m \), \( c \) and \( n \) are fitting factors that reflect degrees of the effects of the slide-to-roll ratio and the surface hardness on the micropitting occurrence, respectively; and \( \sigma_c \) is the Mises stress expressed as,

\[ \sigma_c = \frac{1}{3\sqrt{3}} \left( \sigma_x - \sigma_y \right)^2 + \left( \sigma_y - \sigma_z \right)^2 + \left( \sigma_z - \sigma_x \right)^2 + 6 \left( \tau_{xy}^2 + \tau_{yz}^2 + \tau_{zx}^2 \right) \]

The criterion is related to the microstructures of materials and lubricant additives. In this study, material yield strength at the asperity level is used as the micropitting criteria. The value on the left hand side is calculated and compared to \( W_{cr} \). If the value exceeds the micropitting threshold at a certain location, the material within its affected zone will be removed. After all layers in the subsurface are examined, a modified, new, surface will be used for the following round of calculations and rolling/sliding recommences until the micropitting criterion is not satisfied at all grid points. Consequently the wear history can be simulated.

NUMERICAL RESULTS
Three surface finishes - smooth ground (SG), intermediate ground (IG) and rough ground (RG) - were simulated. Figure 1 visually illustrates the surface evolutions due to micropitting on SG, IG and RG surfaces. It can be observed that the severity of
surface material loss increases from the SG surface to the RG surface. Figure 2 quantitatively shows the total accumulated wear volumes at the end of each surface evolution on SG, IG and RG surfaces. It may be concluded that the propagation of the wear on the SG surface is stabilized, whereas the wear continues to progress on the IG and RG surfaces. The predicted maximum wear depth and the total wear volume due to micropitting on SG, IG and RG surfaces is given in Figure 3. Moreover, FZG micropitting tests were conducted on the gears with SG, IG and RG surface finishes. Gear profiles were measured after 100-hour micropitting tests. The measured micropitting wear depths are listed in Table 1. The simulation results on the maximum wear depth and wear volume are also given in the table. Although the definitions of the wear depths for the measurements and for the simulations are different, it is evident that the model is able to determine the ranking of material loss due to micropitting.

**CONCLUSIONS**

Micropitting volume loss is directly related to initial surface finish, consequently it is related to contact stresses. By identifying the stress field, the micropitting model demonstrated the effect of initial surface roughness on surface evolutions and predicted material volume loss and micropitting wear depth.

**REFERENCES**

