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Role of Tribofilm Formation derived from Automobile Transmission Fluids in Improving Gear Fatigue Life

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This study intends to clarify the effect of lubricant viscosity and additive applied to automobile transmission fluids on the gear fatigue life by using a FZG test rig and some surface analyses. As a result, lubricant additive such as extreme pressure agent could give a significant impact on the pitting life in addition to viscosity. The failure mode on the gear flunk observed in this study may be caused by a surface originated rolling fatigue. Thicker tribifilm formed in the interfaces could play a role in minimizing abrasion and adhesion wear, consequently, with a longer gear fatigue life.

Keywords (from 3 to 5 max): lubricants, gear fatigue life, tribofilm, micropitting

1. Introduction

Technologies to increase the efficiency of automobile engines and transmissions are being developed. Hybrid Electric Vehicles (HEVs) and Electric Vehicles (EVs), which provide excellent fuel economy and reduced carbon dioxide emission, are recently increasing. Various manufactures have a variety of specifications for HEV transmissions, with, for example, step type automatic transmissions (ATs) or only transmission gears. In some cases of HEVs/EVs transmissions, the motor, shifting clutches, reduced gear and bearings may be integrated, at present, lubricants for transmissions such as automatic transmission fluids (ATFs) are used as transaxle fluids. Applying a transmission fluid with lower viscosity to gearbox would potentially give an advantage for better efficiency. However, it is necessary to carefully consider a negative impact on the gear components durability. This implies that the role of lubricant additives would be more important for improving lubricity. In this study, we investigated the effects of extreme pressure additive (EP additive) on the gear fatigue life performance.

2. Methods

The gear pitting fatigue life by lubricants was evaluated by using a FZG (Forshungsstelle fur Zahnrader and Getriebebau) gear test rig [1]. Gear type C with a specified surface roughness are run at a pitch line of 8.3 m/s speed in torque stage 302 and 372 Nm at 90 °C oil temperature. The pitting life is defined as the number of load cycles when the area of the mostly damaged gear flunk exceeds about 5 mm^2. The test lubricants were prepared by blending a hydro-cracked mineral base stock and some kinds of additives. Two types of phosphorus based extreme pressure agent was tested. Some surface analyses such as a laser microscope, electron probe microscope (EPMA) and focused ion beam transparent microscope (FIB-TEM) was used gain an insight into the gear fatigue life and tribofilm characterization.

3. Results and discussion

First, the lubricants viscosity on the gear fatigue life was examined, varying viscosity from 3 to 7 mm^2/s at 100 °C oil temperature. Apparently, the gear fatigue life decreased with lowering viscosity, in proportion to the $viscosity^{-0.7}$. This result could be influenced by the difference in the oil film thickness calculated under EHD condition. As to impact of additive, the test sample A containing a sort of phosphorus additive demonstrated more than twice longer life than those of the test sample B with another type phosphorus additive. In all cases of test gears, a significant micropitting was observed in the pinion tooth dedendum[2-3]. These pits propagated to macropitting with a surface originated fatigue mode. Very interestingly, the cross section in the gear interface observed by FIB-TEM in case of the longer life sample revealed that tribofilm composed of calcium and phosphorus species was uniformly formed with 100-200 nm thickness. This thicker tribofilm could minimize abrasion and adhesion in the contact regions below the pitch line on the pinion gear to prevent from strain localization to generating micropitting, consequently with a longer fatigue life. Tribofilm could play a role as a cushion in the contact interfaces, leading to improving fatigue life.

4. References

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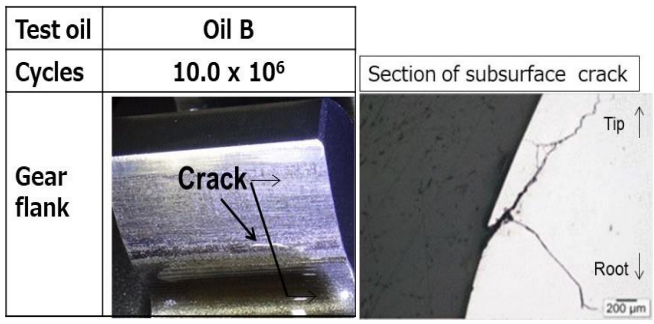

Figure 1: Fatigue failure mode observed at FZG 10 million cycles with oil B.