INFLUENCE OF MATERIAL PROPERTY ON MICROPITTING AND PITTING BEHAVIOR

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ABSTRACT
Recent studies have shown that micropitting initiated pitting appears to be the dominant metal fatigue mode in modern bearings and gears. If the formation of micropits can be controlled, the fatigue life of the bearings and gears can be readily lengthened, so the useful life of the engine or transmission can be radically extended. The lack of in-depth understanding of micropitting initiation mechanism hinders progress to control the micropitting-initiated pitting failure mode. In this study, we explore the initial stages of micropitting in relation to material differences that impact the crack propagation process. To investigate these mechanisms, we study micropitting and subsequent pitting using pinion and wheel pairs made from two different carburized steels, SAE 8620 and SAE 4027, in a 91.5mm helical back-to-back gear test rig using a typical transmission fluid. For comparison, a similar study is being carried out with the pinion and wheel pairs made from the same SAE 8620 steel. The preliminary results show that steel material differences may change the ultimate pitting fatigue life but may not significantly influence the micropit formation process and subsequent pitting failure mode.

INTRODUCTION
With the increasing use of clean steels in the modern bearing and gear industry, contact fatigue in the form of pitting initiated at subsurface oxide inclusions now rarely occurs. Instead, pitting initiated from surface micropitting has become more prevalent [1-4]. As a result, there is a greater need to study the mechanism by which micropits are created and how they lead ultimately to the formation of larger and more detrimental pits.

A large number of studies have already been carried out to investigate micropitting development on gears although there is still lack of understanding of the phenomena needed to produce its initiation [5]. In many studies, the focus has been on the impact of operating variables, such as material and lubricant on the generation of micropitting, but little has been done to understand the mechanism of initiation. Recent work at University of Newcastle has shown that near surface microstructural changes can be linked to the onset of micropitting [6]. This effort suggests that a better understanding of these mechanisms may be instrumental in controlling this mode of failure. The current work explores the initial stages of micropitting in relation to material differences that control crack propagation processes. To investigate these mechanisms, we are studying micropitting, and subsequent pitting, using pinion and wheel pairs made from two different carburized steels, SAE 8620 and SAE 4027, in a 91.5mm helical back-to-back gear test rig using a typical transmission fluid. As a baseline for comparison, we are also conducting a similar test on pinion and wheel pairs made from the same steel material. In both cases, helical gears are used. Combining these gear sets with a practical load and speed, we simulate fatigue failure mode experienced in the real world.

EXPERIMENTAL
Several sets of helical type pinion and wheel pairs are made from SAE 8620 and SAE 4027 steels, respectively. The center-to-center distance is 91.5mm. The pinions are hardened by a carburizing and heat treatment process followed by shot peening with glass beads and steel beads. The wheel (driven) gears are hardened by a similar carburizing and heat treatment process except only shot peened by glass beads. The pinion and wheel gears have the same case hardness and approximately equal case depth of about 0.85 mm. They have a comparable Ra value of 0.5 micron. The only difference is in the maximum residual stress; the values for pinion and wheel gear are 1,100 and 850 MPa, respectively. The sets of pinion and wheel gears
made from the same SAE 8620 steel have comparable physical parameters as the corresponding pinion and wheel gear pairs made from different steels.

The load and speed used for the micropitting test are 1,000 Nm and 650 rpm, respectively. Both the pinion and wheel gear are checked every 24 hours for micropitting. A test is stopped when pits form across an area greater than 4% of any single tooth flank. The tested pinion and wheel gears are then sectioned to determine the microcrack propagation process using SEM analysis.

RESULTS

Tests have been carried out on SAE 8620 and SAE 4027 steels. The gears have failed consistently via macropitting initiated from micropitting development. Figure 1 shows an example of a tested gear pair where final tooth breakage from macropitting has occurred. The higher magnification images show micropitting on both the pinion and wheel.

In order to understand the development of micropitting, sections through gear teeth are examined to identify microstructural changes in the regions of micropitting. Figure 2 compares micrographs of unmodified (original) and modified microstructures [6]. Figure 2b shows crack initiation resulting from micropitting. This crack is associated with near surface microstructural changes resembling those seen in an over-tempered microstructure. Work is on going to understand these changes, but the current work does show that an understanding of changes of this type may lead to a greater ability to control and prevent the onset of this form of damage.

The final paper will present full findings comparing the different test combinations and will aim to characterise these microstructural changes in more detail.

![Figure 1](image1)

![Figure 2](image2)

Figure 1. (a) Macropitting and tooth breakage on tested gear pair, (b) and (c) micropitting on pinion and wheel (bars are 200 microns long).

Figure 2. Micrographs of tooth cross-sections showing unmodified microstructure (a) and modified microstructure (b) associated with surface initiated fatigue crack.

REFERENCES