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Micro-pitting and wear assessment of engine oils operating under boundary lubrication conditions

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ABSTRACT:
Current state-of-the-art engine oils tend to enhance micro-pitting damage in rolling contacts under certain operating conditions. ZDDP anti-wear additive was shown to promote such behavior. However, in order to optimize an engine oil formulation for rolling contacts, further studies are needed to assess engine oils in terms of micro-pitting and wear damage. This investigation studies the micro-pitting and wear performance of a number of engine oils for rolling contacts in a ball-on-disc configuration under conditions prevalent in crankshaft roller bearing applications. Based on the results it was concluded that an engine oil containing higher blend of PAO base oil compared to the oil mixture of Group III and PAO has a lower tendency towards micro-pitting and wear.

KEY WORDS:
Micro-pitting; ZDDP; Mild Wear; Rolling contact

1 Introduction

The automotive industry is continuously forced to improve internal combustion engines (ICEs) and develop low cost, low emission solutions in order to meet the demanding CO_2 regulations. One such improvement is to reduce the friction losses that arise in ICEs. For example, in passenger cars around one third of the fuel energy is wasted in overcoming friction losses [1]. Around 12% fuel energy is lost in the actual engine due to friction. Currently, the majority of ICEs employ crankshaft journal bearings due to their straight forward assembly in split pairs, better reliability and low cost production. By switching to roller crankshaft bearings, the engine efficiency improvement has been shown to be up to 5%, [2–4]. However, several challenges have to be addressed before successful replacement of journal bearings with roller bearings for crankshaft production engines.

One such challenge is the smooth and durable operation of rolling elements together with a low viscosity engine oil. Baubet et al. [2] showed the likely failure modes of crankshaft roller bearings lubricated with current state-of-the-art low viscosity engine oils, where micro-pitting and polishing wear presented the failure mode of rollers lubricated with fully formulated engine oil. In addition, pitting and wear were identified as likely failure modes when lubricated with a pure base oil only. It was concluded that engine oils tend to promote the formation of micro-pitting on the rolling contact surfaces due to the action of ZDDP additives. This anti-wear additive is beneficial for tribology of sliding contacts but detrimental for rolling contacts [2].

Benyajati and Olver [5] experimentally showed that the ZDDP additive protects rolling surfaces from wear and promotes micro-pitting formation. The mechanism was explained to be the action of ZDDP additives forming a protective reaction layer on the interacting