In-Situ Lubricant Film Thickness Measurements of I.C.E. Big-End and Main Bearings – WTC 2021, Lyon

Andy Hunter [1)*], Henry Brunskill [1)], Nam Ho Sung [2)], Junsik Park [2)], Rob Dwyer-Joyce [3)]

[1)]Peak to Peak Measurement Solutions Ltd., Sheffield, UK
[2)]Hyundai Motor Company, Seoul, S. Korea
[3)]Leonardo Centre for Tribology, University of Sheffield, Sheffield, UK
[*]Corresponding author: andy@pktopk.co.uk

In this work micro active ultrasonic sensors have been embedded into a four-cylinder diesel engine, which was then tested across a range of speeds and loads with different lubricant viscosities. These sensors yielded measurements of the lubricant film thickness, from which the bearing power losses were calculated, in the con-rod big end and crankshaft main bearings.

Keywords: I.C.E's, hydrodynamic bearings**,** lubricant film thickness, ultrasound

1. Introduction

Stricter emission standards have increased pressure on automotive manufacturers to reduce CO_2 emissions. One approach to meeting these requirements has been to reduce the viscosity of the engine lubricants used, this reduces engine losses thereby decreasing emissions. However, reducing the lubricant viscosity risks the lubricant films in the engine hydrodynamic bearings, such as those on the crankshaft, breaking down. This can lead to damage and in the extreme, engine failure. To understand the effectiveness of less viscous lubricants, this work measures the lubricant films within the crankshaft bearings of a four-cylinder diesel engine in-situ during a dyno test across a range of speeds and loads for different viscosity lubricants. The results have been compared to simulations of the same system.

2. Methods

Ultrasonic sensors were embedded within the engine components and used to generate an acoustic wave that reflected from the bearing lubricant layer. The amplitude of the reflected wave is proportional to the layer stiffness which can be linked to layer thickness via the following model [1]:

$$h = \frac{2\rho c^2}{\omega z}\sqrt{\frac{|R|^2}{1-|R|^2}} \qquad (1)$$

Where h is the film thickness, ρ and c are the density and acoustic velocity of the lubricant, ω is the ultrasonic wave frequency, z is the bearing acoustic impedance and R is the reflection coefficient. This was used for minimum film thickness measurements, and additional resonance techniques [2] were also used to yield the lubricant film thickness around the circumference of the big-end bearing. In addition, a newer method is also being trialed which can measure in-situ fluid viscosity.

2.1. Instrumentation

The ultrasonic sensors were installed on the rear face of two main bearing shells and inside a crankshaft big-end pin. The crankshaft mounted sensors rotated with the shaft drawing a full profile of the lubricant film around the bearing circumference with each revolution.

2.2 Results

Minimum main bearing thicknesses in the order 0.3 to 0.8µm were measured and the big end bearing film thicknesses varied up to ~100µm, consistent with bearing clearance. From the film thickness and a calculated lubricant viscosity the power losses in the big-end bearing during combustion where calculated for different lubricants, and example of this is shown in Figure 1.

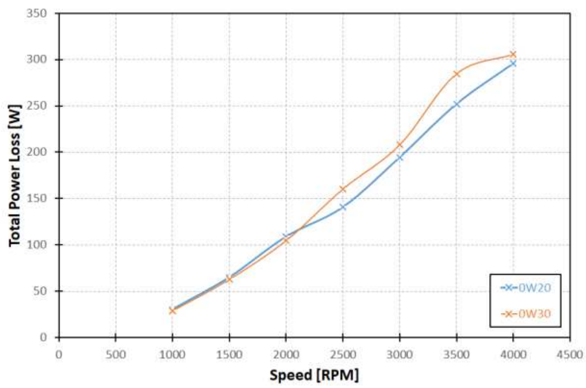

Figure 1: Estimated power loss in the con-rod big end bearing

3. Discussion

The ultrasonic lubricant film thickness measurement method has been successfully demonstrated in automotive engine main and big end bearings. The results consistently showed that lower viscosity oils reported thinner films and reduced total power loss, proving that viscosity reduction is one viable approach to work towards meeting the new regulatory standards.

4. References

[1] Dwyer-Joyce R. S. et al. "The measurement of lubricant–film thickness using ultrasound". Proc. R. Soc. Lond. 2003, 459957–976.

[2] Beamish, S. L. et al., "Circumferential film thickness measurement in journal bearings via the ultrasonic technique" Tribology International, 148, 2020.