7th World Tribology Congress, WTC 2022
July 10-15, 2022, Lyon, France

In-Situ Measurement of the Oil Film Meniscus at the Entry and Exit of a Rolling Bearing Contact

W. Gray and R.S Dwyer-Joyce

[1)]The Leonardo Centre for Tribology, The University of Sheffield, Sheffield, United Kingdom, S32 3ZA

Rolling element bearings are essential components in many items of machinery and their failure prevention is important for prolonging life and avoiding costly downtime. The thickness of the lubricant film and the distribution of oil around the bearing is important as this determines the separation of the contact and required surface roughness. This study uses ultrasonic sensors on a full-scale wind turbine gearbox bearing test rig to assess the film thickness at various locations around the bearing. It proved possible to measure the oil film in the contact entry and exit meniscus regions.

Keywords: bearing, elastrohydrodynamic, lubrication, meniscus, ultrasound

1. Introduction

Elastrohydrodynamic lubrication (EHL) is an essential mode of lubrication to reduce surface contact and wear in the non-conformal contacts that are found in rolling bearings. The loss of a lubricant film can lead to premature failure of components, such as wind turbine gearbox bearings (WTGBs). The measurement challenge is that the oil films are very thin, occur over a small region, and are hidden inside the working component. Measurements from the contact are difficult because the spatial resolution of the sensors is greater than the contact width, and this effectively blurs the results. Measurements of the free surface film away from the contact can be performed when the oil film thickness is within a certain range such that it causes a resonance of the incident sound wave. This study aims to use ultrasonic sensors to measure meniscus development and film thickness within an EHL contact.

2. Methods & Results

A full-scale rig housing WTGBs representative of those used in a 2.5-3MW wind turbine was instrumented. Bare piezoelectric elements were used for minimum rig modification. Recordings are of the contact between the inner raceway and rollers, using different frequency sensors along the axis of the bearing. The rig was operated using different viscosity oils with varying loads and revolution speeds.

2.1. Minimum Reflection Coefficient

As an ultrasonic wave propagates through a material and hits a boundary, a portion of the wave is transmitted and the remainder is reflected. The ratio of the reflected wave amplitude to the incident wave is known as the reflection coefficient, *R*. The magnitude of R depends on the acoustic mismatch between the materials either side of the interface. *R* varies from 0 for two perfectly bonded identical materials to 1 for a steel air interface. Where the roller passes directly over the sensor location, a minimum reflection coefficient (MRC) is observed. A very thin oil film or solid contact will lead to a low value of the MRC. In these experiments, mean MRC values for every roller pass were compared for different testing parameters. Figure 1a shows the value of *R* as four rollers pass over the sensor location. A roller pass causes *R* to drop to around 0.4. In-between the rollers a distinct pattern of reflection is observed (i.e. *R* does not fully return to 1) indicating there is lubricant present. This is best observed in the signal frequency domain.

2.2. Meniscus Spectrogram

Each sensor possesses a bandwidth of frequencies; in the case here between around 4 and 15MHz. The lubricant layers will resonate at a frequency where the film thickness corresponds to multiples of ¼ of the sound wavelength. Figure 1b shows a spectrogram of the same four passes of a rolling element; in this plot the ultrasonic frequencies that correspond to reduced reflection are seen as dark regions.

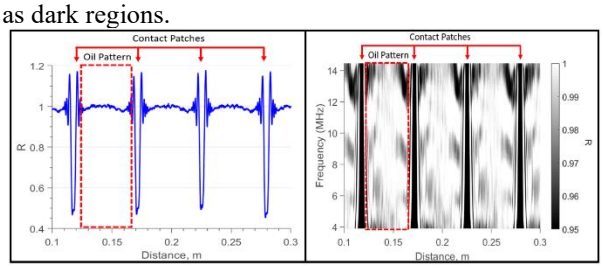

Figure 1: Contact patch and meniscus formation shown through both analysis processes.

Figure 2 is a zoom around a single roller pass. Horizontal fringes can be observed – this is where a certain frequency has caused resonance and hence corresponds to a quarter wavelength. The measured film thickness is shown on the plot.

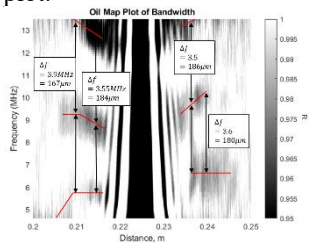

Figure 2: A single roller pass showing meniscus film thickness at entry and exit

3. References

[1] Dwyer-Joyce, et al., "The measurement of lubricant- Film thickness using ultrasound," *Proc. R. Soc.* 459, no. 2032, pp. 957–976, 2003.