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FILM THICKNESS IN A GREASE LUBRICATED BALL BEARING

CATEGORY: GREASE

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INTRODUCTION

For a grease lubricated bearing, the film thickness between the rolling elements and raceway plays a key role in determining the bearing life: a very thin film will result in direct contact, wear, surface damage and will reduce the life of the bearing. By now, many numerical and experimental studies have been carried out on the grease film thickness using a ball-on-disc configuration [1]. However, the single contact test configuration does not properly simulate a bearing in which the working conditions of the grease are very different. After all, grease lubrication is dominated by starvation, which is determined by a complex feed and loss mechanism. This is strongly determined by the internal geometry of the bearing. Therefore, in addition to single contact measurements, it is most valuable to study the grease film thickness in a full bearing directly.

In this work, the film thickness of an axially loaded deep groove ball bearing lubricated by various greases will be described and analyzed. The results were obtained using an in-house made bearing film thickness measuring rig based on the capacitance method [2]. A dynamic film thickness profile was observed, which deviates from the fully flooded Elasto Hydrodynamic Lubrication (EHL) film thickness calculated using the Hamrock and Dowson equation [3].

GREASE FILM THICKNESS MEASUREMENT

Figure 1 shows the schematic drawing of the main part of the bearing film thickness measuring rig. After 30% of the free volume was filled with the grease sample, the tested bearing (SKF 6209/C3) was closed by shields and mounted into the bearing case which was then assembled onto the frame. The tested bearing was axially loaded by an air spring ($\frac{C}{P} = 40$) and driven via a shaft (supported by a tapered roller bearing) by an electric motor (not shown) through a magnetic coupling, giving a medium running speed range (Ndm=162500 mm/min). The grease film thickness was obtained using Lubcheck Mk3 [4] and calibrated using bled oil [5]. The self-induced running temperature was collected by a thermocouple attached to the bearing outer ring.

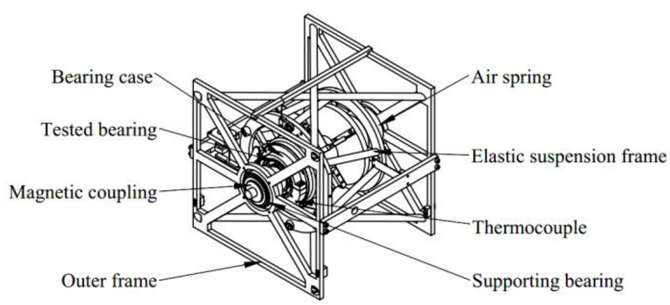

Figure 1 Bearing film thickness mearing rig

GREASE FILM THICKNESS PROFILE

The 100 hours grease film thickness profiles h_{grease} (in μm) for polyurea based grease with ester as base oil (denoted as PU/E) and calcium sulphonate complex grease with mineral oil as base oil (denoted as CaS/M) are plotted on logarithm time scale (in $hours$) in Figure *2*. Also plotted is the calculated EHL bled oil film thickness h_{oil} (in μm) at the bearing temperature $T_{bearing}$ (in ℃).

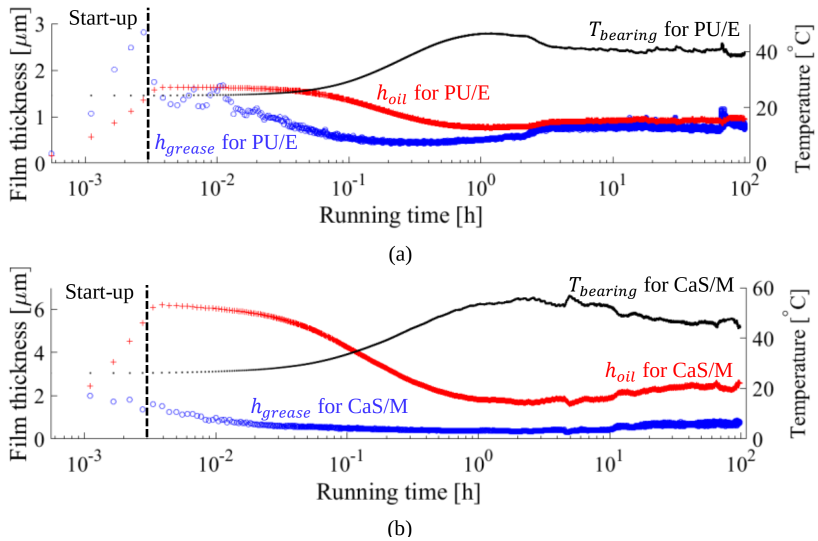

Figure 2 100h grease film thickness profile for (a)PU/E, (b)CaS/M

After starting up, for PU/E, a fully flooded condition takes place ($h_{grease} > h_{oil}$), because there is sufficient grease at the contact inlet and grease is functioning as the lubricant directly. Afterwards, h_{grease} decreases rapidly due to grease channeling and a rising temperature. In the meantime, the grease reservoir starts releasing oil, which is promoted by the increasing temperature and grease shear degradation [6]. This leads to a considerable film thickness recovery up to a relatively stable value, where a lubricant feed-and-loss balance is reached. Some film thickness fluctuations can be observed in this stable stage, which is ascribed to the incidental release of grease lumps, falling into the contact area because of vibration, creeping, cage scraping, etc. Similar grease film profiles were also observed for lithium and lithium complex thickened greases.
As for CaS/M, starvation takes place throughout the test. This is attributed to the high grease yield stress and low bleeding rate (at these low temperatures), which limits the lubricant feed to the contacts. As a mechanical stable grease [7], shear did not change the grease properties and no significant grease film thickness recovery can be observed.

IMPACT OF GREASE SHEAR DEGRADATION

As mentioned above, grease shear degradation is considered to contribute to the grease film thickness recovery of PU/E. To explore this further, the impact of grease shear degradation on film thickness was studied. PU/E was sheared in an in-house made Couette Aging machine [8], covering a full aging spectrum reflected by a decreasing yield stress (measured using Oscillatory Strain Sweep tests [9]) and an increasing grease bleed (measured using the SKF Grease Test Kit [10]).

As shown in Figure 3-a and Figure 3-b, the PU/E film thickness increases with aging and counteracts the effect of starvation (the grease film thickness h is higher than the EHL h_{oil}). The decrease of yield stress and increase of grease bleed is caused by the disruption of the grease micro-structure [11], which promotes more grease migration and replenishment. In addition, the size of the thickener fibers is reduced by aging, which also increases the film thickness [12]. However, grease shear degradation also softens the grease resulting in leakage (Figure 3-c). This will ultimately lead to a drain of the grease reservoir. It is thus expected that the grease film thickness will drop again after long running times (compared to the current 100 hours running).

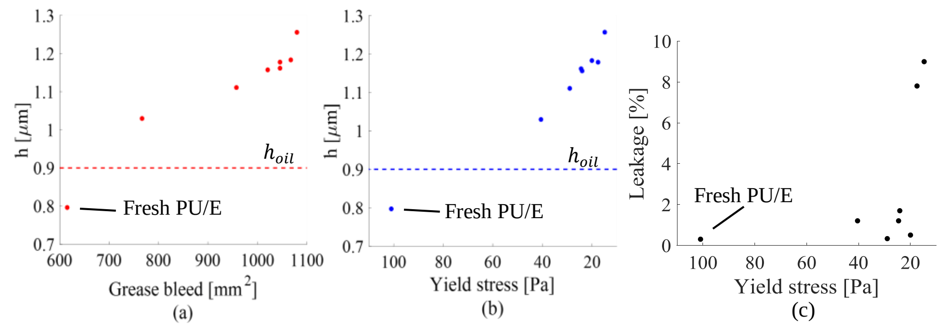

Figure 3 Bearing test results for fresh/aged PU/E: (a)h vs grease bleed; (b)h vs yield stress; (c)bearing leakage vs yield stress

CONCLUSION

This work presents an experimental study of the grease film thickness inside an axially loaded rolling bearing. The film thickness shows a dynamic behavior: a thick film after starting up, followed by a rapid decreasing film thickness due to starvation and an increasing temperature. For shear-sensitive greases (polyurea, lithium, lithium complex thickened greases), a predominant film thickness recovery takes place, indicating that grease shear degradation may be positive from a starvation point of view. Mechanical stable greases (calcium sulphonate complex thickened greases) provide a relatively constant film thickness dominated by starvation throughout the running time.

ACKNOWLEDGMENTS

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KEYWORDS
EHL with greases, greases, ball bearings