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Research Article

Experimental Investigations on Effectiveness of Axial and Circumferential Grooves in Minimizing Wear of Journal Bearing Operating in Mixed Lubrication Regime

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Abstract

In the present work, experimental investigations have been conducted to determine the effectiveness of providing axial and circumferential grooves in minimizing wear of journal bearing operating in mixed lubrication regime. Three bearings, with axial, circumferential and combined axial and circumferential grooves were fabricated for testing on a journal bearing test setup. Suitable running-in of the bearings was conducted before the normal wear test to achieve distinct bearing performance measured in terms of its weight loss. The bearing was operated in mixed lubrication regime by a proper combination of load and speed. Based on the experimental results a grooving arrangement that minimized the bearing wear is recommended.

***Keywords**: Journal Bearing, Mixed Lubrication, Wear, Axial Groove, Circumferential Groove, Combined axial and circumferential groove*

1. Introduction

The operation of journal bearing in mixed lubrication regime is generally avoided but there are many applications (S M Muzakkir, Hirani, Thakre, & Tyagi, 2011) where heavy load and slow speed always causes the bearing to operate in mixed lubrication regime. The contact between the interacting surfaces under these conditions causes wear. The minimization of the wear of such bearing by using axial and circumferential grooves is the focus of the present research work. On the review of literature it was identified that many novel methods to either completely eliminate or minimize the wear were proposed and implemented. The concept of levitating the journal from the bearing was proposed (Hirani & Samanta, 2007) and its feasibility was determined. The concept of hybridization of passive magnetic levitation and hydrodynamic lubrication was investigated experimentally but was not found to be suitable for bearing operating under heavy load and slow speed conditions (S.M. Muzakkir, Lijesh, & Hirani, 2014). The active magnetic bearing technology(Chittlangia, Lijesh, Akash, & Hirani, 2014; K P Lijesh & Hirani, 2015b), even though successful in levitating the journal, is much costlier to implement (Shankar, Sandeep, & Hirani, 2006) and so also other hybrid technologies that were not suitable for heavy loaded journal bearings (Samanta & Hirani, 2008). The passive magnetic bearing is also an alternative solution for levitating the journal from the bearing surface(K P Lijesh & Hirani, 2015a; K. P. Lijesh & Hirani, 2009; Samanta, P Hirani, 2007). The other alternatives included the use of suitable lubricant additives for minimizing wear (S M Muzakkir & Hirani, 2014; S. M. Muzakkir, Hirani, & Thakre, 2013). The journal bearing with an axial groove on the bearing allows proper distribution of lubricant thereby preventing lubricant thinning and improving the load carrying capacity (Khonsari & Booser, 2001). Costa *et al* (Costa & Claro, 2000) experimented with two arrangements of axial grooves located at +30° (in the convergent film zone) and at -30° (in the divergent film zone). As per Costa *et al* placement of axial groove in convergent region is preferable over location of axial groove in divergent region. Based on full film lubrication theory accounting cavitations, Vijayaraghavan *et al.* (Vijayaraghavan & Keith, 1992) recommended placement of groove in divergent region. Ahmad *et al* (Ahmad, Kasolang, & Dwyer-Joyce, 2014) conducted experimental studies and showed that different oil groove locations tend to affect the pressure profile in journal bearing lubrication. It was shown experimentally that pressure profile varied significantly by changing the groove location from 0° to 45°. It was also shown that the pressure profile in the converging region before the

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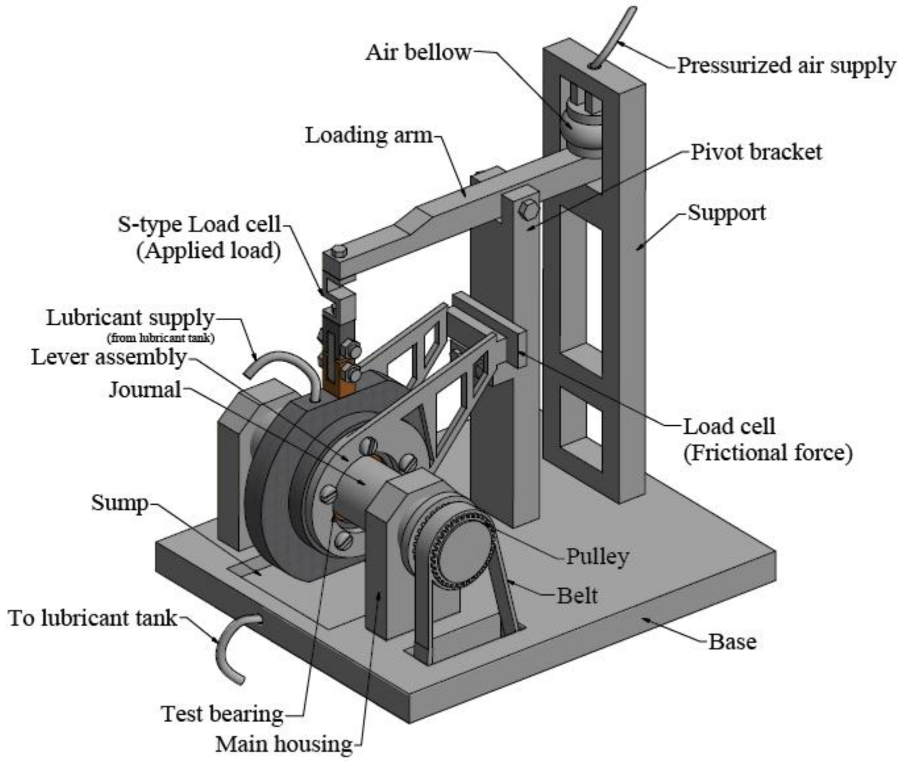

Figure 1 Schematic diagram of Journal bearing experimental test set-up (S. M. Muzakkir *et al*., 2014)

minimum film thickness is the lowest at 30° oil groove position for all cases. Theoretical study by Wang *et al* (Wang & Khonsari, 2008) suggested that the cavitations region extents to a larger portion of the journal surface with increasing the oil inlet position from 0° to 90°, which means groove must be placed in divergent region. These contradictory observations by different researchers make it difficult to design axial groove arrangement in journal bearing. Singh *et al* (Singh, Roy, & Sahu, 2008) recommended a groove length equal to half of the bearing length, while Costa *et al* (Costa, Miranda, Fillon, & Claro, 2003) preferred longer (80% of bearing length) over shorter axial groove (50% of bearing length). Brito *et al* (Brito, Miranda, Claro, & Fillon, 2012) has experimentally investigated that under heavy loaded operation, two-groove arrangement deteriorate the bearing performance as compared with a single groove. Theoretical study by Hirani and Rao (Hirani & Rao, 2003) using genetic algorithm for determining the optimum location of groove, its configuration and oil feed pressure using mass-conserving algorithm emphasized that the optimum groove location depends on the journal speed and loading conditions of the journal bearing.

The experimental studies by Zhang *et al* (Zhang, Tang, & Filc, 2002) showed that the axial grooves acts as sink in accumulating wear debris thereby providing lubricant without worn out particles and contributing in wear reduction. From literature survey, it can be inferred that under mixed lubrication regime, groove arrangement is meant to control friction as well as wear of the bearing surface. The main purpose of providing grooves is to ensure sufficient lubricant supply at the contact zone so as to reduce wear. Three journal bearings consisting of only axial groove, only circumferential groove, and combined axial and circumferential groove were fabricated for conducting wear tests. The wear tests were conducted after suitable running-in (S. M. Muzakkir, Lijesh, Hirani, & Thakre, 2014) of the new bearings on a journal bearing test set-up. A load and speed combination that causes the bearing operation in the mixed lubrication regime was used. The wear of the bearing was measured as its weight loss after the test.

The experimental results were analyzed and a grooving arrangement that was able to reduce the wear of the bearing to the minimum was identified.

2. Experimental Details

In the present work experiments are carried out on a journal bearing test set-up. The complete description of the journal bearing experimental test set-up is given in (S. M. Muzakkir *et al*., 2014). The schematic diagram is shown in figure 1.

The load ranging from 10 N to 10,000 N may be applied using the pressurized air bellows by the help of a loading arm. A load cell is attached to the loading arm to measure the applied load. The journal is connected to the motor by the help of a belt drive. A load cell is used to measure the frictional force. A continuous supply of the lubricant is ensured by a pump at a controlled temperature(S. M. Muzakkir *et al*., 2014). The phosphorus bronze bearings with diameter of 50mm and length 25mm, having different grooving arrangements were fabricated for testing as per the following details:

1. Bearing without groove (with only oil hole)
2. Bearing with only axial groove (along 80% of bearing length)
3. Bearing with only circumferential groove (extending till 90° along the circumference)
4. Bearing with both axial (along 80% of bearing length) and circumferential groove (extending till 90° along the circumference)

The photographs of these fabricated bearings are shown in figure 2 to 5.

Figure 2 Bearing without groove

Figure 3 Bearing with only axial groove

Figure 4 Bearing with only circumferential groove

Figure 5 Bearing with combined axial and circumferential groove

The figure 6 depicts the developed surface of the bearing with combined axial and circumferential groove along with the dimensions.

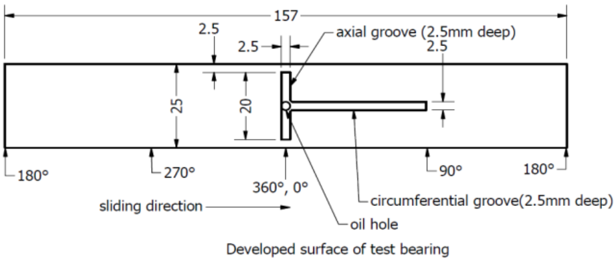

Figure 6 Developed bearing surface with both axial and circumferential groove

The lubricant supply hole is located on the top. The axial groove is located on the top with lubricant supply hole at the centre. The circumferential groove starts from the same position.

The test duration for normal test was taken to be 6 hours so as to obtain measureable wear of the bearing. The time duration for running-in test was taken to be 1.5 hours corresponding to a sliding distance of 850 meters with a load of 7500N at 60 rpm. The lubricant inlet temperature was kept at 75°C. The bearings were operated at a load of 7500 N. The journal speed was kept 10 rpm which is much lower than the lift-off speed. The wear was measured as a weight loss of the bearing.

3. Experimental Results and Discussion

The results are shown in figure 7.

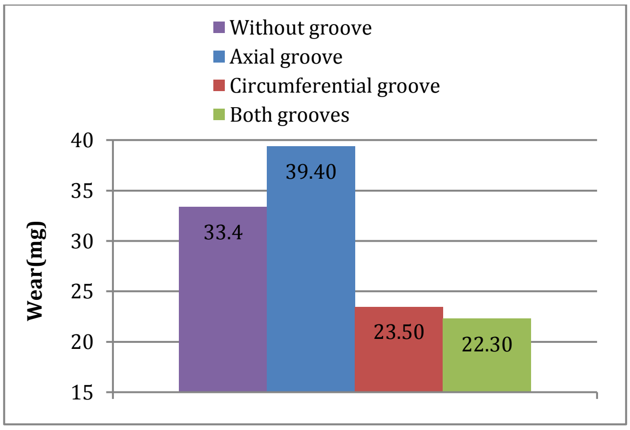

Figure 7 Result of wear tests (6 hours duration)

The result indicates that reduction in wear is achieved due to the use of grooves in the bearing except that of an axial groove only. However, higher wear is obtained when only one axial groove is used in the bearing because of the lubricant leakage to the sides. In the circumferential groove and when both the grooves are used the wear obtained was less as compared with the bearing without any grooves. It is possibly due to sufficient supply of lubricant at the contact zone. It was also observed that use of a combination of axial and circumferential groove causes reduced wear due to proper lubricant supply at the starved zone as compared to bearing with either axial or circumferential groove. The provision of two grooves increases the lubricant flow to the contact zone and helps maintain the wear in the mild zone.

Conclusion

The following conclusions are drawn based on the experimental observations:

- The wear of a journal bearing operating in mixed lubrication regime may be reduced with the use of circumferential groove.
- The axial groove alone is not preferable as it increases the lubricant flow to the sides and causes increased wear.
- The circumferential groove is preferable as it reduces the wear.
- The combination of axial groove and circumferential groove causes maximum reduction in the wear.

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