

Study of Pressure Profile in Hydrodynamic Lubrication Journal Bearing

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Abstract--In hydrodynamic lubrication, the pressure condition of the fluid is critical to ensure good performance of the lubricated machine elements such as journal bearings. In the present study, an experimental work was conducted to determine the pressure distribution around the circumference of a journal bearing and fluid frictional force of the bearing caused by shearing actions. A journal diameter of 100mm with a 1/2 length-to-diameter ratio was used. Pressure results for 600 RPM speed at different radial loads were obtained. The experimental results were compared to predicted values from established Raimondi and Boyd charts. It was observed that the location of the maximum pressure for the given operating conditions is close to the predicted value.

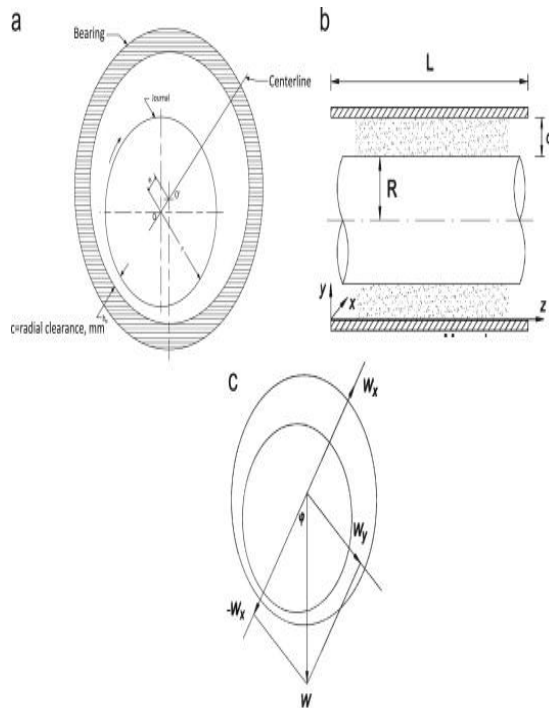
I. INTRODUCTION

Journal bearings are common in many types of machinery. The main function is to support radial load and facilitate motion and as well as transfer of power. A journal bearing consists of two main components where the shaft called journal rotates freely in its shell or bushing known also as bearing. Basu et.al [1] identified journal bearing as an important member of hydrodynamic slider family with the simplest construction. The bearing operates with a small clearance of the order of 1/1000 of the journal radius. The clearance is filled with lubricant and this lubricant layer is responsible for the load carrying capacity of the journal bearing. The lubrication mechanism in a journal bearing is often referred to as hydrodynamic lubrication which has been widely studied and reported. Hydrodynamic lubrication or sometimes called fluid film or thick film lubrication occurs when the journal and bearing surfaces are totally separated by the established fluid layer. In the case of journal bearing,

hydrodynamic lubrication occurs in a very tiny film much more than a micron which is sufficient to prevent the asperities contact. During the development or designing stage of journal bearing, several important parameters or characteristics in hydrodynamic lubrication such as film thickness, viscosity, pressure, temperature and friction have important roles in ensuring optimum journal bearing operations. In this study, pressure profile around journal bearing circumferential and fluid friction parameter in hydrodynamic lubrication was investigated. This friction losses can affect the total mechanical power losses [2, 3]. The torque and frictional force was measured to identify the changes when the loads and speeds vary. Theoretically, friction is independent of the area of contact and sliding velocity. Previously investigation on viscosity and film thickness related to journal bearing has been done [4-6]. Currently, there is insufficient information on pressure distribution from experimental studies. Based on literatures, many studies related to pressure distribution in journal bearing are by mathematical means. This is believe due to experimental work being demanding and unfeasible [7-13]

II. PRESSURE IN JOURNAL BEARING

Pressure in journal bearing can be plotted by resolving Reynolds equation [14, 15]. This differential equation governs the pressure distribution in fluid film lubrication for incompressible fluid Reynolds equation forms the foundation of fluid film lubrication theory. From this equation, relation between the geometry of the surface, relative sliding velocity, the property of the fluids and the magnitude of the normal load can be



predicted. In this study, bearing length L over bearing diameter D ratio (L/D) is equal to 0.5. From this value, Sommerfeld number was calculated using equations [16],

$$S = S = \left(\frac{r}{c}\right)^2 \frac{uN}{P}$$

Where, it is viscosity (Pa.s), N is speed (rps), r is journal radius (m), c is clearance (m) and P is radial load per unit of projected bearing area (N). Equation (1) was used to obtain the predicted values of eccentricity ratio, friction coefficient, maximum film pressure, position of maximum film pressure, and position of minimum film thickness from Raimondi and Boyd chart. These predicted values are used for validation purposes with the following assumptions,

- The surface are smooth,
- The fluid is Newtonian and the flow is laminar, and
- Inertia force resulting from acceleration of the fluid and body forces are small compared with the surface forced,
- It is interesting to study the pressure distribution in the hydrodynamic region of a fluid film bearing.

FLUID FRICTION IN JOURNAL BEARING

Friction is known as a resisting force that always opposes motion between mating parts. Bhushan [15] has defined friction as the resistance to motion during sliding or rolling when one solid body moves tangentially over another. In the case of journal bearing, fluid friction is generated in the fluid film when pressure induces shear. The mathematical models for predicting viscous shear force on journal and bearing surfaces have been derived in [1]. Friction coefficient f on the bearing surface can be calculated by,

$$F = \left(\frac{c}{r}\right) (2 + e^2)(1 - e^2)/3e$$

Where c is radial clearance, r is journal radius and e is eccentric ratio.

III. METHODOLOGY

4.1. Journal Bearing Test Rig

The Journal Bearing test rig was used in this experiment. The bearing part was modified to fix 12 pressure sensors (MEAS) around the journal bearing circumference at every 30 degrees interval. The journal was then mounted horizontally into the bearing. A pneumatic bellow was used to apply the required load. The maximum speed of the journal test rig is 1000 rpm. The speed used for testing was 600 rpm. Frictional torque sensor was mounted on the spindle housing. The loading arm was fixed on the bearing surface. This arm would press the loading pin of the load cell during operation. This sensor was mounted 180mm from the centre of the journal. During tests, the journal bearing was run at different loads (6, 8, 10 kN). Details of test bearing dimensions, lubricant properties and operating parameters are given in Table 1. Frictional torque sensor was mounted on the spindle housing. The loading arm was fixed on the bearing surface. This arm would press the loading pin of the load cell during operation. This sensor was mounted 180mm from the centre of the journal. During tests, the journal bearing was run at different loads (6, 8, 10 kN). Details of test bearing dimensions,

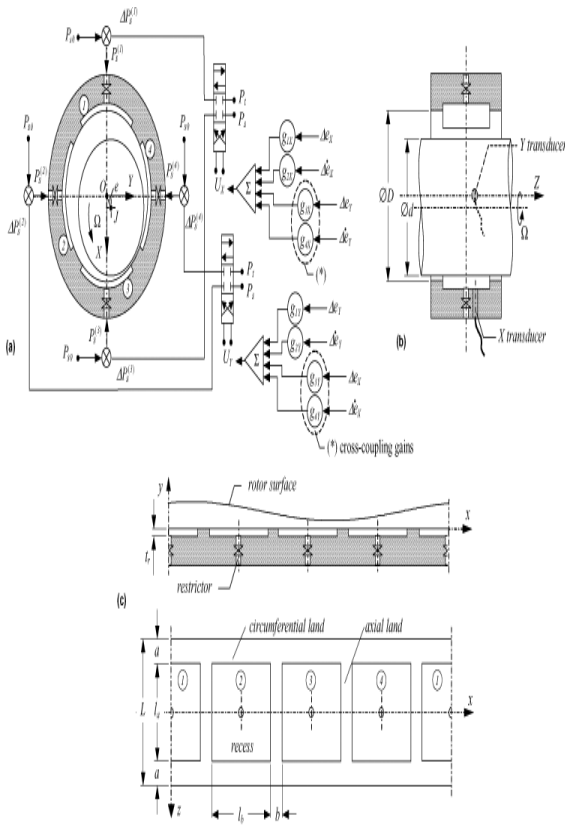
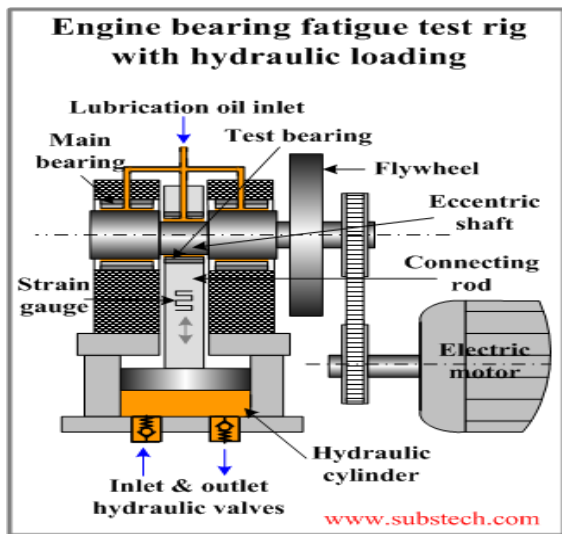


Figure 1. Active Hybrid Journal Bearing – geometric characteristics and operational principle.



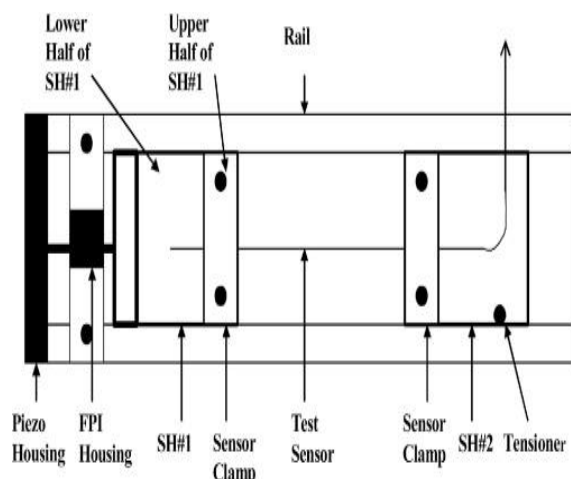
lubricant properties and operating parameters are given in Table 1. The lubricant pressure profile was measured by the 12 pressure sensors mounted to the bearing. The pressure sensors measure fluid pressure developed through holes bored to within 0.5 mm from the bearing surface [17, 18]. The oil inlet pressure was regulated using a power pack lubrication system and maintained at 0.3 MPa throughout the experiments.

Table 1. Dimensions of test bearing, lubricant properties, operating parameters and sensor specifications

Parameter	Values
Journal diameter, D	100 mm
Bearing Length, L	50 mm
Radial clearance, c	52 μm
Load range, W	5, 10, 15, 20 kN
Journal Speed	200 - 800 RPM
Lubricant viscosity	68 cSt @ 40 °C 8.8 cSt @ 100 °C
Pressure sensor Model	MEAS (M 5156)
Range	10 Mpa
Accuracy	0.001± 1% Mpa
Frictional Torque sensor Model	Beam type load cell (Sensortronic)
Range	30 kg
Accuracy	(0.01 ± 1%) Nm

IV. RESULT AND DISCUSSION

Experimental results of pressure profile at 600rpm at different loads were plotted. The theoretical values obtained from Raimondi and Boyd charts were also shown on the plotted profile. For the same operating conditions in the test, the predicted maximum pressure location from Raimondi and Boyd chart is to be at 197.5 degrees. Based on the experimental set up, the maximum pressure position was recorded at 195 degrees. For the maximum pressure, the experimental value obtained is 2.62MPa and the predicted value from Raimondi and Boyd chart is 2.93MPa. The inlet pressure, at the groove was maintained at 0.3MPa to ensure the continuity of oil supply. The minimum film thickness from Raimondi and Boyd chart for 600 rpm speed and 6kN load is at 236° position. Conventionally, the converging and diverging sections are defined by the minimum film thickness. In diverging section the pressure may drop to negative values [12]. However, in this study, values of zero were assumed in this diverging section.



the corresponding pressure profiles for fluid lubrication for the case of 8kN and 10kN. The speed was maintained at 600 RPM. Theoretically, when the load increases, the position of film thickness will shift to a new position. However, the position of maximum pressure remains the same as predicted from Raimondi and Boyd chart. The experimental and theoretical results for friction coefficient. The theoretical values were obtained from Raimondi and Boyd chart. In comparison, the experimental values are three times higher than the theoretical values. It was also observed that the friction coefficient values decreased slightly as the load increased. This is true for both experimental and predicted values. It is also expected that the smaller the bearing unit load, the lower the viscosity and the speed needed to float.

V. CONCLUSION

In this paper, the preliminary study of pressure profiles around a journal bearing under hydrodynamic lubrication were described and compared with theoretical profiles obtained from Raimondi and Boyd charts. From the experimental results, it was found that the experimental maximum pressure values were higher than the theoretical maximum pressure values. It was also observed that the position (i.e. angle) of the maximum pressure has not changed significantly with loads. Generally, the pattern of pressure distribution obtained was similar to those reported in other studies [1, 16]. However the position of the minimum film thickness varied clearly with changes in loads. Friction coefficients of oil lubricant in this experiment decrease when the loads increase. This shows a similar trend as in Raimondi and Boyd chart. It was also observed that the experimental friction coefficient values are significantly higher than the predicted values

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