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Experimental Determination of Temperature and Pressure Profile of Oil Film of Elliptical Journal Bearing

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Abstract

The excessive rise of pressure and temperatures in the lubricant film of hydrodynamic Journal bearings occurred as they are used for supporting high-speed rotating machinery. Experimental data of pressure and temperature along the profile of the bearing of an oil film is very useful and will be helpful for designer to design such journal bearings. Here, in this an elliptical journal bearing with journal diameter=100mm, L/D ratio=1.0, Ellipticity Ratio=1.0 and clearance=0.1mm has been designed and tested to access the pressure and temperature rise of the oil film at the central plane of the bearing. The pressure and temperature profiles have been taken at constant load of 500N and at variable journal speeds=1000, 1500 and 2000rpm. The results show that at constant load, with the increase in journal speed the pressure as well as temperature of the lubricant film increases. Further, two lobes have been observed due to non-circular profile of the bearing under study.

Keywords: Elliptical journal bearing; Pressure and Temperature Profile

Introduction

Hydrodynamic journal bearings are used to support the shafts of high speed machineries which accounts excessive rise in temperature of the lubricant. Hence, it affects the performance of the bearing as high temperature leads to lowering the viscosity of the oil which consequences to the metal contact of journal and bearing. This ultimately results a decrease in the life of bearing. Elliptical journal bearing is the form of non-circular journal bearing which provides superior stiffness, damping, low power losses, and reduced temperature in oil film as compared to the circular bearings as they operate with more than one active oil film. It becomes necessary to study the real temperature and pressure rise of the lubricant in such bearing. This helps the researchers to study the behaviour of the lubricant film on performance characteristics of the bearing. Experiments related to calculation of pressure and temperature inside the bearing of lubricating film gives the real scenario for calculation of performance parameters of the bearing. Only a limited experimental work has been reported for the thermal effects of elliptical bore journal which is two lobed bearing. This leads to unavailability of standard procedures for their design. Here, only few recent experimental and theoretical works has been reviewed. Pinkus and Lynn [1] have theoretically presented an analysis of elliptical journal bearings based on the numerical solution of Reynolds equation for finite bearings with the assumption that there is no heat loss to the surroundings. The solution of the differential equation was supplemented by additional work on the nature of the oil flow, power loss, and eccentricity in elliptical bearings. Fitzgerald and Neal [2] have presented some experimental data for 76 mm diameter two-axial groove circular bearings. The authors have observed that the axial temperature variation was negligible but the circumferential temperature variation could be very significant. Hussain et al. [3] have predicted the temperature distribution in non-circular journal bearings: two-lobe, elliptical, and orthogonally displaced. The prediction of temperature by the authors is based on a two-dimensional treatment following Mc Callion's approach (an approach in which the Reynolds and energy equations in oil film are decoupled by neglecting all pressure terms in the energy equation). Mishra et al. [4] have considered the non-circularity in bearing bore to be elliptical and made a comparison with the circular case to analyze the effect of irregularity. It has been observed that with increasing non-circularity the pressure gets reduced and temperature rise is less in case of journal bearing with higher non-circularity value. Ostayen and Beek [5] have carried out a finite element analysis of a lemon-bore journal bearing. The thermo-hydrodynamic model presented by the authors is an inverse model, that is, a model in which the shaft eccentricity and attitude angle are calculated given a certain known and prescribed load and load angle. In analysis carried by the authors, care has been taken to accurately model the heat to and from the oil supplied and the model is used to check the design of the lemon bearings in a specific naval application. Chauhan et al. [6] have presented a comparative theoretical analysis of three types of hydrodynamic journal bearing configurations namely: circular, axial groove, and offset-halves. It has been observed that the offset bearing runs cooler than an equivalent circular bearing with axial grooves. Review of the existing literature reveals that a very little experimental work related to the elliptical journal bearings have been reported or carried out by the researchers.

In the present work, pressure and temperature profile along the central plane of an elliptical journal bearing have been studied experimentally. The pressure and temperature profile have been obtained by applying a constant load of 500N on the bearing at three different journal speed=1000, 1500 and 2000rpm. These experiments were conducted on the specially designed journal bearing test rig which evaluates simultaneously both pressure and temperature along the circumference of the bearing in its central plane at 09 different locations. The lubricating grade oil: Hydrol 68 has been chosen for experimentation depending on the availability of the oil in local market.

Experimental Set Up

The journal bearing test rig is versatile equipment which is easy to operate with a provision to measure pressure and temperature values at the same location point at an interval of 30° along the circumference of the bearing. The journal is mounted horizontally on a housing supported on self-aligned bearings; it is rotated by AC motor which can attain a maximum speed of 6000rpm. An elliptical bearing centrifugally casted made of brass freely slides over the journal and is pulled upwards for applying radial load through a pneumatic cylinder arrangement. 09 no's of pressure sensors are mounted on back plate and tightened to front face of the test bearing for measuring the pressure. Similarly 9 no's of temperature sensors (PT-100) are fixed on the circumference of the bearing and gives the value of temperature at the same location from where pressure value is measured. (Fig. 1) Two ports are provided at 90° and 270° from the vertical load line for oil inlet inside the bearing. The used oil flows back to the lubricating tank from the bottom of the housing. The oil flow is regulated by a pressure gauge. In addition, one sensor is fixed to measure oil inlet temperature from the lubricating sump. A proximity sensor fixed on the journal, senses its speed. The measured data of oil temperature, pressure and speed obtained during the experimentation in analog form is converted into digital form and pre-processed on the instrumentation card. The data received is displayed and stored on the PC using LabVIEW based software WINDUCOM 2010. An oil sump is provided beneath the bearing for collecting the used oil which flows into metallic tank for its re-circulation.

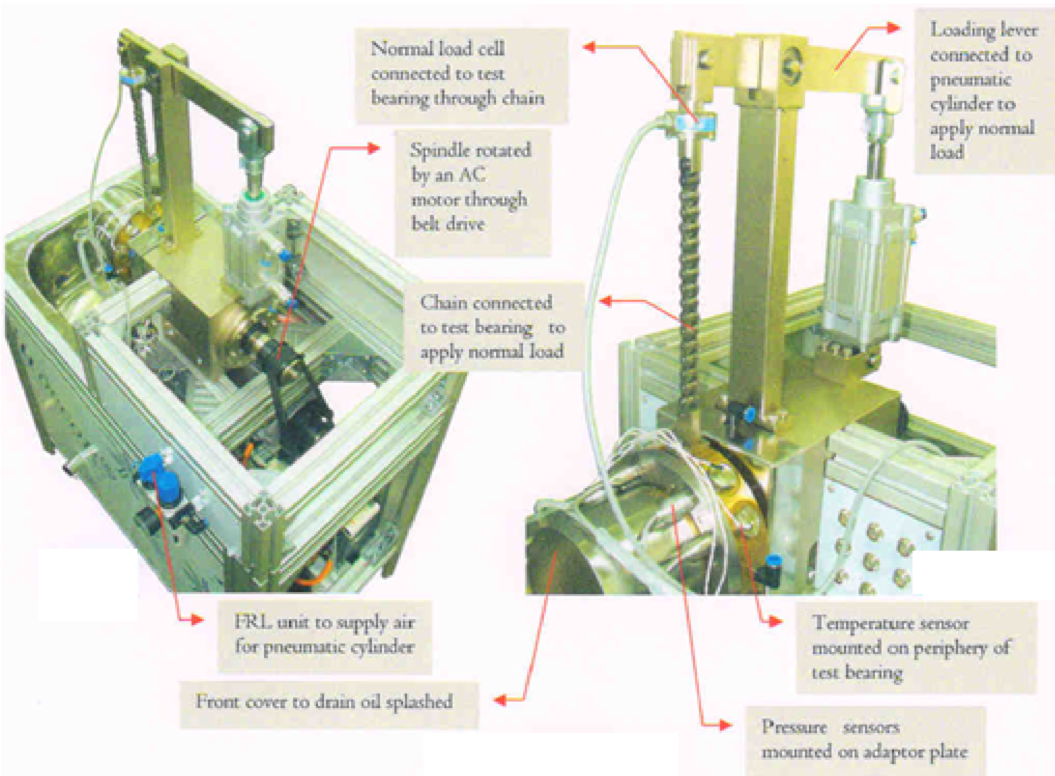

Fig. 1: Schematic of Journal Bearing Test Rig

Experimental procedure

In present experimentation, an elliptical journal bearing of l/d ratio=1.0, ellipticity ratio=1.0 (Fig. 2) has been tested using lubricating grade oil HYDROL 68 having kinematic viscosity=68 at 40°C at constant load of 500N. The pressure and temperature for elliptical journal bearing has been measured at three different journal speeds=1000, 1500 and 2000rpm. The oil flow rate and inlet temperature during the experiments has been 0.8liters per minute and 33°C respectively.

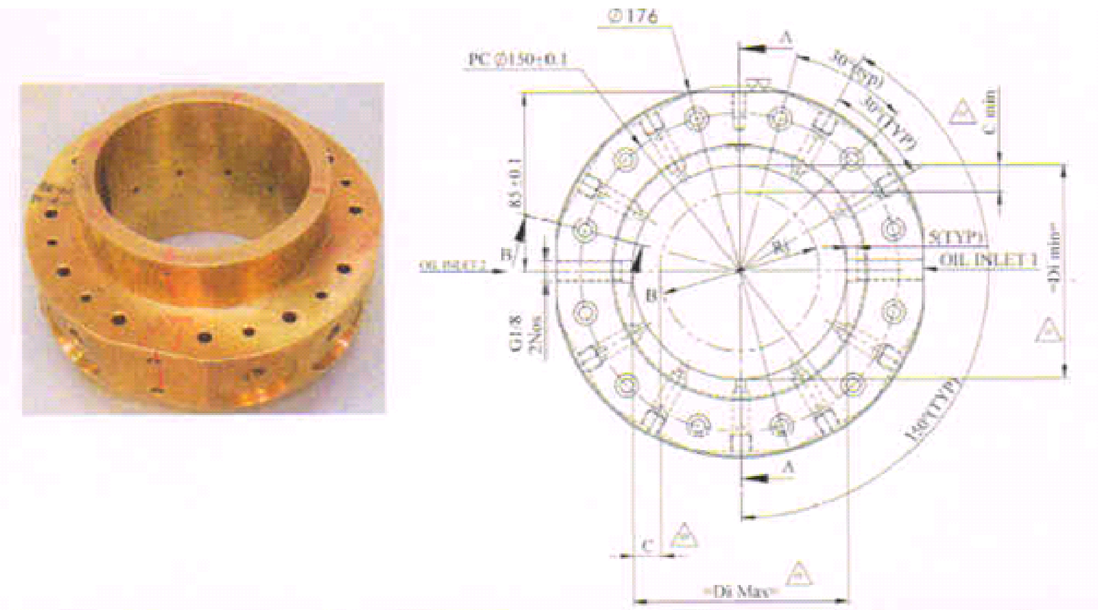

Fig. 2: Schematic of Elliptical journal bearing

Results and Discussion

Input parameters and properties of the lubricating oil under study have been given in Table 1. The experimentally obtained pressure and temperature distribution along the mid plane of the circumference of elliptical journal bearing has been shown in Fig. 3 and Fig. 4 respectively. It has been observed that both the pressure and temperature increases with increase in journal speed.

Table-1: Operating Conditions and Lubricating Properties

Journal Diameter	100 mm
Bearing Length	100 mm
Max Inner Diameter of Bearing (Major Axis)	100.4 mm
Min Inner Diameter of Bearing (Minor Axis)	100.2 mm
Radial Clearance	100 microns
Lubricant density	850 Kg/m^3
Lubricant Viscosity at 40°C	68 Centistokes
Oil Flow Rate	0.8 litres per minute

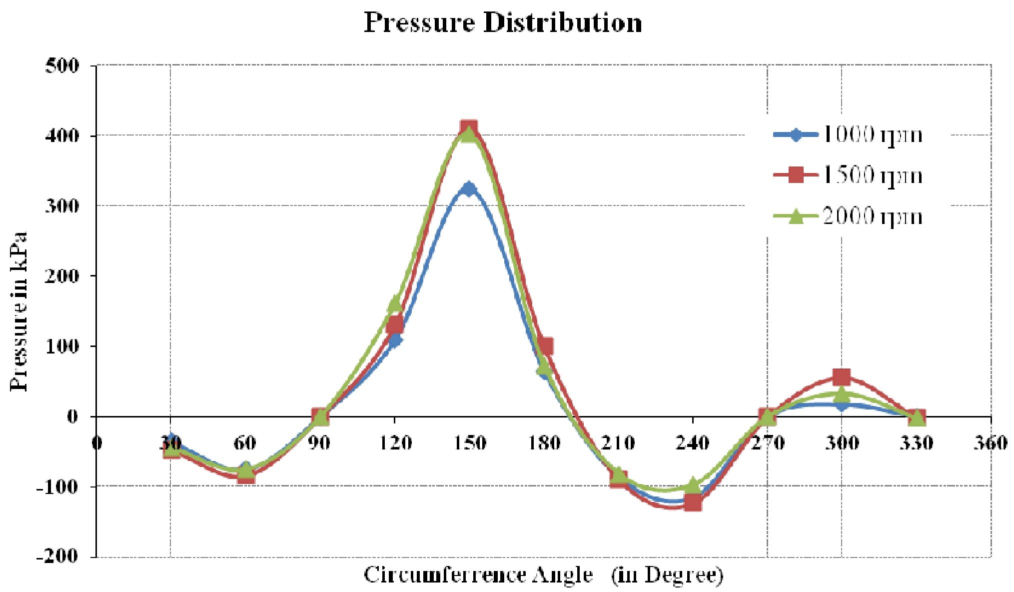

Fig. 3: Pressure distribution of elliptical bearing at journal speeds=1000, 1500 and 2000rpm

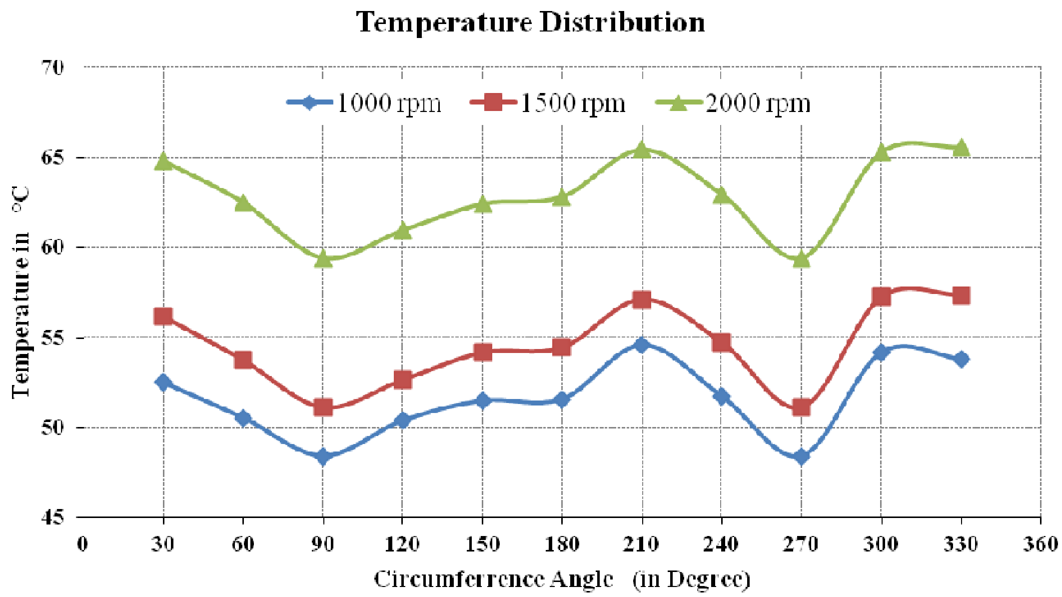

Fig. 4: Temperature distribution of elliptical bearing at journal speeds=1000, 1500 and 2000rpm

The maximum pressure and temperature was observed 325kPa and 54°C respectively at the journal speed of 1000rpm. With the increase in journal speed from

1000 to 2000rpm, the pressure and temperature rises to 400kPa and 65°C respectively. The inlet temperature of oil also rises from 48°C to 59°C with the increase in journal speed from 1000 to 2000rpm which is due to recirculation of oil back to the lubricating tank. The rise of pressure in the first lobe is less at 2000rpm as compared to 1000rpm, this is because of the decrease in viscosity of the lubricant at high temperature.

Conclusions

Thermal characteristics for elliptical journal bearing have been measured experimentally. It has been concluded that the thermal behaviour of elliptical profile journal bearing is affected significantly by rotational speed at constant load and type of oil used. Pressure and temperature increases markedly with increase in journal speed. Due to the geometry of the bearing under study two different lobes has been observed in both pressure and temperature distribution.

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