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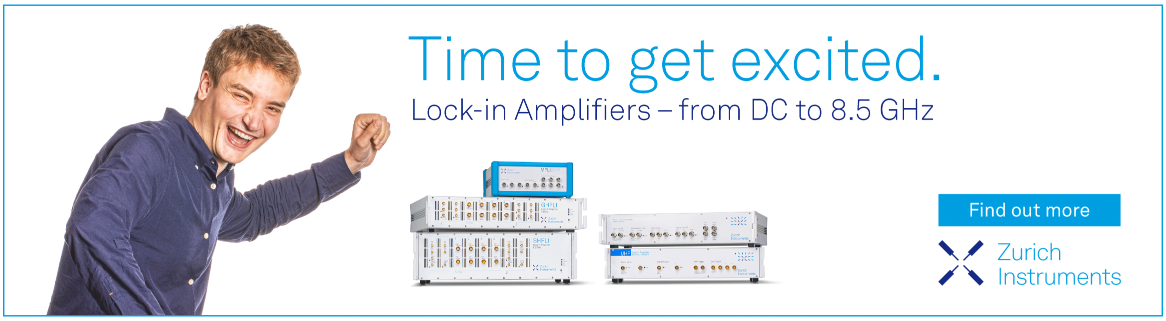

Effect of Eccentricity Ratio on Journal Trajectory in Three-Lobe Journal Bearing

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Abstract. Fluid film bearings are used in heavy machinery for supporting loads which are subjected to either static or dynamic. Due to this load the rotating shafts centres move away from the centre of the bearing. Due to this deviation of the journal axis from the bearing centre eccentricity is developed. This pulls the journal near to the bearing surface by decreasing the film thickness between the journal and bearing during relative motion. The film pressure is increased to at an edge, which leads to vibrations of the journal. The uneven pressure distribution can be reduced by dividing the projected area of the bearing into lobes. These lobes create film pressure which supports the journal during loading. In this paper three lobe journal bearing characteristics have been investigated for different eccentricity ratios. The journal trajectory is plotted for eccentricity ratio considered from the experimental investigation. The effect of eccentricity ratio on the journal centre trajectory is studied.

INTRODUCTION

Torque transmitted from rotating members when subjected to dynamic loading, delivers amplitude to the driven parts. The displacement of journal axis from the centre of the bearing, leads to variation of film pressure around the journal. As the speed of the journal increases with varying load, the journal delivers huge amplitude indicating that the speed of journal is near to its natural frequency. During this condition, it may lead to the failure of the lubricant film surrounding the journal, which further leads to failure of the bearing during running condition.

The pressure around the journal has to be stabilized. In order to have film pressure around the bearing and damping the vibrations, it is not possible in circular journal bearing. The pressure film obtained in a circular journal bearing is one.

Initially when the journal start rotating it climbs the bearing surface and after attaining the certain speed it moves to an equilibrium position. During the relative motion the lubricant film separate the bearing and journal. At this position the lubricant film convergence between the gaps which support the load which is acting on the bearing system.

In order to have proper cushioning for the journal around its projected area, the projected area has to be divided into lobes. Each lobe is separated with oil holes such that the every lobe generates a film pressure to support the journal. Based on the partition of projected area of the bearing, theses are classified into multi lobe journal bearings.

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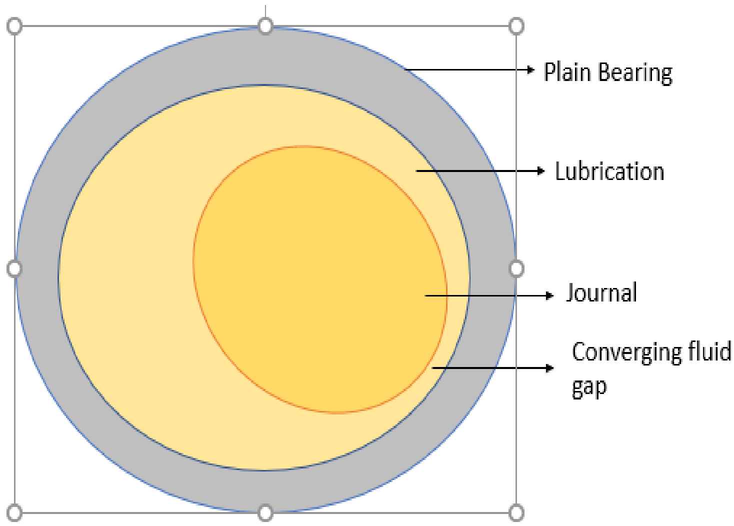


FIGURE 1. Converging fluid gap geometry produced by journal eccentricity

LITERATURE REVIEW

Bearing model are developed for different speed and eccentricity ratio to study the behavior of the bearing at static pressure and elastic .CFD analysis is done to find out at centre of the bearing how the force is acting [1]. It is observed that static pressure of the bearing could be applicable for accurate performance of the hydrodynamic journal bearing. Three lobes journal bearing different oil fans of gas turbine are analyzed. In the three lobe journal bearing lobes created at angle 1200. The journal speed is considered as 8000rpm [2]. The main objective of the paper is because of lobes performance of bearing will increase.

Journal bearing have wider range of applications printing press, textile machinery, and these two applications using dynamics loaded journal bearing [3]. By providing the recess on bearing surfaces which leads to increase the performance of bearing. Multi lobe journal bearings have been analyzed to determine the stability of the bearings [4]. Non linear analyses of the bearings have been performed by considering the surface roughness [7]. Bearing characteristics were derived at different eccentricity ratios [11].

Hydrodynamics journal bearing are extensively used for to carry heavy loads. If bearing carries heavy load oil film thickness will reduces which increases the pressure distribution between journal & bearing with the help of fluid structure interaction technique 3-lobe journal bearing oil film pressure analyze by compassing CFD data with experimental results it is that bearing load carrying capacity increase with increase in speed of journal [5,17]. For analyzing the performance of bearing CFD, FSI technique are used. For different eccentricities and three lobe journal bearing fluid filing pressure distribution temperature, temperature distribution has been analyzed[6].

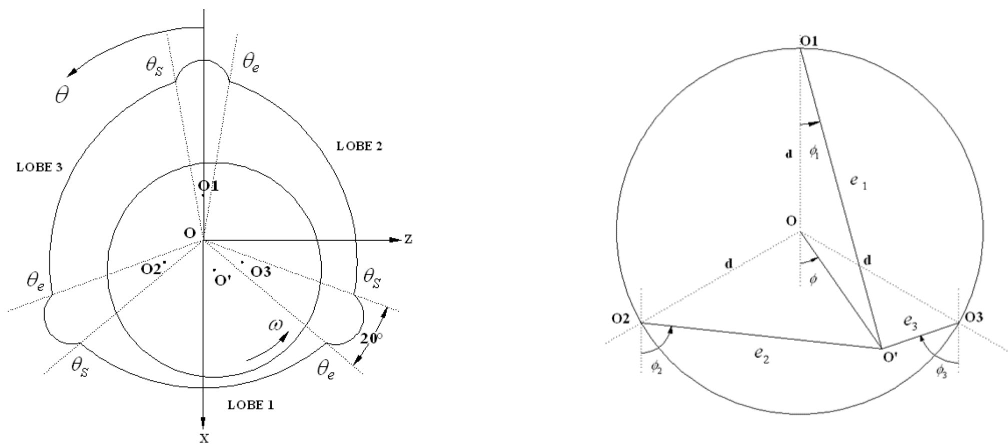
Plain journal bearing having bore of a shape of cylinder. Plain journal bearing are easy to fabricate, it can carry heavy loads [8,19]. The main disadvantages of plain journal bearing are oil groove. Because of more vibrations, a forces result bearing is unstable. The maintain the stability of bearing lobe is provide on bearing, which will improves performance of bearing. Three lobe journal bearing static and dynamic performance analysis has been analysed, with the help Reynolds equation is fluid film thickness and journal ratio governed [9]. Performance of bearing has been compared plain bearing,3 lobe bearing & protrusicies 3 lobe journal bearing gives belts performance than other.

With the help of CFD journal bearing performance has been analyzed in transient analyses surface rough also taking in to account. In three lobe journal bearing lobes arranged at 1200 .Gambit software is used to design 3 lobe bearing and speed rotation of journal is 6000rpm [10]. By using Ansys fluent software transient flow is analyzed Journal bearing linear and non-linear stability analysis has been calculated for different between ratios, and eccentricity ratios [12,16]. Reynolds equation help to identify the lubricant flow with the help of forth order R.K method journal trajectory has been analyzed .Journal trajectory has been find out with the help of MT lab program. Numerical analysis journal shines load carrying[19-20].

Bearing support the shaft in machine whenever bearing is loaded with lubricant oil film will form when journal is rotating pressure is developing in the oil film that leads to define the load carrying capacity of bearing whenever lubricant is applied between journal and bearing because of vibration of machine it is very difficult to maintain oil film. So that is the reason why lobes are providing on journal bearing [13,20]. Multipurpose journal bearing can be created with the help of shim because of shims carrying capacity of bearing will increases [14]. By using FEA technique these (Circular, 2 lobe,3 holes) bearing profiles has been analyzed. Four lobe journal bearing static & dynamics analysis has been done with couple stress key parameters of bearing load carrying capacity, eccentricity ratio aspect ratio has been analyzed [15,18].

METHODOLOGY

The geometry of lobes and its design parameter as shown in Figure.2.Its consist of three discontinues arc which are separated by oil hole. Each lobe has an eccentricity with respect to the journal centre. The eccentricity is limited to avoid surface to surface contact of journal and bearing during operating conditions.



2(a) 2(b)

FIGURE 2. (a), (b) Geometry of three lobe journal bearing

The lobe eccentricities and attitude angles for all the three lobes are calculated with the following expressions.

For Lobe 1:

$$e_1^2 = e^2 + c^2 + 2ec\cos\phi$$

$$\varepsilon_1^2 = \varepsilon^2 + \delta^2 + 2\varepsilon\delta\cos\phi \tag{1}$$

$$\varepsilon_1 = \sqrt{\varepsilon^2 + \delta^2 + 2\varepsilon\delta\cos\phi}$$

$$\phi_1 = \tan^{-1}\left(\frac{\varepsilon\sin\phi}{\delta + \varepsilon\cos\phi}\right) \tag{2}$$

For Lobe 2:

$$e_2^2 = e^2 + c^2 - 2ec\cos\left(\frac{\pi}{3} + \phi\right)$$

$$\varepsilon_2^2 = \varepsilon^2 + \delta^2 - 2\varepsilon\delta\cos\left(\frac{\pi}{3} + \phi\right) \tag{3}$$

$$\varepsilon_2 = \sqrt{\varepsilon^2 + \delta^2 - 2\varepsilon\delta\cos\left(\frac{\pi}{3} + \phi\right)}$$

$$\phi_2 = \frac{2\pi}{3} - \tan^{-1}\left(\frac{\varepsilon \sin\left(\frac{\pi}{3}+\phi\right)}{\delta - \varepsilon\cos\left(\frac{\pi}{3}+\phi\right)} \right) \quad (4)$$

For Lobe 3:

$$e_3^2 = e^2 + c^2 - 2ec\cos\left(\frac{\pi}{3}-\phi\right)$$
$$\varepsilon_3^2 = \varepsilon^2 + \delta^2 - 2\varepsilon\delta\cos\left(\frac{\pi}{3}-\phi\right) \quad (5)$$
$$\varepsilon_3 = \sqrt{\varepsilon^2 + \delta^2 - 2\varepsilon\delta\cos\left(\frac{\pi}{3}-\phi\right)}$$

$$\phi_3 = \frac{2\pi}{2} - \tan^{-1}\left(\frac{\varepsilon \sin\left(\frac{\pi}{3}-\phi\right)}{\delta - \varepsilon\left(\frac{\pi}{3}-\phi\right)} \right) \quad (6)$$

In three lobe bearing, the pressure wedge is created in the left-hand side of the first lobe has a very high convergence and therefore the resultant horizontal force will be high. This force is not sufficiently balanced by forces acting to the left unless the shaft centre moves upward and to the right, as shown in the Figure.3.Due to eccentricity of the lobes the variation of film thickness around the journal is formed. During operating conditions the minimum film thickness is obtained don any of the lobes depending upon the loading conditions. The trajectory of journal centre indicates the performance of the bearing.

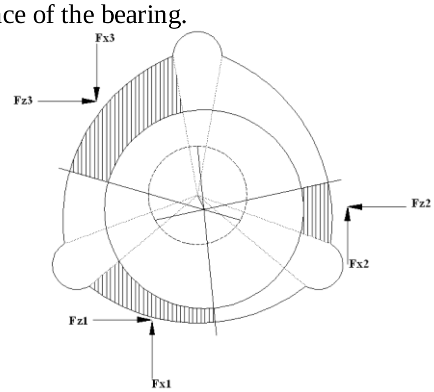


FIGURE 3. Hydrodynamic forces in three lobe bearings

EXPERIMENTAL INVESTIGATION

Fluctuating displacement are obtained by applying dynamic loading to the hydrodynamic bearing via two orthogonally positioned electromagnetic shakers attached directly to the test bearing housing. Sinusoidal input forces Fa and Fb, of equal frequency but independently variable amplitude and phase angle, are applied to the bearing housing. The orthogonal input forces Fa and Fb are transformed to the established Cartesian coordinate system producing vertical and horizontal forces Fx and Fy. Proximity sensors where placed orthogonally to the rotation of the shaft. The path trajectory of the journal centre is plotted for different eccentricity ratios. The speed of the journal is maintained constant and maintained by using optical speed sensors. The input data from the proximity sensors are plotted to trace the path trajectory of the journal centre and find its stability during the dynamic loading. The bearing surface roughness was isotropic. Isotropic surface roughness was consider for the design of three lobe bearing, the isotropic surfaces roughness as (γ =1) which represents the aspect ratios along longitudinal and lateral dimensions of surface roughness.

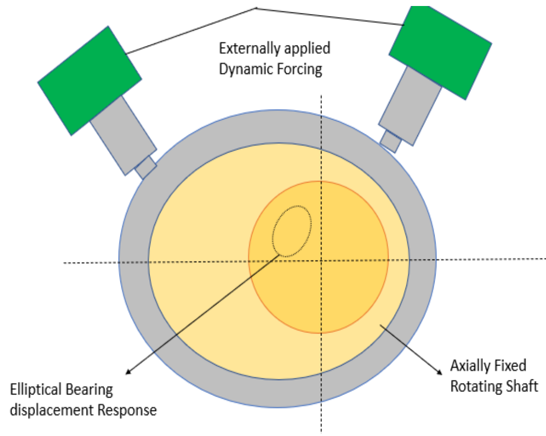


FIGURE 4. Schematic Diagram of Bearing Displacement Response from Externally Applied Harmonic Excitation.

RESULTS & DISCUSSION

The three lobe bearing has been analyzed for different operating speeds and eccentric ratios. The material of the bearing is phosphor bronze and the material of the journal is chrome steel. The results determined from numerical technique using finite element method are shown below. The path trajectories of the journal centre are plotted for three lobe bearing at different eccentricity ratios.

TABLE 1. Test bearing specifications

Design Parameter	Design Specification
Bearing Type	Three lobe journal bearing
Bearing Material	Phosphorus Bronze
Lubrication Supply	Inlet port diameter 0.00635m
Length	0.04 m
Diameter	0.04 m
Mean radial clearance	0.249 mm
Bearing Excitation Orbits	9 Distinct Orbits
Dynamic Excitation Frequencies (Hz)	42

From the Figure.5 (a) it is observed that the journal centre moved away from the bearing centre during its initial operation, as the eccentricity ratio increased to 0.2, the journal attained a stable condition and remained the same for eccentricity ratio 0.3 as shown in the figure.5(b) and 5(c). An increasing the eccentricity ratio further it is observed that the journal was moving closets to bearing surface where the film thickness between the bearing surface and journal decreased at eccentricity ratio at 0.6 as shown in the figure.5(f) the minimum film thickness is observed where the load carrying capacity was maximum.

On further increase of eccentricity ratio due to the isotropic surface roughness, the film between the journal and bearing is disturbed as the eccentricity is increased the lubricant around the journal is scattered due to low viscosity and creates a jump in the relative motion which is observed in Figure.5(g) and 5(h).

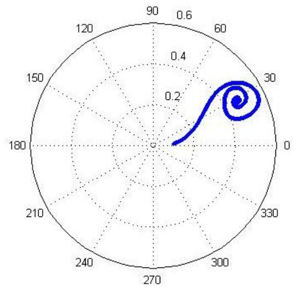


Figure. 5(a) Eccentricity Ratio is 0.1

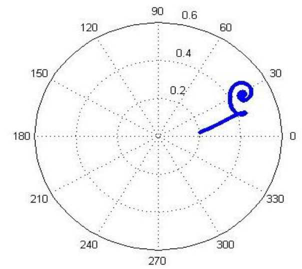


Figure. 5(b) Eccentricity Ratio is 0.2

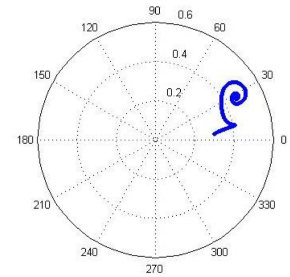


Figure. 5(c) Eccentricity Ratio is 0.3

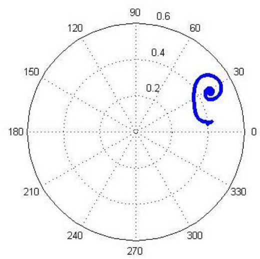


Figure. 5(d) Eccentricity Ratio is 0.4

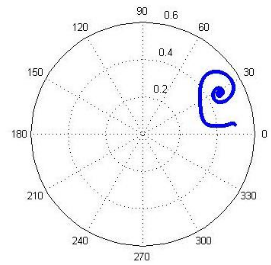


Figure. 5(e) Eccentricity Ratio is 0.5

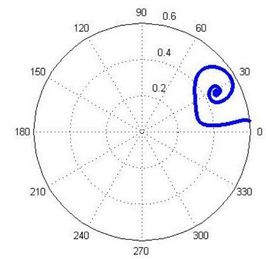


Figure. 5(f) Eccentricity Ratio is 0.6

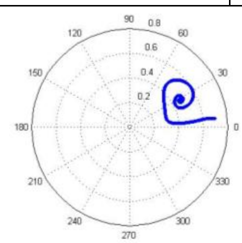


FIGURE 5. (g) Eccentricity Ratio is 0.7

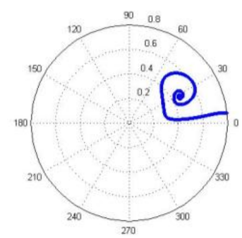


FIGURE 5. (h) Eccentricity Ratio is 0.8

FIGURE 5. Path Trajectories of journal centre

CONCLUSIONS

As the journal moves away from the bearing centre and the film pressure is increased between the journal and bearing surface. The thin film bears a maximum load carrying capacity as the journal nears to the bearing surface, the thin film breaks due to rise in temperature. From this it is observed that surface properties also effect the bearing characteristics. The three lobes create pressure on the journal which stabilizes the position of the journal to support the applied loads. From the Figure.5(f) it is observed that the as eccentricity ratio increases the journal keeps moving towards the wall of the bearing. At an eccentricity ratio of 0.6 it is observed that minimum film thickness is attained due to the relative motion of journal with three lobe journal bearing. At this instant the bearing has a maximum load carrying capacity.

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