Analysis of Performance Characteristics of Hydrodynamic Journal Bearing

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Abstract- *This paper presents the 3D simulation of Hydrodynamic plain journal bearing using COMSOL multiphysics 5.0 software. Using the numerical simulation approach, pressure distribution in plain journal bearing is obtained by steady state operating conditions.The general Renolds equation is used forAnalyzing hydrodyanamic journal bearing byCOMSOL as well as by analytical method. Numerical results obtained for pressure Development and load carrying capacity are Compared with analytical results. A simulaton Shows that the solutions are approximately Similar to the analytical solutions. Also in this Paper, effect of different journal speed, eccentricity Ratio, clearance and oil viscosity on performance Characteristics like pressure distribution and Load carrying etc. is studied.*

Keywords- pressure development ,load carrying Capacity, numerical analysis, etc

I. INTRODUCTION

Journal bearings are used to carry vertical loads, for example, to support a rotating shaft.A simple journal bearing consists of two rigid cylinders. Normally, the position of the journal center is eccentric with the bearing center. A lubricant fills the small annular gap or clearance between the journal and the bearing. The amount of eccentricity of the journal is related to the pressure that will be generated in the bearing to balance the vertical load. Hence, it is necessary to analyze the fluidfilm of lubricant using latest simulation software like COMSOL Multiphysics.

In the present work, a three dimensional CFD model is developed, using COMSOL multi-physics package, to study the behavior and the performance characteristics of a journal bearing lubricated with a lubricant. Generalized Reynolds equation is used to obtain the pressure distribution as well as load carrying capacity. This Reynolds equation is solved journal bearing theoretically and implemented in COMSOL to get the simulation results.

II. MODEL OF PLAIN HYDRODYNAMIC JOURNAL BEARING

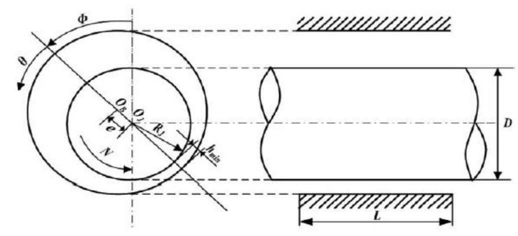


Figure 1. Co-ordinate and model of a plain hydrodynamic journal bearing

Fig. 1 shows the coordinate and the schematic of a simple plain journal bearing in a steady-state configuration. The plain journal bearing is immersed in water lubricant. The hydrodynamic action creates dynamic pressure in water lubricant, mainly in the convergent part of the journal-bearing gap, to counteract the load there by separating the journal surface l from the bearing surface with a thin water lubricant film. The hydrodynamic pressure ultimately terminates in the divergent part of the gap, and the pressure might go below the vapor pressure, and cavitation occurs. When steady state is reached, the journal is displaced from the bearing with a center distance (e), which is referred to the journal eccentricity. The eccentricity ratio(ε) and the clearance(C) are important measures of the load carrying capacity and pressure distribution of the journal bearing. With the help of these parameters, measure of the lubricant film thickness which separates the journal and the bearing is determined.

III. GOVERNING EQUATION

The hydrodynamic theory applied to the hydrodynamic lubricated bearing is mathematically explained by Reynolds's Equation. The classical theory of Reynolds is based on several assumptions that were adopted to simplify the mathematical derivations. The following are the basic assumptions of classical hydrodynamic lubrication theory i) the flow is laminar, ii) the fluid lubricant is continuous Newtonian, and incompressible, iii) there is no slip at the boundary, iv) the velocity component in y direction is negligible in comparison to the other two velocity components in the x and z directions, v) velocity gradients along the thin and z directions, are small and negligible relative to the velocity gradients across the film, vi) the effect of the curvature can be ignored, vii) the pressure variations in the y direction are very small and their effect is negligible in the equations of motion, viii) the force of gravity on the fluid is negligible, ix) fluid viscosity is constant.

The Reynolds equation for Newtonian incompressible and constant-viscosity fluid in a thin clearance between two rigid surfaces of relative motion is given by;

$$\frac{\partial}{\partial x}\left(\frac{h^3}{\mu}\frac{\partial p}{\partial x}\right)+\frac{\partial}{\partial z}\left(\frac{h^3}{\mu}\frac{\partial p}{\partial z}\right)=6U\frac{\partial h}{\partial x} \quad (1)$$

This is the common Reynolds equation is widely usedfor solving the pressure distribution of hydrodynamic bearings. Where, h is the variable film thickness is due to the journal eccentricity;

$$h(\theta) = C(1 + \varepsilon \cos\theta)$$

3.2 Parameters and Variables

3.2.1Parameters

The parameters used for analysis are given in Table 1.

Table 1. Parameters set for analysis

Na me	Expression	Description
R_j	25 mm	Journal radius
L	50 mm	Journal Length
c	50 µm	clearance
ome ga	1490/60*2*p i rad/s	journal angular velocity
ε	0.6	Eccentricity Ratio
µ	25[cP]	Oil Viscosity

3.2.2 Variables

The parameters used for analysis are given in Table 1.

Table 2. Variables set for analysis

Name	Expression	Description
θ	atan2(y, x)[rad]	angle along circumference
h	c*(1+ε*cos(θ))	lubricant film thickness
u	-omega*R*sin(θ)	x-component of journal velocity
v	omega*R*cos(θ)	y-component of journal velocity

3.3 Material Properties and Boundary Conditions

3.3.1 Material Properties

Oil Lubricant is used for lubrication. The density and dynamic viscosity of water are 860 kg/m3and 25[cP]respectively.

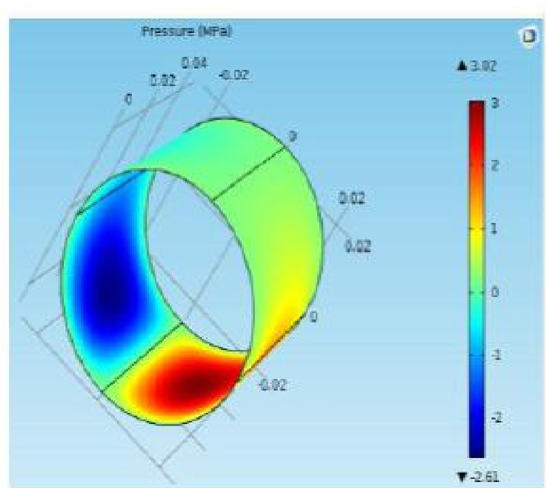
3.3.2 Boundary conditions

The governing equations are solved in steady state, taking no account of gravity force, and the operating pressure is set to 1atm. The boundary conditions of the inlet and outlet are respectively “pressure inlet” and “pressure outlet” with gauge pressure at zero Pascal. The inner surface of the water film is modeled as “sliding wall” with an absolute rotational speed which equals the velocity of the journal.

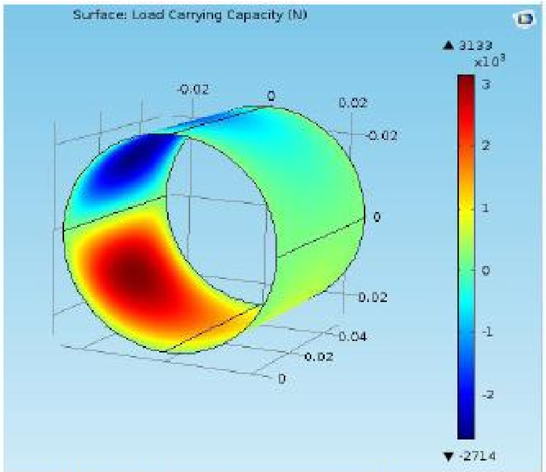
3.4Analysis

3.4.1 Analysis of smooth surface journal bearing

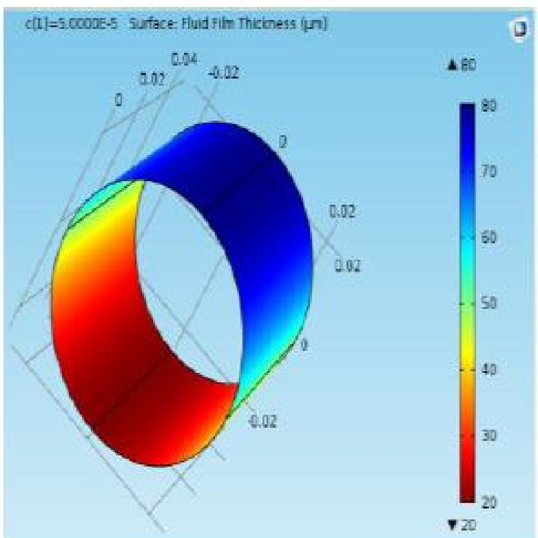
In the analysis of smooth surface journal bearing, fluid film pressure and load carrying capacity is studied at different journal speed, eccentricity ratio, clearance and oil viscosity. Fig.3 (a) and 3 (b) shows fluid film pressure distribution and load carrying capacity. The red zones are the maximum positive pressure and support to external load. Fig. 3(c) shows minimum film thickness. The red zone is for minimum film thickness. These numerical results are compared with theoretical results and results are showing good agreement as shown in Table 3



(a) Fluid film pressure (P_{max})



(b)Load carrying capacity (W)



(c)Minimum film thickness (h_{min})

Fig. 2. Numerical analysis of smooth surface journal bearing at eccentricity ratio (ε=0.6)

IV. RESULTS AND DISCUSSION

The performance characteristics of a hydrodynamic journal bearing are analyzed and discussed in this section. In the first stage, the numerical results are compared with theoretical results of smooth surface journal bearing and it is found that the results are quite agreeable in trends In the second stage, various characteristics like maximum fluid film pressure and load carrying capacityare studied under various operating conditions like at different speed (RPM), eccentricity ratio (ε), clearance (c) and oil viscosity (μ).

Table 3: Performance characteristics of smooth surface journal bearing

Characteristics	Theoretical Results	Simulation Results
Maximum Pressure (P_{max}) in MPa	3.08	3.01
Load Carrying Capacity (W) in N	3200	3133.25
Minimum Film Thickness (h) in μm	20	20

4.1Maximum film pressure (Pmax)

The fluid film pressure is examined under different journal speed, eccentricity ratio, clearance and oil viscosity.

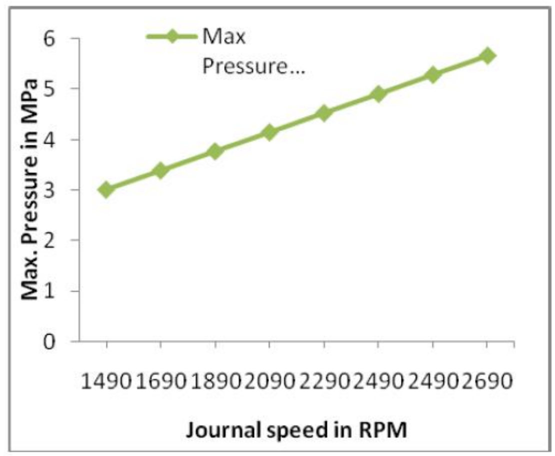


Fig.3: Effect of journal speed on fluid film pressure development

Given the fixed eccentricity ratio ε = 0.6, simulations with different journal speed were performed and the fluid film pressure are plotted for different configurations shown in fig. 3. From Fig. 3, it is seen that as the journal speed increases, the fluid film pressure increases.

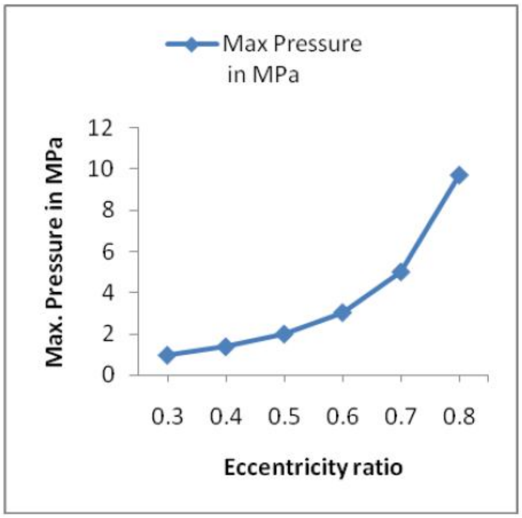


Fig.4: Effect of eccentricity ratio on fluid film pressure development

Similarly the film pressure developed for different configurations are plotted with increasing eccentricity ratio (ε). Fig. 4 shows that with increase in eccentricity ratio from 0.3 to 0.6, the fluid film pressure. The maximum pressure is observed in journal bearing with eccentricity ratio 0.6

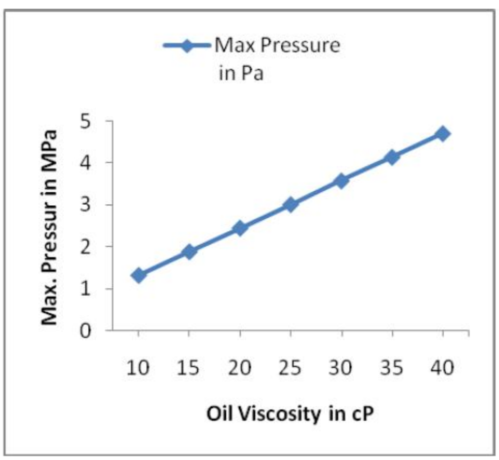


Fig.5: Effect of oil viscosity on fluid film pressure development

Fig. 5 demonstrates the effect of different oil viscosity values on pressure development in journal bearing. It is observed that, as oil viscosity increases, film pressure increases. Also it is observed that, minimum pressure is developed in journal bearing with oil viscosity 10cP.

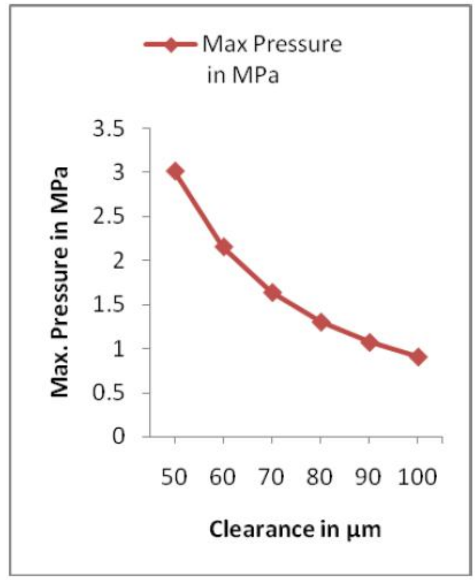


Fig.6: Effect of clearance on fluid film pressure development

Fig. 6 examines film pressure distribution of journal bearing with different configurations corresponding to different clearances. It is very clear that, with increase of clearance (c), the hydrodynamic pressure continuously reducing.

4.2 Load carrying capacity (W)

The load carrying capacity is examined under different journal speeds, eccentricity ratio, clearances and oil viscosities.

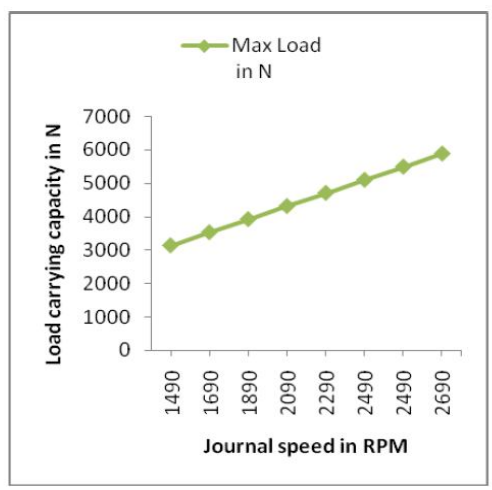


Fig.7: Effect of journal speed on load carrying capacity

Given fixed eccentricity ratio (ε = 0.6), performance characteristic like load carrying capacity is analyzed corresponding to various values of journal speed. From Fig. 7 it is clear that, with the increase of journal speed, the load carrying capacity continuously increases

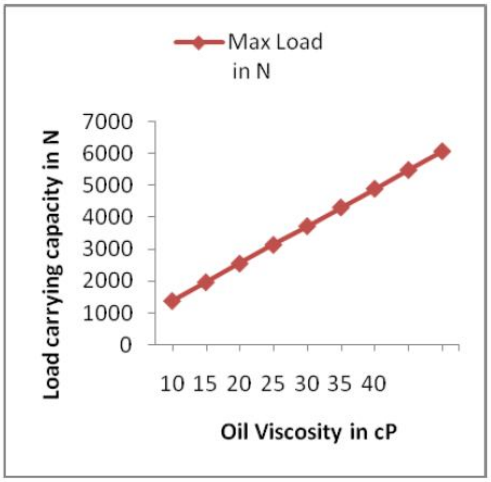


Fig.8: Effect of oil viscosity on load carrying capacity

From Fig 8, it is observed that, load carrying capacity increases with increase in oil viscosity. The load carrying capacity is more in journal bearing with oil viscosity 40 cP.

V. CONCLUSION

The pressure development and load carrying capacity of the hydrodynamic journal bearing lubricated with oil under steady state is analyzed. Based on the results and discussion, following conclusions can be made for journal bearing studied. Using Reynolds equation, present model of smooth surface journal bearing is simulated and compared with theoretical results and found to be in good agreement with less than 3% error. In the analysis of journal bearings influence of different journal speed, eccentricity ratio,clearance and oil viscosity on performance characteristics like pressure distribution and load carrying capacity etc. are studied. From analysis, it is found that maximum film pressure developed for high journal speed, less clearance, more eccentricity ratio and more oil viscosity.Also it is found that maximum load carrying capacity occurred at high viscosity and high journal speed.

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