CFD Analysis of Conical Shape Journal Bearing under different Operating Conditions

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Abstract- *In this paper, Computational Fluid Dynamic analysis (CFD) of conical shape hydrodynamic journal bearing is carried out by using COMSOL Multiphysics 5.0 software. Bearing performance analysis is numerically carried out by using the thin film flow physics of COMSOL Multiphysics 5.0 software. The effects of operating parameters like different journal speed, top radius of cone, eccentricity ratio and clearances on the bearing performance parameters viz. fluid film pressure, load carrying capacity and fluid film thickness are studied in detail. A simulation result shows that the fluid film pressure and load carrying capacity increases with increase in the journal speed and eccentricity ratio. It is observed that, fluid film pressure and load carrying capacity decreases with increase in top radius of cone and clearance between journal and bearing. It is also observed that, fluid film thickness is minimum at low eccentricity ratio which helps to increase load carrying capacity.*

Keywords- Pressure development, load carrying capacity, Numerical analysis, etc

1. INTRODUCTION

Now a day, there are a lot of demands to provide the need for high speed applications; hybrid journal bearings are most suitable for high load carrying capacity and long life. Conical journal bearing is a radial–axial hybrid bearing which offers different advantages over the plain journal bearing. The main advantage of the conical shape journal bearing is that it carry radial as well axial load at a time, in this manner eliminating the need for separate thrust and plain journal bearing. Conical shape journal bearing are applied both in low speed heavy load machine and high speed high precision machine. Most of the researchers were very much attracted in investigating the theories and experiments of hydrodynamic lubrication and paid no attention to how to improve load carrying capacity of a hydrodynamic journal bearing. Reduction of environment pollution and energy saving are important issues in machine design (Xiaolei Wang, and Koji K, 2003). Water-lubrication system is convenience, green, safe and energy saving. The application of water-lubricated journal bearings is wide spread, such as ship building, transportation industry, food industry, industrial machinery and equipment, and pharmaceutical industry (Santos and Blanco, 2012). The drawback of water as a lubricant is that its viscosity is much lower than that of oil and other lubricants (Yamakiri and Sasaki, 2011). Most of the study is available on plain journal bearing. Therefore, to improve the performance of journal bearing, conical shape configuration is considered for analysis.

The conical journal bearing is immersed in lubricant. The hydrodynamic action creates dynamic pressure in lubricant, mainly in the convergent part of the journal-bearing gap, to counteract the load there by separating the journal surface from the bearing surface with a thin 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.

2. CFD MODEL—ANALYSIS (SIMULATION MODEL)

2.1 GOVERNING EQUATIONS

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;

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

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;

$$h(\theta) = C(1 + \varepsilon \cos\theta) \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots 2$$

2.2 PARAMETERS AND VARIABLES

3.2.1 PARAMETERS

The parameters used for analysis are given in Table 1.

Table 1: Parameters set for analysis

Name	Expression	Value	Description
E	0.4	0.40000	Eccentricity ratio
R1	12[mm]	0.012000 m	Journal base side radius
H	26[mm]	0.026000 m	Journal height
c	70[um]	7.0000E-5 m	Clearance between the bearing and the journal
RPM	1000/60[s]	16.667 1/s	Journal Speed In RPM
omega	RPM*2*pi[rad]	104.72 rad/s	Journal angular velocity
visc	800[cP]	0.80000 Pa·s	Viscosity of fluid
den	860[kg/m^3]	860.00 kg/m³	Density of fluid
R2	14[mm]	0.014000 m	Journal top side radius

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

3.2.3 GEOMETRY

All the geometric information of conical shape journal bearing is mentioned in table no.1

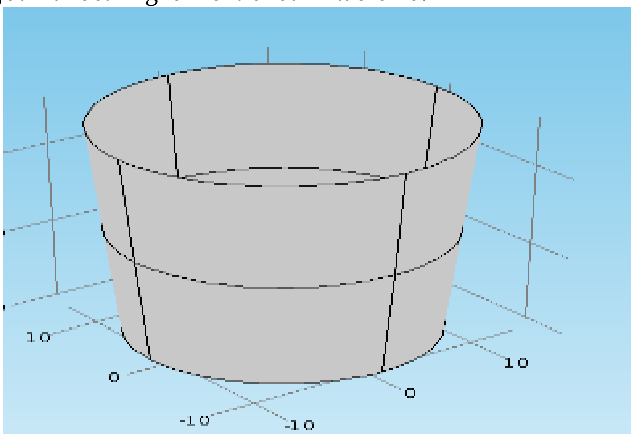


Fig 1: geometry

3.3 MATERIAL PROPERTIES AND BOUNDARY CONDITIONS

3.3.1 MATERIAL PROPERTIES

Oil Lubricant is used for lubrication. The density and dynamic viscosity of lubricant are 860 kg/m^{3}and 800 [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.

3.4 MESHING

Conical shape journal bearing model is meshed by using mapped mesh with quadrilateral mesh elements. The minimum element quality is 0.99. The minimum growth rate is 1 as well as average growth rate is also 1.

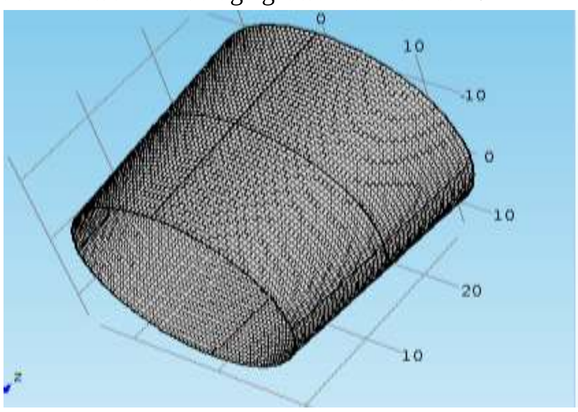
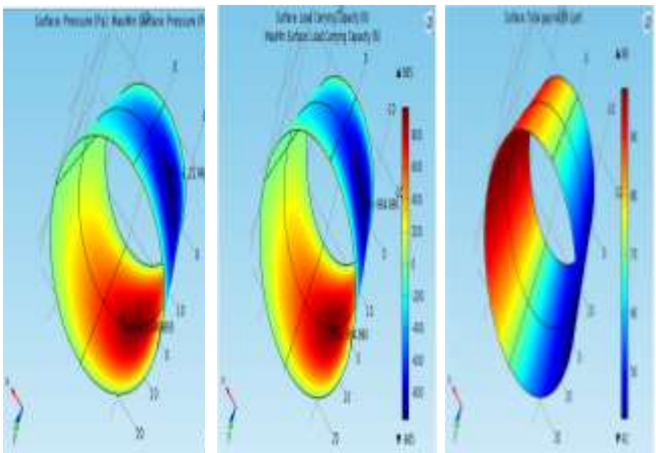


Fig 2 : Conical shape journal bearing

3.5 ANALYSIS

3.5.1 ANALYSIS OF CONICAL SHAPE JOURNAL BEARING

In the analysis of **conical shape** journal bearing, fluid film pressure load carrying capacity is studied at different top size radius, eccentricity ratio, journal speed and clearance. Also the minimum fluid film thickness is studied at different eccentricity ratio. Fig.3 (a) and 3 (b) shows fluid film pressure distribution and load carrying capacity at fixed eccentricity ratio of 0.4. The red zones are the maximum positive fluid film 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 results are shown in Table 3.



a)Fluid film pressure (P_{max}) b)Load carrying capacity(w) Minimum film thickness (h_{min})

Fig. 3. Numerical analysis of conical shape journal bearing at eccentricity ratio (ε=0.4)

4. RESULTS AND DISCUSSION

The performance of a conical shape journal bearing are analyzed and discussed in this section. In the CFD analysis various characteristics like maximum fluid film pressure and load carrying capacity are studied under various operating conditions like at different top side radius (R2), speed (RPM), eccentricity ratio (ε) and clearance (c).

Table 3: Performance characteristics of conical shape journal bearing

Characteristics	**Simulation Results**
Maximum Pressure (P_{max}) in MPa	3.18
Load Carrying Capacity (W) in N	964
Minimum Film Thickness (h) in µm	42

4.1MAXIMUM FILM PRESSURE (P_{MAX})

The fluid film pressure is examined under various operating conditions like journal speed, eccentricity ratio, clearance and top side radius of cone.

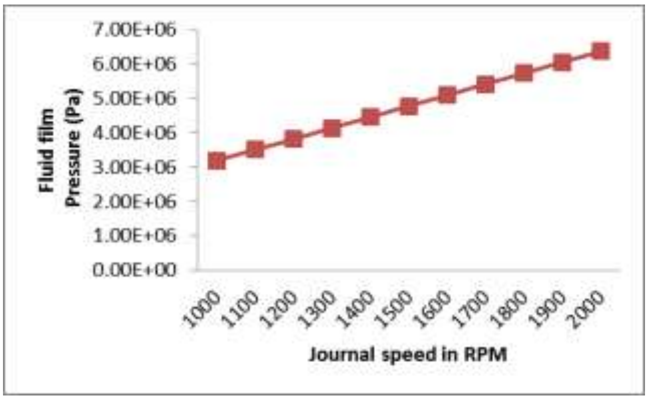


Fig.4: Effect of journal speed on fluid film pressure development

Given the fixed eccentricity ratio ε = 0.4, 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. It is clear that, the maximum pressure is developed at conical shape journal bearing with 2000 RPM.

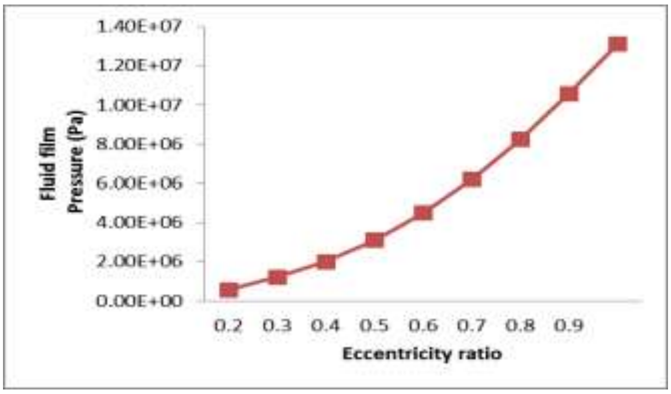


Fig.5: Effect of eccentricity ratio on fluid film pressure development

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 0.2 to 0.9, the fluid film pressure increases exponentially. The maximum pressure is observed in journal bearing with eccentricity ratio 0.9.

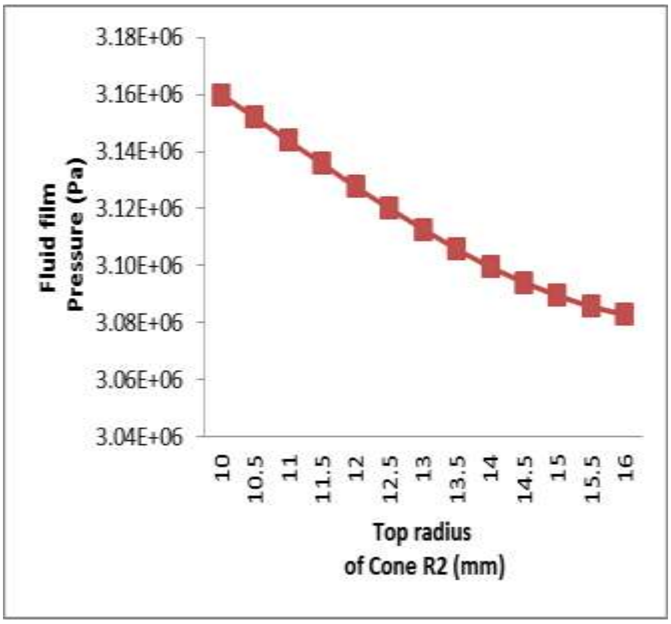


Fig.6: Effect of top radius of cone on fluid film pressure development

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

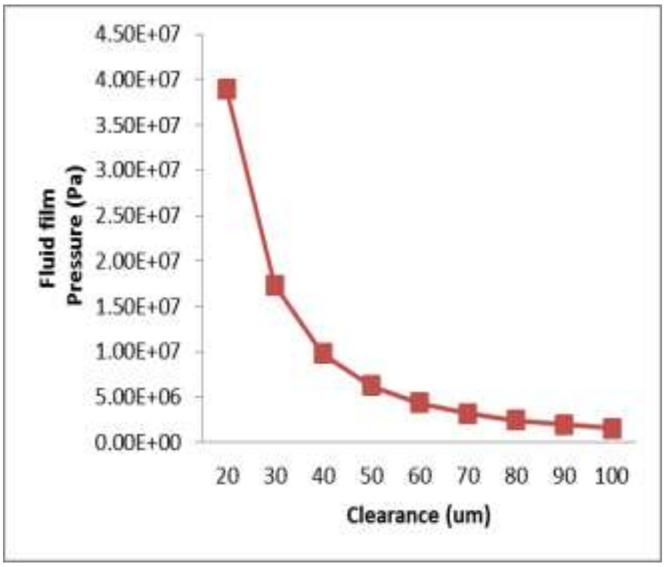


Fig.7: Effect of clearance on fluid film pressure development

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 nonlinearly. The maximum fluid film pressure is achieved at 20 um clearance between journal and bearing.

4.2 LOAD CARRYING CAPACITY (W)

The load carrying capacity is examined under different journal speeds and tor radius of cone.

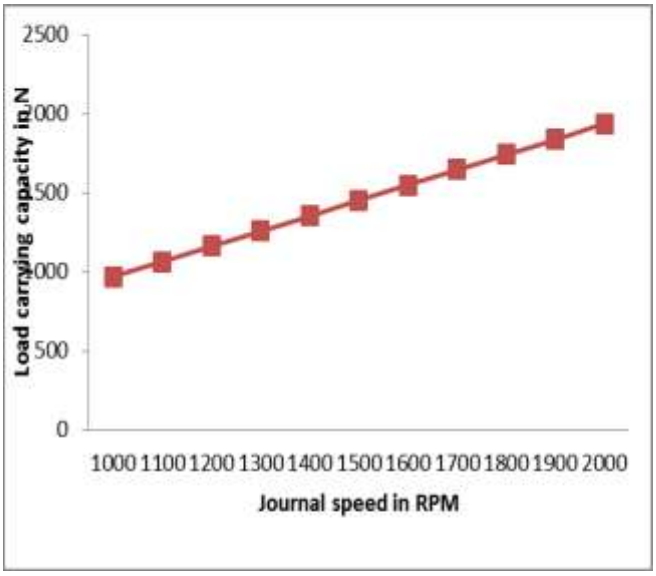


Fig.8: Effect of journal speed on load carrying capacity

Given fixed eccentricity ratio (ε = 0.4), 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 linearly. The maximum load carrying capacity is achieved at 2000 RPM of journal speed.

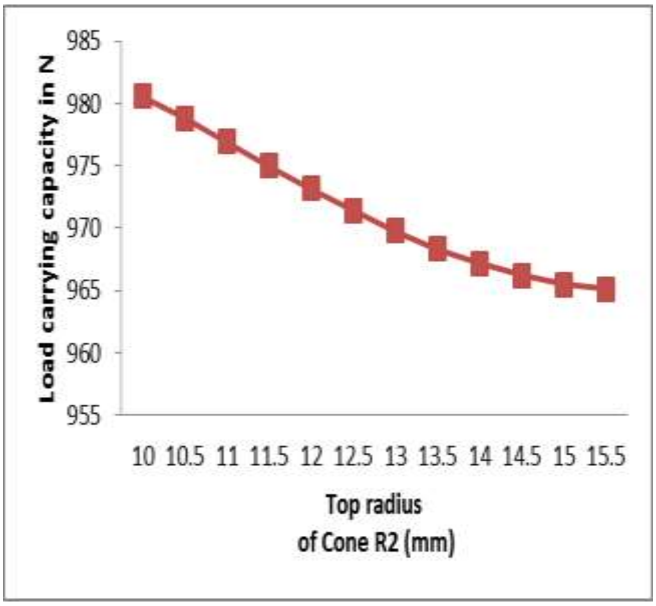


Fig.9: Effect of top radius of cone (R2) on load carrying capacity

From Fig 8, it is observed that, load carrying capacity increases with decrease in top radius of cone. The load carrying capacity is more in journal bearing with 10 mm top radius of cone. The minimum load carrying capacity is developed at 15.5mm radius of top side of cone.

4.3 MINIMUM FLUID FILM THICKNESS

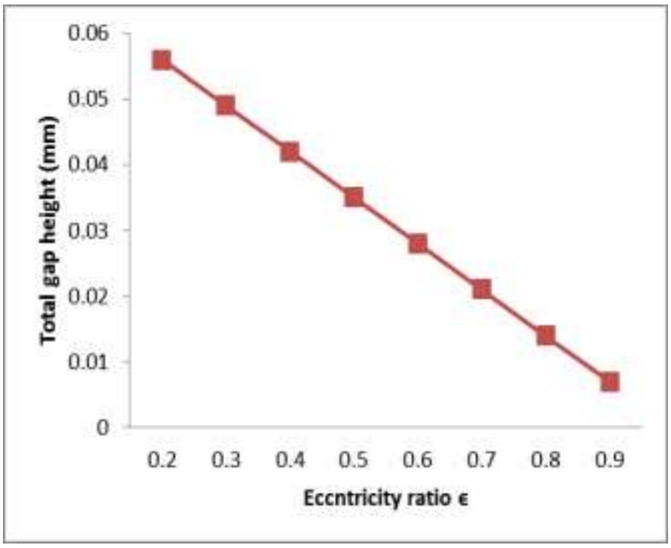


Fig.10: Effect of eccentricity ratio on fluid film thickness

The effect of eccentricity ratio on fluid film height is studied as shown in figure 9. From figure, it is clear that, as eccentricity ratio increases, fluid film thickness decreases which results in increase in fluid pressure as well as load carrying capacity. The maximum fluid film thickness is observed at 0.2 eccentricity raio.

5. CONCLUSION

The fluid film pressure distribution and load carrying capacity of the hydrodynamic journal bearing lubricated with oil under steady state is analyzed. Based on the numerical results, following conclusions can be made for conical shape journal bearing studied. Using Reynolds equation, present model of conical shape journal bearing is simulated. In the analysis of conical shape journal bearings, influence of different journal speed, eccentricity ratio, clearance and top side radius of cone on performance characteristics like fluid film pressure distribution and load carrying capacity etc. are studied. From analysis, it is found that maximum fluid film pressure developed for high journal speed and more eccentricity ratio. Also it is found that maximum load carrying capacity and pressure occurred at less top radius of cone and less clearance.

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