Numerical Analysis of Static Characteristic of Hydrodynamic Journal Bearing With Dimples

Charanraj K[1], Dr.M.Nataraj[2]
[1, 2] Dept of Mechanical
[1, 2] Government college of technology,coimbatore

Abstract- *In this study an attempt has been made to replace the existing white material with the surface textured brass material in hydrodynamic journal bearing. Surface texturing in terms of topographical modification and design have been discussed to eliminate friction and improving hydrodynamic performance at the oil lubricated interface. The texture will act as the reservoir for oil trap and also generate hydrodynamic pressure. Numerical solution of hydrodynamic lubrication is obtained by finite volume approach followed by numerical investigation of static characteristics of textured journal bearing under the hydrodynamic lubrication regime.*

Keywords- hydrodynamic, journal bearing, finite volume method.

I. INTRODUCTION

Hydrodynamic journal bearing is used in many rotary machines like pump, compressors, internal combustion engines etc. as it is suitable for moderate load carrying capacity, possessed better hydrodynamic performance and vibration damping. The oil film between the journal and the bearing sustain the given load eliminating the metal to metal contact. The oil film is generated in bearing surface when the shaft rotates. If the shaft is rotating in low speed during start and finish then adequate oil film cannot be formed. The contact between the journal and bearing surface is covered by thin layer of soft material called white metal along the axis.

Surface texturing is the phenomenon which enhance the hydrodynamic performance of lubrication, so that researchers have done both analytical and experimental studies for last decades many researchers used different models of surface texturing (dimple model, groove model, sinusoidal model, etc.) to improve the load carrying capacity as well as pressure distribution and reduces hydrodynamic friction coefficient from a the designer's perspective, a journal bearing must support the required load by occupying minimum space with minimum energy loss and slow wear out.

II. REYNOLDS EQUATION

The Reynolds equation is solved for a given bearing configuration to obtain bearing performance including pressure and film thickness distribution, film stiffness, fluid flow rate and viscous shear forces, viscous loss, and temperature rise. Numerical methods are used for the solution of real bearing configurations. Analytical solutions can only be obtained for very simple cases. For an infinitely wide bearing, side flow can be neglected. In addition to this simplification, it is assumed that the pressure and temperature effects on viscosity and density can be neglected. Liquids are essentially incompressible and their density can be assumed to be independent of pressure. For these simplifications, closed-form analytical solutions can be obtained. Analytical solutions for various thrust bearing configurations and a journal bearing are presented first, followed by limited details on numerical solutions of finite-width bearings and gas (compressible fluid) bearings.

$$\frac{\partial}{\partial x}\left(\frac{h^3}{\eta}\frac{\partial p}{\partial x}\right)+\frac{\partial}{\partial y}\left(\frac{h^3}{\eta}\frac{\partial p}{\partial y}\right)=12\,\bar{u}\,\frac{\partial h}{\partial x}$$

III. NUMERICAL PROCEDURE

The approach will be described for the one-dimensional version of the Reynolds equation. Given a discretization of a 1D domain, x_{i-1}; x_i; x_{i+1}, the starting point for obtaining the finite volume discretized form of the second-order partial differential equation is the conservation of the flux q at each discretization cell boundary. For a continuous film thickness this results in

$$q_{i+1/2}-q_{i+1/2}=0$$

$$q_{i+1/2}=\frac{h^3}{12\mu}\frac{p_{i+1}-p_i}{x_{i+1}-x_i}+\left(\frac{Vh_{i+1/2}}{2}\right)$$

$$q_{i-1/2}=\frac{h^3}{12\mu}\frac{p_i-p_{i+1}}{x_i-x_{i+1}}+\left(\frac{Vh_{i-1/2}}{2}\right)$$

This consistency rule then leads to the following discretized equation,

$$t_i P_i = t_{i+1} P_{i+1} + S_i$$

where

$$t_i = \frac{\frac{h^3}{12\mu}_{i+1/2}}{x_{i+1} - x_i} + \frac{\frac{h^3}{12\mu}_{i-1/2}}{x_i - x_{i-1}}$$

$$t_{i+1} = \frac{\frac{h^3}{12\mu}_{i+1/2}}{x_{i+1} - x_i}$$

$$t_{i-1} = \frac{\frac{h^3}{12\mu}_{i-1/2}}{x_i - x_{i-1}}$$

$$S_i = -\left(\frac{V(h_{i+1/2} - h_{i-1/2}}{2}\right)$$

The coefficients of the discretized equation are always positive, t_i ; $t_{i\pm1} > 0$ and (with the exception of the domain boundaries) the main diagonal coefficient is always the sum of neighboring coeffcients, $t_i = t_{i+1} + t_{i-1}$. One of the concerns when introducing the film thickness discontinuity is that the resulting system of discretized equations obeys the same rules.

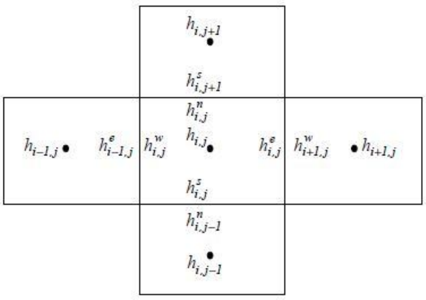


Figure 1

Figure 1 presents a one-dimensional film with thickness discontinuities and its finite volume disretization. As a basic rule it is considered that the discontinuity should always coincide with a discretization cell boundary. It is also a necessary condition that, in a finite volume approach, the discretization pattern is given by the cell boundaries, which must cover all the domain without super-posing, and not by the nodes, which can be located (at least theoretically) anywhere inside the cell. In a classic approach, pressures are defined at nodes. In order to take into account discontinuities, the present approach also introduces supplementary pressures defined on the cell boundaries, on each side of the step. Film thickness is also defined at the cell center and on its boundaries. Discontinuities are thus included in the discretization. The approach can be rendered very natural by replacing the arrays of node-related values by arrays of derived type (sometimes called structures). Each term of derived type array will have one component related to the node value and many components related to each boundary. For the one-dimensional example, pressure and film thickness in cell i are characterized by $(P, P^w; P^e)_i$ and by $(h; h^w; h^e)_i$, respectively.

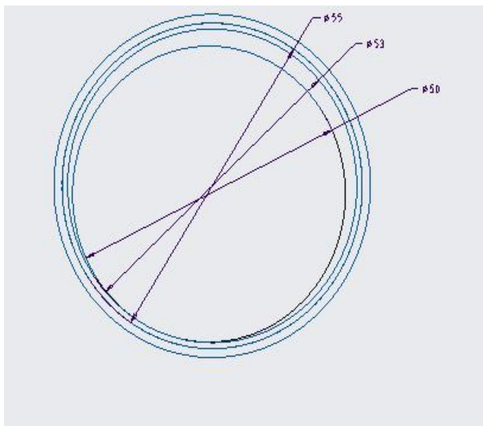
IV. JOURNAL BEARING SPECIFICATION

The numerical procedure for the below mentioned bearing is obtained by finite volume approach using MATLAB

Table 1 Specification of journal bearing

PARAMETER	PLAIN BEARING	ST1	ST 2
diameter(D)mm	55	55	55
length(l) mm	50	50	50
maximum clearance(mm)	2.5	2.5	2.5
dimple diameter(d) mm	-	0.5	2

MODEL OF THE JOURNAL BEARING



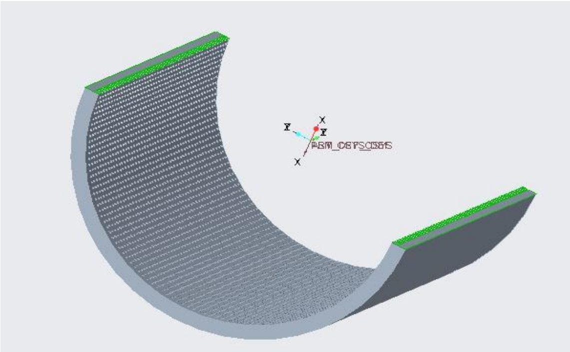


Fig.1 Journal bearing

V. NUMERICAL RESULTS

The above mentioned finite volume method is used to solve the two dimensional Reynolds equation governing the hydrodynamic lubrication in bearing. The pressure at the each control volume is determined. The center of the circular dimple coincide with the center of the control volume. The solution for the three different cases of bearing plain, surface textured-1 and surface textured-2. The solution with negative pressure is equated to zero, which is equivalent to Reynolds boundary conditions. Converged solution is obtained for the pressure distribution which is usually parabolic in nature

Using the pressure distribution the horizontal and the vertical load is calculated at the oil-film. The results obtained in figure 1 shows that cente of loci of journal bearing for three cases of bearing. The figure 2 illustrates the variation of eccentricity ratio with respect to the sommerfeld number. The figure 3 illustrates the variation of the attitude angle with respect to the sommerfeld number.

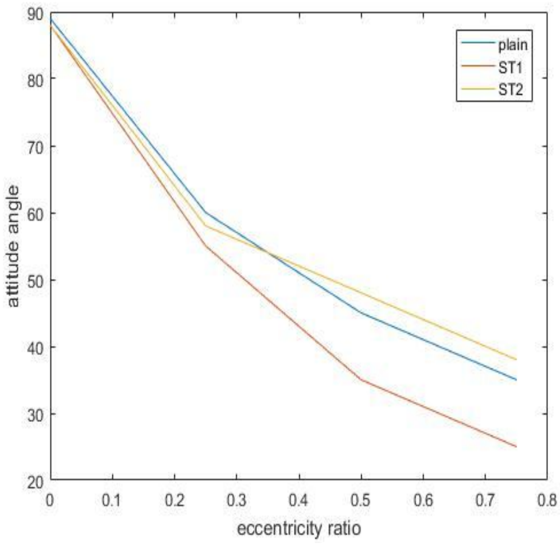


Fig.2 eccentricity ratio vs attitude angle

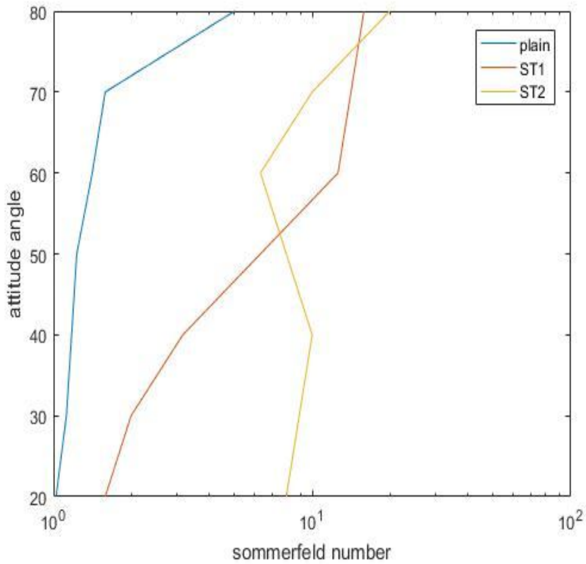


Fig.3 Attitude angle vs sommerfeld number

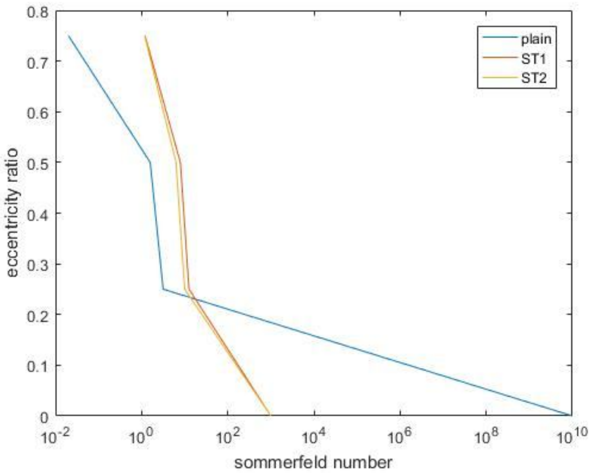


Fig.4 eccentricity ratio and sommerfeld number

The two surface textured bearing are found to have higher eccentricity ratio compared to the plain bearing .considering the results of surface textured bearing-1 which has higher eccentricity ratio and lower attitude angle compared to the surface textured-2

VI. CONCLUSION

The static characteristics of journal bearing with circular dimples were numerically investigated. The characteristics includes ecccentricity ratio , attitude angle and sommerfeld number. The analysis shows that the surface textured bearing-1 has higher eccentricity ratio and lower attitude angle for the same range of sommerfeld number. The centre loci of the journal bearing starts to move towards the loadline. The effect of surface texturing is more in bearing with large number of dimples. The numerical model of Reynolds equation was solved using finite volume method and static characteristics of bearing were found in this study further the shape of the surface texture can be varied.

REFERENCES

[1] Shahab Hamdavi, H. H. Ya and T. V. V. L. N. Rao,2016, "Effect of surface texturing on hydrodynamic performance of journal bearings" APRN journal of engineerring and applied sciences,vol11.

[2] H. Hirani, T. V. V. L. N. Rao, K. Athre and S. Biswas, 1997 "Rapid performance evaluation of journal bearings" Elsevier science vol 30,NO.11, pp 825-834

[3] Mihai Arghir , Ahmad Alsayed, Daniel Nicolas,2002,"The finite volume solution of the Reynolds equation of lubrication with film discontinuities" International Journal of Mechanical Sciences 44 (2002) 2119 – 2132

[4] Gupta, K. K., Kumar, R., Kumar, H., and Sharma, M., 2013, “Study on Effect of Surface Texture on the Performance of Hydrodynamic Journal Bearing,” Int.J. Eng. Adv. Technol., 3(1), pp. 49–54.

[5] Arghir, M., Alsayed, A., and Nicolas, D., 2002, “The Finite Volume Solution of the Reynolds Equation of Lubrication With Film Discontinuities,” Int. J. Mech. Sci., 44(10), pp. 2119–2132

[6] Castelli V, Pirvics J.1996 Review of numerical methods in gas bearing lm analysis. Journal of Lubrication Technology, ASME;99(4):777–92.

[7] James DD, Potter AF.1967 "Numerical analysis of the gas-lubricated spiral-groove thrust-bearing compressor", Journal of Lubrication Technology, ASME ;89(4):439–44.

[8] Reddi MM. 1969 "Finite element solution of the incompressible lubrication problem. Journal of Lubrication Technology", ASME;91(3):524–33.

[9] Zuk J.,1967" Compressible seal 8ow analysis using the finite element method with the Galerkin solution technique", ASLE Transactions;19(1):61–71.

[10] Bonneau D, Absi J.1994" Analysis of aerodynamic journal bearings with small number