An Analysis of 180 Degree Partial Arc Orifice Compensated Hydrostatic/Hybrid Journal Bearings

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Abstract— *The dissertation report presents a theoretical analysis to investigate the influence of non-Newtonian pseudo-plastic and dilatant lubricant behaviour on 180 degree partial arc orifice compensated hydrostatic/hybrid journal bearings performance characteristics. An approximate solution for bearing performance characteristics has been computed from Reynolds's equation using Finite Element Method technique, considering non-Newtonian power law model. The computed approximate solution shows that all the performance parameters such as minimum fluid film thickness, load carrying capacity, stiffness and damping of fluid etc. are affected by powerlaw index (n).*
Keywords— Non-Newtonian, orifice, hydrostatic/hybrid, Finite Element Method.

I. LITERATURE REVIEW

To study the impact of non-Newtonian fluid on performance of partial contact hydrostatic/hybrid journal bearings. The literature review pertaining to these types of bearings was scanned. Since,during the last few decades, a very large number of studies concerning the hydrostatic/hybridjournal bearings had been done. Now some study related to these bearings discuss in the literature.
Study pertaining to impact of non-newtonian fluids on journal bearings:
R. Sinhasan et al. presented a computer-aided study of transient behavior of full journal bearings. Non-Newtonian fluid was used as lubricant. The flow field in the clearance space in full journal is represented by the continuity and momentum equations in cylindrical coordinates. These equations were solved by FEM. The non- Newtonian phenomenon is introduced by adding some additives. This thickens oil and it acts as pseudo-plastic or dilatant fluid. Cubic shear stress model was used for analysis. Trajectory motion obtained after solving non-linear equation of motion. In the results stability criteria of journal had been explained by graphically.
M. M. Khonsari et al. suggested a formulation and solution procedure by considering a proper rheological models that could be used for elastohydrodynamic lubrication problem with any non-
Newtonian equation. In this formulation viscosity is treated as scalar and a function of shear strain rate tensor. Equivalent viscosity and the shear strain rate is calculated by iterative manner.
R. Sinhasan et al. studied the transient results of a two-lobe hydrodynamic journal bearing lubricated with non-Newtonian lubricant. FEM is used to get solution of the momentum and continuity equations and then solution is more refined by iteratively. Cubic shear stress model for fluid was used for analysis and according to this model apparent viscosity is modified in each iteration. On the basis of present results journal started whirling at lower value of non-dimensional
mass compare to the critical mass.
R. Sinhasan et al presented a theoretical study of hydrostatic journal bearings compensated with orifice multi-recess restrictor. Lubricating fluid in bearing was act as non-Newtonian fluid.FEM was used to solve the generalized Reynolds having changeable viscosity. So, performance
characteristics of bearing was obtained. Viscosity of non-Newtonian fluid is represented by cubic shear stress law. Dynamic characteristics of hydrostatic journal bearing significantly influenced
Models of Non-Newtonian Lubricant
Studies [1,2,……23] about non-Newtonian lubricant have been shown that most of fluid follow cubic shear stress law and power low of shear strain. Appropriate constitutive relation for these
lubricant explained below:

II. CUBIC LAW MODEL

The cubic shear stress law gives a nonlinear relation between shear strain rate and shear stress for a non-Newtonian fluid. R. Sinhasan et.al [3], Jaw Ren Lin [6], Ji-Huan He [14] etc. had been used for the study of bearing performance. Cubic law models constitutive relation could be written as [19]

$$\bar{\tau} + \bar{K}\,\bar{\tau}3 = \bar{\gamma} \quad (3.12)$$

Power Law Model

Power law model gives shear stress which vary as some power of rate of shear strain and is written As $\square \; \square \; m(\square)n$ (3.13)

Where, 'n' and 'm' are power law and consistency index respectably.

If n=1, Lubricant terms as Newtonian (i.e. m=μ).

For n<1, it is known as pseudo-plastic fluid and its viscosity reduces as shear strain rate reduces.

For n>1, Lubricant becomes dilatant and viscosity increases as rate of shear strain increases.

The numerical value of $\square$ computed at every Gaussian point of elements and shear stress $\square$ is also estimated from appropriate equation of non-Newtonian lubricants. For above model Newton-

Raphson technique was used. Then apparent viscosity ($a\square$) can be easily calculated .

III. SOLUTION PROCEDURE

The solution scheme for partial journal bearing requires an iterative method to solve fluid flow equation. Orifice restrictor flow equation is used as constraint along with relevant boundary conditions to solve fluid flow equation. Nodal pressure is calculated for a tentative value of journal center coordinate $\square$, $\square$ *jjXZ*and iterative method is continued until the journal center equilibrium position is attained for a specified value of external load.The unit IDM reads 2D mesh and input data. After this the unit FFT calculates fluid film thickness at nodal point using for tentative value of $\square$, $\square$ *jjXZ* .In the next unit FLM, fluidity matrix for elements are generated and assembled. The unit BNDRY modifies the system equation by introducing boundary conditions relevant to the problem. In the unit SME, Gaussian elimination technique is used to solve modified system equations for calculating nodal pressure. In the next

unit EQL, the equilibrium position of journal center is obtained for specified external load and iterative procedure is continued until journal center equilibrium position is obtained. Then the next

unit PERCH calculates the static and dynamic performance characteristics of the partial journal bearing system.

IV. CONCLUSION

The analysis results shows that the non-Newtonian behaviour of the lubricants has significant

Influence on the performance of 180 degree partial arc orifice compensated hydrostatic/hybrid journal bearings. This result depicts the following conclusions:

1. For a 180 degree partial arc orifice compensated hydrostatic/hybrid journal bearings lubricated with non-Newtonian fluids (dilatant fluid) gives improvement in minimum fluid film

thickness of approximately 2.3% more than Newtonian fluid for power law index (n=1.2). Therefore there is less wear and frictional power loss in the bearing which results in improvement in bearing life.

2. Rise in maximum pressure in fluid film for this bearing is increases as applied load increases but is not much affected by non-Newtonian fluids.

3. Eccentricity ratio is decreased by around 9% for dilatant fluid (n=1.2). Therefore journal try to become concentric to bearing. So partial arc journal bearing can be operated at higher speeds and load for dilatant fluid (n=1.2) without much chances of whirl.

4. Power loss due to viscosity is reduced for dilatant fluid (n=1.2) compare to Newtonian and other non-Newtonian fluids. So operation cost is reduces.

5. Stiffness and damping of lubricant film are more for pseudo-plastic fluids (n=0.8) compare to other non-Newtonian fluids. So stability of journal is improved and operated at higher speed with less chance of whirl motion by using such lubricants.

On the basis of above conclusions, the current work suggests that if there is requirement of better static performance characteristics for 180 degree partial arc hydrostatics/hybrid journal bearings compensated with orifice restrictor then dilatant fluid (n=1.2) should be used as lubricant and for improvement in dynamic performance characteristics pseudo-plastic fluids (n=0.8) should be used.

V. FUTURE SCOPE

In this report, study on influence of non-Newtonian lubricant behavior on partial arc orifice compensated hydrostatic/hybrid journal bearings is presented. The study is carried out based on the shear stress and strain rate power law model of non-Newtonian fluids. The following works

can be carried out in the future based on the present work. The performance parameters of the bearing can be computed by using cubic shear stress law of non-Newtonian lubricants and compared with power law model to check its influence on the performance of bearing.

1. For more realistic computation of performance parameters, viscosity variation due to temperature and pressure of non-Newtonian lubricants can also be considered in the model.

2. Also deformation and elastic property of bearing shell can be included in the model to obtain more accurate performance parameter.

3. More realistic performance analysis of partial arc journal bearings can be carried out by including the factors such as surface roughness and wear effect in the model.

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