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CFD Analysis on Hydrodynamic Plain Journal Bearing using Fluid Structure Interaction Technique

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***Abstract-*. Hydrodynamic journal bearings are critical power transmission components that are carrying increasingly high loads because of the increasing power density in various machines. Therefore, knowing the true operating conditions of hydrodynamic journal bearings is essential to machine design.Oil film pressure is one of the key operating parameters describing the operating conditions in hydrodynamic journal bearings.Hydrodynamic journal bearings are analyzed by using Computational fluid dynamics (CFD) and fluid structure interaction (FSI) approach in order to find deformation of the bearing. Journal bearing models are to be developed for eccentricity ratios to study the interaction between the fluid and elastic behaviour of the bearing.The deformations of the bearing is significant and should be considered in order to predict accurate performance of the hydrodynamic journal bearings.The work focused onto the modeling of journal bearing by using pro-e for different eccentricity ratios and similations are carried out to determine the pressure,stress and deformation of plain journal bearing by CFD fluid structure interaction approach. It is observed that CFD-FSI method provides a useful platform to study the combined effect of hydrodynamics and elastic behaviour of the bearing. It is observed that the deformations of the bearing are significant and should be considered in order to predict accurate performance of the hydrodynamic journal bearings.**

***Index Terms-* *Journal bearings,Fliuid structure interaction,pressure,stress,deformation*.**

I. INTRODUCTION

Hydrodynamic type journal bearings are considered to be a vital component of all rotating machinery whose function is to support an applied load by reducing friction between the relatively moving surfaces. A journal bearing consists of a circular shaft, called the journal, is made to rotate in a fixed sleeve is called the bearing. The bearing and the journal operates with a small radial clearance of the order of 1/1000th of the journal radius. The clearance space between the journal and the bearing is assumed to be full of the lubricant. The radial load squeezes out the oil from the journal and bearing face and metal-to-metal contact is established. When the journal begins to rotate inside the bearing, it will climb the bearing surface and as journal speed is further increased; it will force the fluid into the wedge-shaped region. Since more and more fluid is forced into the wedge-shaped clearance space, which begins to exert pressure with increasing journal speed.

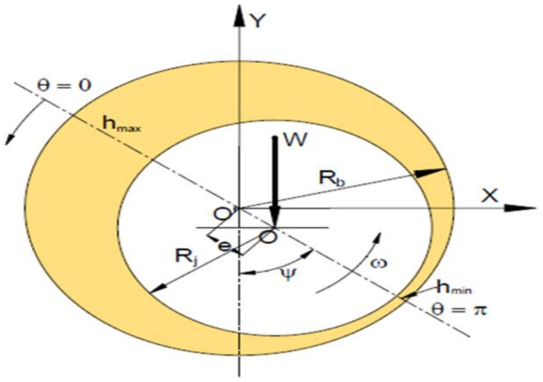

Fig 1. Schematic of Journal bearing geometry

At a particular speed, the pressure becomes enough to support the load and the closest approach between journal and bearing where the oil film thickness is the minimum. A condition of perfect lubrication will exit when minimum oil film thickness is greater than the quantity dependent on the nature of the irregularities of the contacting surfaces. The value of minimum oil film thickness, the angle between the line of center with the vertical is called the attitude angle and the location of the maximum film pressure is important considerations in journal bearing lubrication. Load carrying capacity of journal bearing is dependent on pressure in layer of lubricant during rotation of shaft. Now-a-days the research is focused on increasing the output of the internal combustion engine and to reduce their weights. Hence bearing housing of the connecting rod big end bearings and main bearings are subjected to severe operating conditions. The increase in bearing loads and desire to reduce the dimensions and component masses in modern combustion engines leads to substantial elastic deformations in the connecting rod and main bearings which alternatively affects the properties of the lubricating fluid and henceforth the performance. In such applications, the conventional assumption of rigid bushing fails to predict the accurate performance of the bearing and hence the combination of hydrodynamic lubrication with the structural analysis.

II. LITERATURE SURVEY

The performance characteristics of journal bearing are investigated by means of three-dimensional computational fluid dynamics analysis. The three dimensional Navier Stokes compressible equations were integrated to simulate the flow. Turbulence effects were considered in the computation of unsteady transient analysis of journal bearing, taking into account gravity. The Journal bearing is designed in Gambit software. The journal is modeled as a “moving wall”with rotational speed of 3000rpm. The flow is simulated by using ANSYS Fluent software. Design parameters like relative eccentricity, dimensionless load carrying capacity, dimensionless wall shear stress, Reynolds number, Sommerfeld number, friction coefficient, strain rate, pressure distribution, temperature distribution and lubricant flow properties like turbulent viscosity, and velocity magnitude are considered for the analysis. It is assumed that the flow of lubricant is laminar as well as isothermal. Unsteady transient analysis is carried out for the journal bearing with various L/D ratios of 0.25, 0.5, 1, 1.5, and 2 and the corresponding results: relative eccentricity vs. Sommerfeld number, Dimensionless load carrying capacity vs. relative eccentricity, and dimensionless friction coefficient vs. relative eccentricity are presented in this journal [7]. COMSOL Multiphysics 4.3a software is used for 3D model of hydrodynamic plainjournal bearing and pressure distribution in plain journal bearing is obtained by steady state analysis. Generalized Reynolds equation is used for analyzing hydrodynamic journal bearing by COMSOL as well as by analytical method by applying Sommerfeld boundary conditions. This Reynolds equation is applied for two theories of hydrodynamic journal bearing called infinitely short journal bearing and infinitely long journal bearing. Results for pressure distribution obtained by COMSOL simulation are compared with analytical results shows that the solutions are approximately similar to the analytical solutions[9].The performance characteristics and the core formation of a hydrodynamic journal bearing lubricated with a Bingham fluid are derived by means of threedimensional computational fluid dynamics analysis. The Navier–Stokes equations are solved using the FLUENT. Three-dimensional computational fluid dynamics model are found to be in very good agreement with experimental and analytical data from previous investigations on Bingham fluids. The validated Computational Fluid Dynamics (CFD) model is used to extract a series of diagrams in the form of the Raimondi and Boyd graphs and can be use in the smart bearing design [8]. The thermoelastohydrodynamic study for analysis of elliptical journal bearing (Two-lobe) operating with Newtonian lubricant has been presented and thermoelastic deformations of the solid parts are taken into account. To solve the Reynold's equation generalized form, equation of energy and the displacement field, respectively, using two numerical techniques Computational Fluid Dynamic (CFD) and Fluid Structure Interaction (FSI). The CFD is used to determine the pressure, temperature and velocity fields in the lubricant film and the FSI simulation is used to obtain the stress intensity and displacement field. The effect of the operating conditions on the fields‟ pressure, temperature, displacement and stress intensity is also analyzed [2]. Hydrodynamic journal bearings are analyzed by using CFD and FSI approach in order to find deformation of the bearing. Journal bearing models are developed for different speeds and eccentricity ratios to study the interaction between the fluid and elastic behavior of the bearing. Cavitation effects in the bearing are neglected by setting all negative pressures to ambient pressures. The CFD results were compared in order to validate the model with the experimental work and a good agreement was found. It is observed that CFD-FSI method provides a useful platform to study the elastohydrodynamic behavior of the bearing. It is observed that the bearing deformations are significant and should be considered in order to predict accurate performance of the hydrodynamic journal bearings [5]. A comparative study of pressure distribution and load capacity of a cylindrical bore journal bearing is presented by using finite element method and analytical method. In this calculation the isothermal analysis and Newtonian fluid film behavior were considered. The analytical results and finite element results were compared in order tovalidate the work and these results were also compared with the available published results. Finally it is realized that the finite element results showed better agreement than analytical results [4].

III.GEOMETRICAL MODEL

The bearing dimensions used in the present work are as given below:

TABLE I
Journal bearing dimensions and oil properties:

Journal Radius,R_b	50mm,100mm,150mm
Bearing Length,L	100mm
Radial Clearance,R_c	145μm
Rotational Speed,N	3000 rpm
Eccentricity Ratio, ϵ	0.2,0.4,0.6,0.8
Lubricant viscosity, μ	0.4986 Pa-Sec
Lubricant Density, ρ	860 Kg/m^3
Lubricant specific heat,C_P	2000 J/Kg ° C
Bearing thichness,t	5mm
Young’s modulus,E	200GPa
Poisson’s ratio	0.3

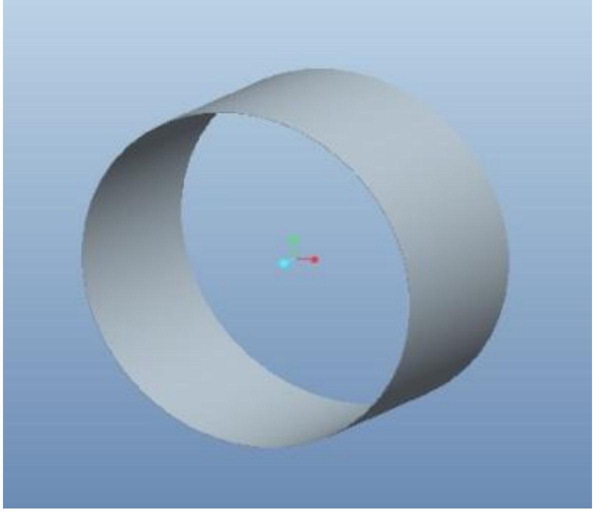

Fig 2. Pro-E model of L/D=0.5

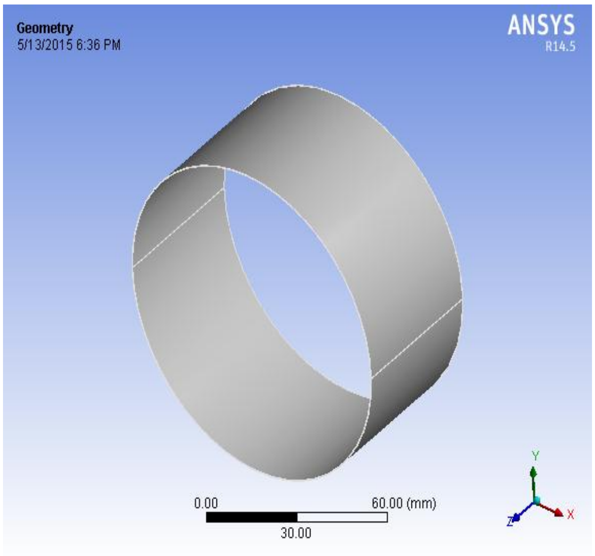

Fig 3.Before Meshing

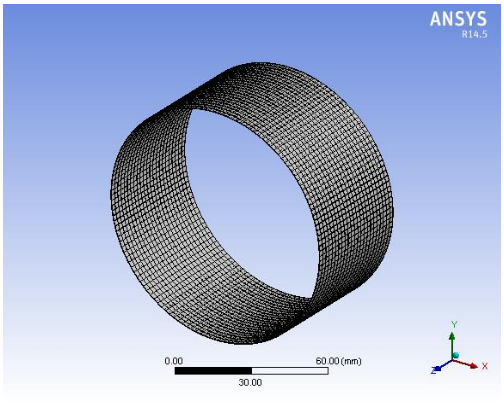

Fig 4.After Meshing

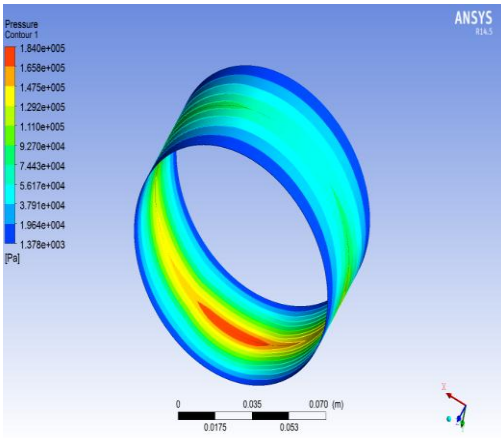

Fig 5.Static Pressure Contour plot for $\epsilon = 0.2$ and $L/D = 0.8$ without negative pressures

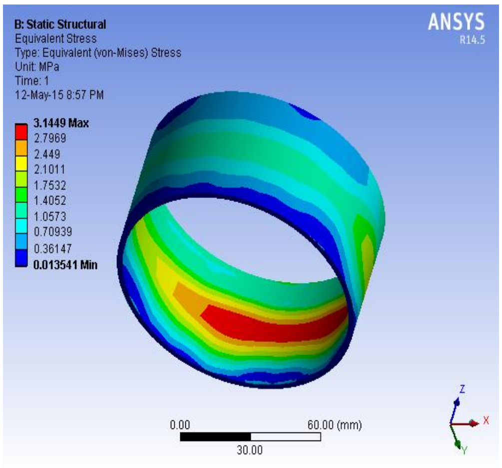

Fig 6. Stress distribution for $\epsilon = 0.2$ and $L/D = 0.8$

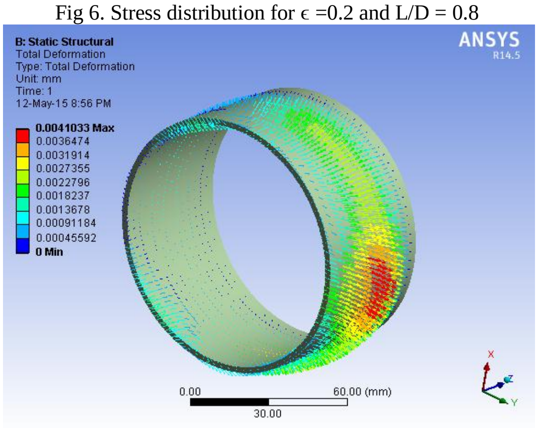

Fig 7. Deformation vector for $\epsilon = 0.2$ and $L/D = 0.8$

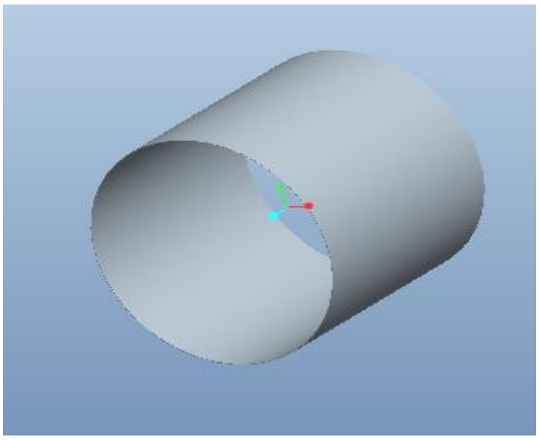

Fig 8. Pro-E model of L/D=1.0

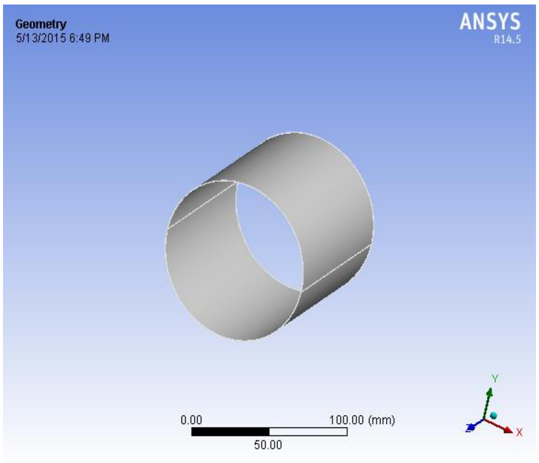

Fig 9.Before Meshing

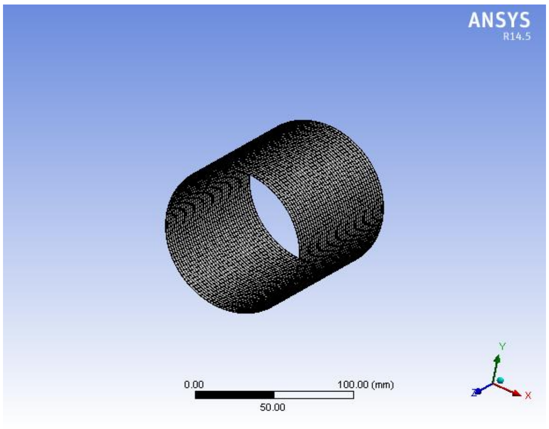

Fig 10.After Meshing

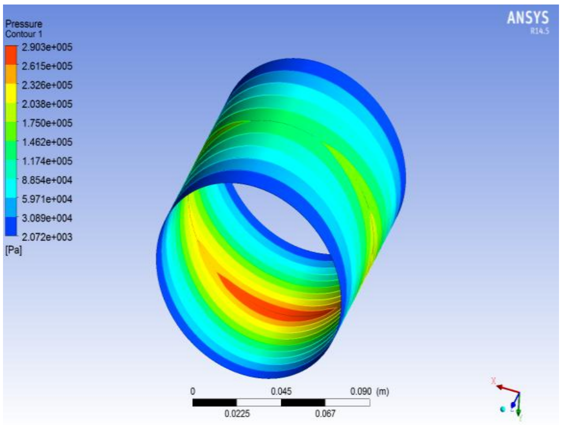

Fig 11. Static Pressure Contour plot for ϵ =0.2 and L/D = 1.0

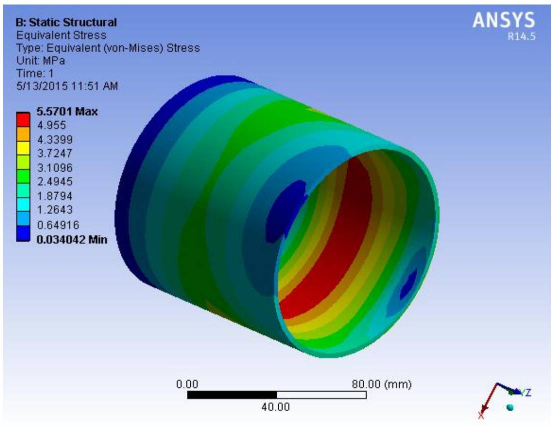

Fig 12. Stress distribution for ϵ =0.2 and L/D = 1.0

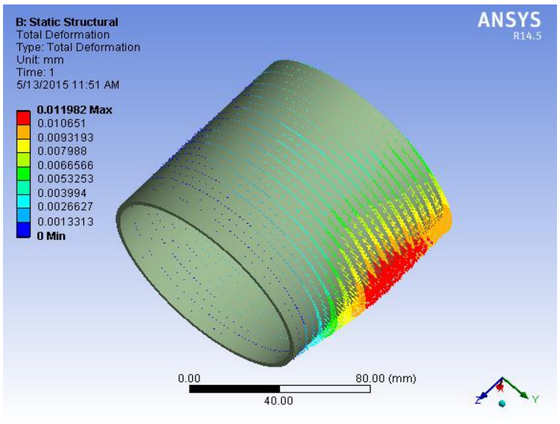

Fig 13. Deformation vector for ϵ =0.2 and L/D = 1.0

RESULTS

Pressure plot

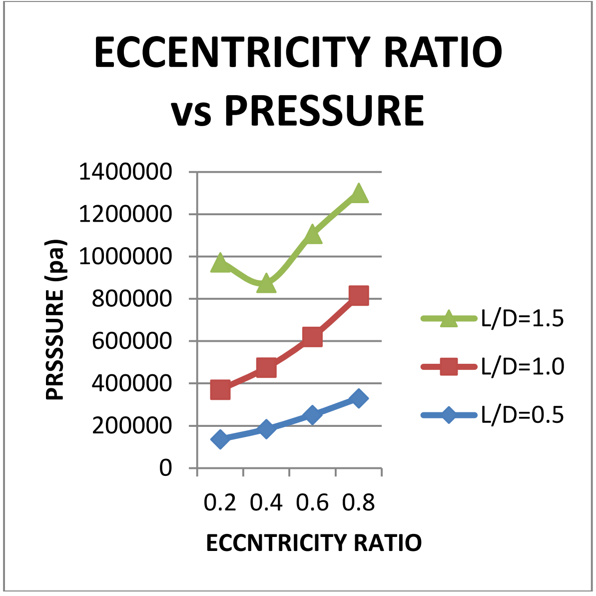

Fig 14.Variation of pressure distribution for various L/D and eccentricity ratios

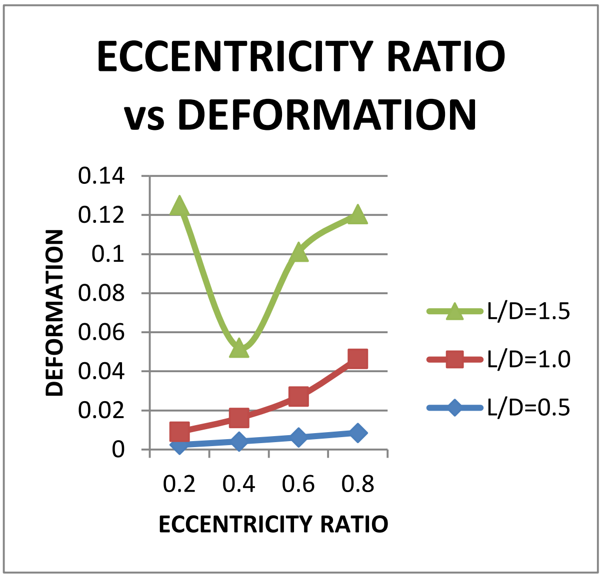

Fig 14.Variation of deformation for various L/D ratios and eccentricity ratios

Stress plot

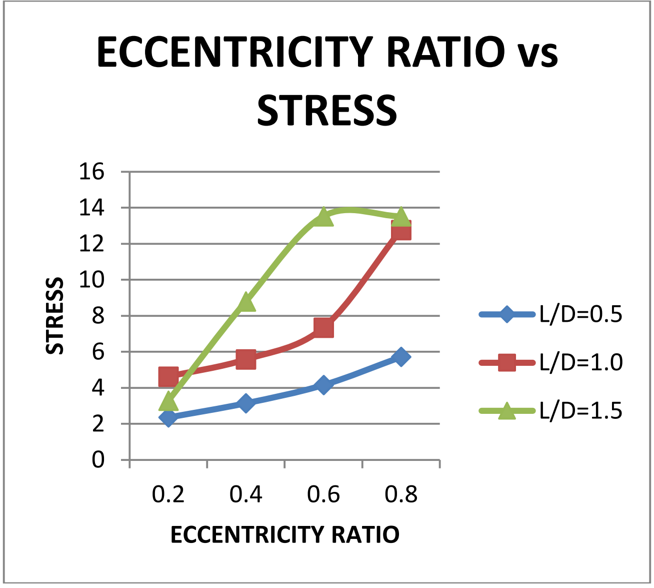

Fig 16.Variation of stress distribution for various L/D and eccentricity ratios

The pressure developed in the bearing for the L/D ratio of 0.5 for different eccentricity ratios are tabulated in the above table. From the above table, for the short bearing as the eccentricity ratio increases from 0.2 to 0.8,the stresses developed in the model is also increasing.Consequently the displacement is also increased from 0.0023596mm to 0.0085264 and the stresses acting on the plain journal bearing is also increased from 2.3518MPa to 5.7192MPa.

The pressure developed in the bearing for the L/D ratio of 1.0 for different eccentricity ratios are tabulated in the above table. From the above table, for the bearing as the eccentricity ratio increases from 0.2 to 0.8,the stresses developed in the model is also increasing.Consequently the displacement is also increased from 0.0067605mm to 0.037875 and the stresses acting on the plain journal bearing is also increased from 4.6198MPa to 12.765MPa

The pressure developed in the bearing for the L/D ratio of 1.5 for different eccentricity ratios are tabulated in the above table. From the above table, for the long bearing as the eccentricity ratio increases from 0.2 to 0.8,the stresses developed in the model is also increasing.Consequently the displacement is decreasing from 0.11599mm to 0.07421 and the stresses acting on the plain journal bearing is also increased from 3.278MPa to 13.526MPa.

The stresses developed from the CFD analysis is increasing gradually as the eccentricity ratios are increasing.The pressure developed in the fluid film is also too increasing for the increase in the eccentricity ratio for the L/D ratio of 0.5. Consequently the deformation is also increasing as the eccentricity ratio is increasing.

Where as for an L/D ratio of 1.0 even though the pressure and stress are increasing with an increase in eccentricity ratio the deformation of the plain journal bearing is also increasing for the increase in eccentricity ratio for the L/D ratio of 1.0.Consequently the deformation is also increasing as the eccentricity ratio is increasing

For the L/D ratio of 1.5, the pressure distribution is decreased from 0.2 to 0.4 eccentricity ratio.Then the pressure distribution increased from 0.4 to 0.6 eccentricity ratio and remained stabilized for increase in eccentricity ratio from 0.6 to 0.8. Similarly the stress as well as the deformation of plain journal bearing is also decreasing from 0.2 to 0.4 and then increasing from0.4 to 0.6 and remained stabilized from an eccentricity ratio of 0.6 to 0.8 as shown in the graphs

CONCLUSION

The objective of the project work is carried out in different stages namely design and analysis.In the design stage the plain journal bearing has been designed using Pro-E software for different L/D ratios and for different eccentricity ratios. The lubricant film is generated in the CFD module of the software. Further pressure distribution is found by sending the lubricant in between the journal and bearing for different L/D ratios and for different eccentricity ratios. Later by using the fluid structure interaction technique as fluid flow exerts pressure on solid structure causing it to deform, the stresses as well as the deformation of the journal bearings are evaluated.The overall elasto hydrodynamic lubrication analysis of plain journal bearing has been conducted using sequential application of computational fluid dynamics. General fluid structure interaction codes makes the analysis effective where complex flow geometries are involved and or when more details are needed. These techniques has been successfully implemented in finding out the bearing surface deformation under static load due to the action of hydrodynamic forces developed which is important for the accurate performance of the bearings operation under severe conditions and this approach can be extended in predicting the bearing performance under dynamic loading condition.

REFERENCES

1. Dinesh Dhande, Dr D W Pande and Vikas Chatarkar, "Analysis of Hydrodynamic Journal bearing using fluid Structure Interaction Approach", International Journal of Engineering Trends and Technology (2013).
2. K. M. Panday, P. L. Choudhury, and N. P. Kumar, "Numerical Unsteady Analysis of Thin Film Lubricated Journal Bearing", IACSIT International Journal of Engineering and Technology (2012)
5. Huiping Liu, Hua Xu , Peter J. Ellison ,Zhongmin Jin , "Application of Computational Fluid Dynamics and Fluid–Structure Interaction Method to the Lubrication Study of a Rotor–Bearing System ", Tribol Lett (2010) 38:325–336
6. Cromton J. S., Gritter L. T., Yushanov Y. S., Kopenhoefer K. C., Edwards R. O., 'Analysis of Lubricant Flow through Reynolds Equation', Multiphysics Simulation Conference, Proceedings, 2010, Boston.
3. RAVINDRA M. MANE AND SANDEEP SONI, "ANALYSIS OF HYDRODYNAMIC PLAIN JOURNAL BEARING", EXCERPT FROM THE PROCEEDINGS OF THE 2013 COMSOL CONFERENCE IN BANGALORE AUTHORS
4 .MAHESH AHER, SANJAY BELKAR, R R KHARDE," PRESSURE DISTRIBUTION ANALYSIS OF PLAIN JOURNAL BEARING WITH LOBE JOURNAL BEARING" IJERT, VOL 2, ISSUE-1, JAN 2013, PG 4-5;
7. Gertzos K. P., Nikolakopoulos P. G., Papadopoulos, 'CFD Analysis of journal bearing hydrodynamic lubrication by Bingham lubricant', Tribology International, Elsevier Publication, Vol. 41, pp. 1190
8. Deligant M., Podevin P., Descombes G., 'CFD model for turbocharger journal bearing performances', Applied Thermal Engineering, Elsevier Publication, Vol. 31, pp. 811 5. Shenoy B. S., Pai R. S., Rao D. S., Pai R., 'Elast hydrodynamic analysis of full 360 bearing using CFD and FSI techniques', Journal of Modeling and Simulation, World Academic press, Vol. 5, pp. 315