Review on Finite Element Analysis of Hydrodynamic Journal Bearing

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Abstract: The current trend of modern industry is use to machineries carrying heavy rotor loads rotating at high speed. In such applications hydrodynamic journal bearings are used. When a bearing operates at high speed, the heat generated due to large shearing rates in the lubricant film raises its temperature which lowers the viscosity of the lubricant and in turn affects the performance characteristics. Thermo hydrodynamic (THD) analysis should therefore be carried out to obtain the realistic performance characteristics of the bearing. In the existing literature, several THD studies have been reported. Most of these analyses used two dimensional energy equations to find the temperature distribution in the fluid film by neglecting the temperature variation in the axial direction and two dimensional Reynolds equation was used to obtain pressure distribution in the lubricant flow by neglecting the pressure variation across the film thickness. In this paper CFD technique has been used to accurately predict the performance characteristics of a plain journal bearing. Three dimensional study has been done to predict pressure distribution along journal surface circumferentially as well as axially. Three dimensional energy equation is used to obtain the temperature distribution in the fluid film.

Index Terms- Journal Bearing, Eccentricity Ratio, Pressure distribution, Thermal analysis, Temperature distribution, CFD, Fluent.

I. INTRODUCTION

A bearing is a machine element that constrains relative motion to only the desired motion, and reduces friction between moving parts. The design of the bearing may for example, provide for free linear movement of the moving part or for free rotation around a fixed axis; or, it may prevent a motion by controlling the vectors of normal forces that bear on the moving parts. Most bearings facilitate the desired motion by minimizing friction. Bearings are classified broadly according to the type of operation, the motions allowed, or to the directions of the loads (forces) applied to the parts. Rotary bearings hold rotating components such as shafts or axles within mechanical systems, and transfer axial and radial loads from the source of the load to the structure supporting it. The simplest form of bearing, the plain bearing, consists of a shaft rotating in a hole. Lubrication is often used to reduce friction. In the ball bearing and roller bearing, to prevent sliding friction, rolling elements such as rollers or balls with a circular cross-section are located between the races or journals of the bearing assembly. A wide variety of bearing designs exists to allow the demands of the application to be correctly met for maximum efficiency, reliability, durability and performance.

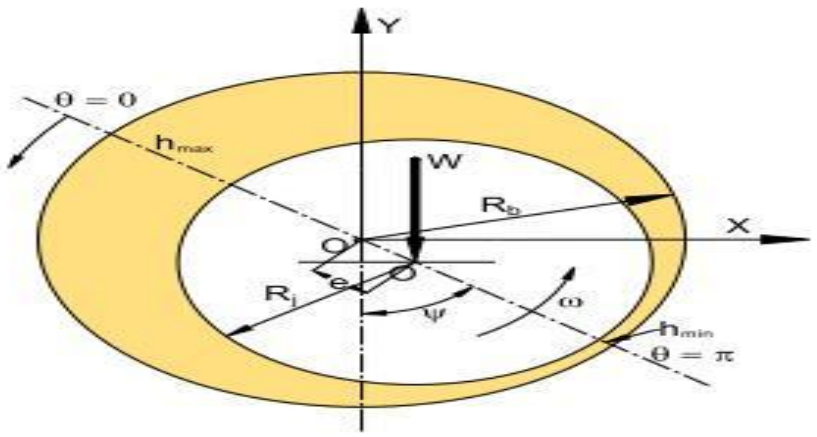

Fig. 1: schematic diagram of circular journal bearin

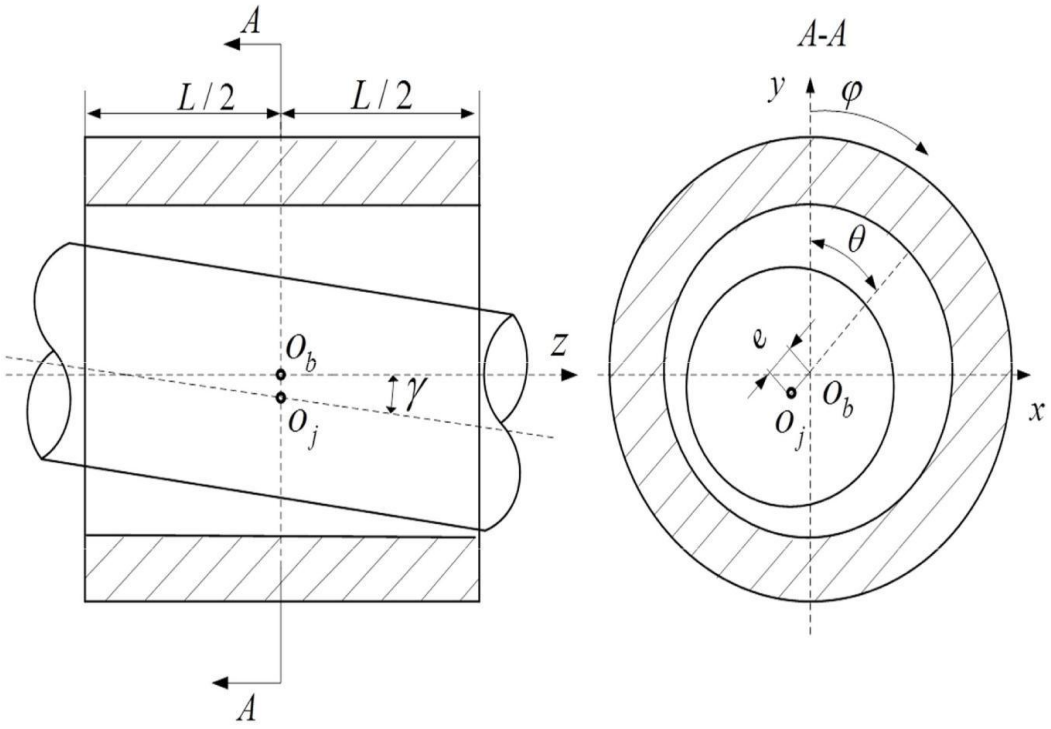

Figure-2: Journal bearing geometry.

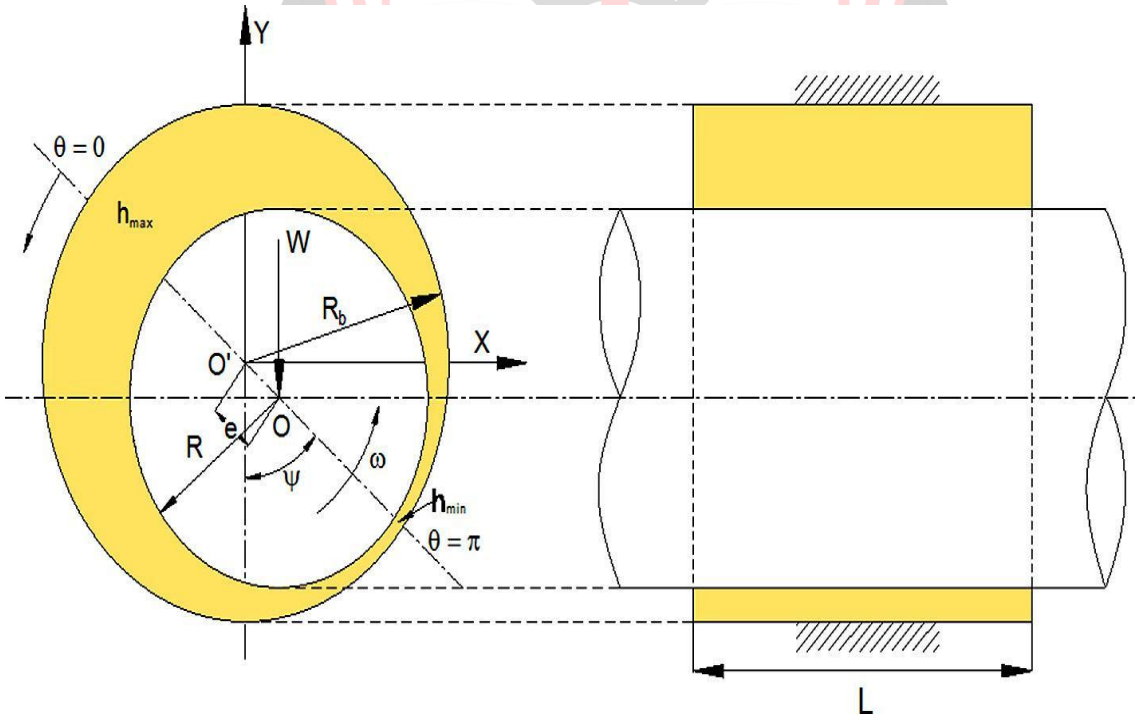

Figure3: Dimensionless axial coordinate of ESP versus dimensionless misalignment angle.

The term "bearing" is derived from the verb "to bear" a bearing being a machine element that allows one part to bear (i.e., to support) another. The simplest bearings are bearing surfaces, cut or formed into a part, with varying degrees of control over the form, size, roughness and location of the surface. Other bearings are separate devices installed into a machine or machine part. The

most sophisticated bearings for the most demanding applications are very precise devices; their manufacture requires some of the highest standards of current technology

Journal bearings are used to carry radial loads, for example, to support a rotating shaft. A simple journal bearing consists of two rigid cylinders. The outer cylinder (bearing) wraps the inner rotating journal (shaft). 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 radial load. The lubricant is supplied through a hole or a groove and may or may not extend all around the journal. Under normal operating conditions, the gases dissolved in the lubricant cause cavitation in the diverging clearance between the journal and the bearing. This happens because the pressure in the lubricant drops below the saturation pressure for the release of dissolved gases. The saturation pressure is normally similar to the ambient pressure. The following model does not account for cavitations and therefore predicts sub-ambient pressures. Such sub-ambient pressures are the result of the so-called Sommerfeld boundary condition. For practical purposes, these sub-ambient pressures should be neglected. Future versions of the Lubrication Shell physics interface will offer additional tools for modeling cavitation.

II. LITERATURE REVIEW

Rahul Patil and Dr.S.K. Dhagat. investigated Circular Journal Bearing profile is the most commonly used to support the rotating shaft extensively in high speed machinery, example turbines, electric motors etc.These bearing support the external load and the presence of thick film of lubricant between the clearance spaces avoid the metal contact of rotating part of machinery with the surface of bearing. High speed of rotation causes the considerable rise in the temperature of the lubricant which significantly affects the performance of the bearing. Therefore the investigation of bearing performance based on a thermo hydrodynamic (THD) analysis requires simultaneous solution of the complex equations of flow of lubricant, the energy equation for the lubricant flow and the heat conduction equations in the bearing and the shaft. Previously, the researchers investigate the performance of the lubricant by solving the Reynolds Equation through Finite Difference Method approach. With the progress of computer technology many researchers uses commercial computational fluid dynamics (CFD) software to solve these complex equation. CFD codes provides a solution to flow problems by solving the full Navier-Stokes equations instead of Reynold's Equation. Also, CFD software solve the three dimensional energy equation to predict the temperature distribution in the fluid film where most of the researchers does THD analysis by solving the two dimensional energy equation for finding the temperature variation in the lubricant and two dimensional Reynolds Equation for pressure.[1,9]

Amit Chauhan, Amit Singla, Narender Panwar and Prashant Jindal.analyzed the Circular Journal Bearing profile is the most commonly used to support the rotating shaft extensively in high speed machinery, example turbines, electric motors etc. These bearing support the external load and the presence of thick film of lubricant
between the clearance spaces avoid the metal contact of rotating part of machinery with the surface of bearing. High speed of rotation causes the considerable rise in the temperature of the lubricant which significantly affects the performance of the bearing. Therefore the investigation of bearing performance based on a thermo-hydrodynamic (THD) analysis requires simultaneous solution of the complex equations of flow of lubricant, the energy equation for the lubricant flow and the heat conduction equations in the bearing and the shaft. [2]

S. S. Gautam,M. K. Ghosh. investigated Circular step hydrostatic thrust bearings and mechanical face seals have similar geometries. However, both have different functions to perform. Thrust bearings are used as load carrying element whereas seals are basically meant to prevent leakage. Externally pressurized bearings where fluid is supplied from an external source can meet some extreme requirement, such as very low frictional characteristics, heavy load at low speed and high positional accuracy. Generally bearing performances are evaluated assuming a constant lubricant viscosity and neglecting the effect of rotation. At high speed of rotation the power dissipated through the lubricant becomes greater and the lubricant temperature rises severely and the assumption of constant viscosity no longer holds well. The effect of shaft rotation also has to be considered [3,4]

A plain bearing (sometimes called a solid bearing) is the simplest type of bearing, comprising just a surface and no rolling elements. Therefore the journal (i.e., the part of the shaft in contact with the bearing) slides over the bearing surface. The Simplest example of a plain bearing is a shaft rotating in a hole. A simple linear bearing can be a pair of flat surfaces designed to allow motion; e.g., a drawer and the slides it rests on or the ways on the bed of a lathe. Plain bearings, in general, are the least expensive type of bearing. They are also compact and lightweight, and they have a high load-carrying capacity [5,7]

In addition, the fluctuations and uncertainty in the crude oil market, increasing crude oil prices, and issues related to environment make bio-based lubricants more valuable. However, vegetable oil has some drawbacks, such as low oxidation stability, low thermal stability, and a comparatively high wear rate. Bowden and Tabor stated that the wear rate is high due to chemical attack on the surface by the fatty acids present in bio-based lubricants. Biodegradability is the main concern in ecotribology, because 40% of the lubricant can be lost to the environment [6,8]

Table -1: Experimental works on the Hydrodynamic Journal Bearing.

Sr.No	AUTHOR	TYPE OF ANALYSIS	OBSERAVTION
01	Rahul Patil and Dr.S.K. Dhagat	A Comparative CFD Analysis of a Journal Bearing with a Microgroove on the Shaft & Journal	Available investigationsNumerical simulations of a journal bearing with a single dimple on the rotor using Computational Fluid Dynamic (CFD) have been performed using the commercial software ANSYS CFX 11. Comparison was made between the single mesh and combined mesh by an interface to evaluate eventual artifacts generated by the interface. The result shows a little difference in load (2.8 %) attributed to the interface, which may generate numerical diffusion. This result shows nevertheless the capability of ANSYS CFX 11 to handle moving objects in the flow. Comparison between the textured rotor and smooth rotor showed no significant increase in load carrying capacity of the journal bearing. Few points deserve future investigation: Explanations of the load variation over a period function of the dimple position.
02	AmitChauhan , AmitSingla, NarenderPanwar and Prashant Jindal	CFD Based Thermo-Hydrodynamic Analysis of Circular	In this article the Thermo-hydrodynamic analysis for circular journal bearing has been carried out using the application of Computational Fluid Dynamics. It has been found that when viscosity is kept constant the temperature rise is more in the lubricant and the maximum pressure obtained is also high. But it does not represent real life time scenario as when temperature increases, viscosity of lubricant decreases which affects the load carrying capacity of bearing. Therefore obtaining the bearing performance characteristics by keeping constant viscosity may gives wrong prediction about the bearing. So the present analysis may be helpful in prediction of bearing performance parameters in actual working conditions and may help in increased life of the bearing.
03	S. S. Gautam, M. K. Ghosh	Thermal analysis of externally pressurised step bearing including centrifugal inertia effect for a bubbly lubricant.	Bubbly oil improves the performance of the bearing when the air bubble content is low. Higher air bubble content does not alter the performance. There is thus an optimum value of air bubble content in the oil (x=0.01) up to which performance improves. Temperature increases from leading edge to trailing edge. There is a surge in temperature at the recess edge due to discontinuity in the film thickness. Load carrying capacity improves initially with increase in the air bubble content and then asymptotically attains a constant value when air bubble content becomes high. Region of cavitations diminishes with increase in the air bubble content. Due to centrifugal inertia effect cavitations zone increases. The frictional power loss and lubricant mass flow rate decreases with the air bubble content. Cavitations region is reduced by misalignment and coning.
04	MukeshSahu, Ashish Kumar Giri, Ashish Das	Thermohydrodynamic Analysis of a Journal Bearing Using CFD as a Tool	In This Investigations Result it is clear that temperature created from the frictional force increases decreases the viscosity of the lubricant and lesser viscosity decreases the maximum pressure of the lubricant inside the bearing. For this reason it is recommended that when any analysis of journal bearing is done to measure its performance always thermohydrodynamic analysis

05	K Aparna, Manjunath	Fluid Structural Thermal Analysis of Cylindrical Bearing.	By observing the CFD analysis results, the pressure is decreasing by increasing the eccentricity ratio thereby decreasing the displacements and stress values for cylindrical journal bearing in Structural analysis. The stress values for both materials Stainless Steel and Aluminum alloy are less than the respective allowable strength values. Comparing the results between materials Stainless Steel and Aluminum alloy, the deformation and stress values are less for Stainless Steel than Aluminum alloy. By comparing the results in thermal analysis, the heat flux values are increasing by increasing the eccentricity ratio. The heat flux values are more for Aluminum alloy than Stainless Steel. So the heat transfer rate is more when Aluminum alloy is used. So it can be concluded that increasing eccentricity ratio and using Aluminum alloy is better for cylindrical journal bearing.
06	Pantelis G. Nikolakopoulos and Dimitrios A. Bompos	Experimental Measurements of Journal Bearing Friction Using Mineral, Synthetic, and Bio-Based Lubricants.	The use of the synthetic lubricant yields the best possible performance among the three lubricants examined in this work. These benefits in terms of friction coefficient are significant, such as in the case of 1536 rpm and 351.8 Nt where the friction coefficient presents a fourfold decrease. The bio lubricant also exhibits a decrease of the friction coefficient in comparison to the SAE-30 oil. The performance benefits though for both the synthetic SAE-10W40 and the ISO AWS-100 bio lubricant depend on the specific operating conditions of the journal bearing. Additionally the effect of temperature on the performance of the bio lubricant may prove to be significant.
07	KapilHiraman Bagul, Pundlik N. Patil	Thermal Analysis of Journal Bearing Using CFD Software for Performance Enhancement.	Thermo-hydrodynamic analysis for circular journal bearing has been carried out using the application of Computational Fluid Dynamics and applied fins on external surface of journal bearing. It has been found its increased the efficiency of journal bearing and bearing life upto five percentages.
08	D.Y. Dhande, D.W. Pande	Multiphase flow analysis of hydrodynamic journal bearing using CFD coupled Fluid Structure Interaction considering cavitation.	This research work studies hydrodynamic journal bearing with multiphase flow. A new numerical method comprising CFD and FSI methodology with optimization is proposed where both inertial as well as cavitation effects are considered. The experimental data obtained provide very good concordance with numerical results. The following conclusions can be made: The magnitude of the pressure build up lowers as compared to the pressure build up in journal bearings without cavitation. The oil vapour distribution in the bearing goes on increasing with increase in the shaft rotational speeds thus lowering the value of the pressure build up. The multiphase flow analysis with cavitation hence is extremely important in case of the bearings operating with higher speeds. The peak pressure increases with increase in both shaft speed as well as eccentricity ratio but more sensitive to eccentricity ratio change, thus making the situation tightly coupled. The computation time is also significantly reduced by this approach.
09	FangruiLv, Na Ta, ZhushiRao	Analysis of equivalent supporting point location and carrying capacity of misaligned journal bearing.	The geometry of journal bearing with misalignment in vertical direction is analyzed and the numerical model of misaligned bearing in hydrodynamic lubrication regime is established. Equivalent supporting point (ESP) location is described through dimensionless axial coordinate of ESP, and the numerical calculation approach for solving dimensionless axial coordinate of ESP is given. With same eccentricity ratio, dimensionless carrying capacity and the dimensionless axial coordinate of ESP increase with the increase of dimensionless misalignment angle and that of length-diameter ratio. The curves of dimensionless axial coordinate of ESP versus dimensionless misalignment angle, eccentricity ratio, and length-diameter ratio are achieved. Based on the curves, a function of dimensionless axial coordinate of ESP dependent on dimensionless misalignment angle, eccentricity ratio, and length-

			diameter ratio is obtained. Using the function, designers can efficiently calculate the approximate ESP location. Similarly, a function of misalignment factor for carrying capacity is achieved. If the carrying capacity of the corresponding aligned bearing is known, the carrying capacity of misaligned bearing can be estimated by the function of misalignment factor for carrying capacity. Through typical examples, the accuracy of the functions in meeting the engineering standards is verified. The experimental validation of the functions will be addressed in future work.

CONCLUSION

In the present paper, the techniques which are used for improvingstudies hydrodynamic journal bearing.If the heat transfer rate is more when Aluminum alloy is used. So it can be concluded that increasing eccentricity ratio and using Aluminum alloy is better for cylindrical journal bearing.andThe peak pressure increases with increase in both shaft speed as well as eccentricity ratio but more sensitive to eccentricity ratio change, thus making the situation tightly coupled.The computation time is also significantly reduced by this approach.

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