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CFD ANALYSIS OF FLUID FILM JOURNAL BEARING: A REVIEW

Miss. Kirtee L.Chidle[1], Dr. Mrs. R. N. Baxi[2]

[1] *Student of M.Tech CAD-CAM, Department of Mechanical Engineering, G. H. Raisoni college of Engineering, Nagpur, Maharashtra, India.*

[2] *Professor, Department of Mechanical Engineering, G. H. Raisoni college of Engineering, Nagpur, Maharashtra, India.*

Abstract - ***This paper, present a review of the performance analysis of journal bearing. Major emphasis is given to the pressure and temperature distribution based identification analysis on bearing. This paper attempts to evaluate the journal bearing performance on various parameters such as pressure distribution, bearing surface deformation, temperature distribution, and load carrying capacity. The objective of this paper is to find computational fluid dynamic analysis of journal bearing. Various researchers have been working on performance of journal bearing such as lubrication behavior, steady state analysis, and turbulence analysis. Here, a brief review is presented of the literatures available in recent years.***

Key Words: *CFD analysis, journal bearing, pressure distribution, temperature distribution, vegetable oils*

1. Introduction

The current modern industry uses machineries which are rotating at high speed and carrying heavy rotor loads. In such application fluid film journal bearing is used. Fluid film journal bearing is a mechanical element designed to support a high load while permitting relative motion between journal and bearing surface. The fluid film bearing also called as hydrodynamic journal bearing. The journal and bearing wall are separated by fluid film which is applied between clearance spaces. Generally, radial clearance is very small in order of 1/1000th of journal radius. In existing fluid film bearing major problems occurs due to the failure of fluid film during the working condition. In existing fluid film journal bearing, under maximum load, metal to metal contact between journal and bearing takes place. Due to this maximum heat as well as friction is generated which overheats the surface of journal and bearing. Hence increases the power loss and reduces the life of bearing. [1] For this problem, various researchers have done remarkable investigation on different parameters of journal bearing. They found out steady state and transient analysis, loading capacity effect on journal bearing. But still some problems exist. This trouble is associated with lubricant that is used in fluid film journal bearing. So the need is to find out solution on lubricant used in fluid film journal bearing to enhance the performance of bearing. The pressure distribution is important parameter in load capacity estimation and dynamic analysis. In recent studies, CFD results have been compared with experimental as well as analytical results, and it shows that CFD results get validated. The paper presents various researchers effort done on journal bearing to improve the performance of the bearing.

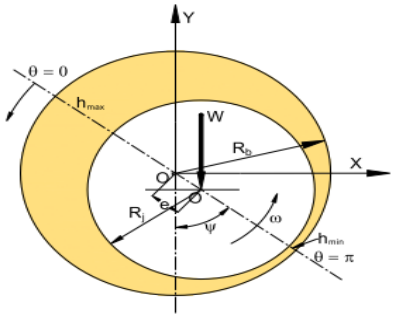

Fig 1: schematic diagram of circular Journal bearing.

Table -1: Nomenclature

Ω	Angular Velocity
W	External Load
ɵ	Eccentricity
Θ	Bearing Angle
Hmax	Maximum Film Thickness
Hmin	Minimum Film Thickness
C	Radial Clearance
E	Eccentricity Ratio
O	Journal Center
O′	Bearing Center
Ψ	Attitude Angle
Rb	Radius Of Bearing
Rj	Radius Of Journal

2. Material and Method

The main objective of this paper is to find out the recent work done on journal bearing. In this review, recent 25 papers on journal bearing have been considered. Various researchers focus on different parameters of journal bearing which influence the performance of bearing during the operating condition. They used different methods to analyze the operations of hydrodynamic journal bearing. The papers are categorized in various parameters such as pressure distribution, temperature distribution, bearing surface deformation, stress distribution in the bearing, load carrying capacity. In this review paper contain CFD, CSD, FEM and FSI technique of analysis. This paper considers 14 papers on pressure and temperature distribution in journal bearing under different conditions, 5 papers on bearing surface deformation, and 6 papers on load carrying capacity of journal bearing.

3. Result

Accurate valuation of bearing's performance is an important factor, for that it is required to study various parameters which influence the performance of fluid film journal bearing. The parameters such as pressure and temperature distribution, load carrying capacity, bearing surface deformation. The paper presents the survey of this analysis of journal bearing.

3.1 PRESSURE AND TEMPERATURE DISTRIBUTION

The fluid film pressure and temperature distribution is one of the fundamental operating parameters to identify the operating conditions of journal bearing. The pressure distribution is crucial in load capacity estimation as well as dynamic analysis. In fluid film journal bearing, viscous shearing phenomenon occurs, that causes power loss and temperature rise. Rising temperatures lead to viscosity reduction of oil and bearing deformation. Hence it is needed to study pressure and temperature distribution in journal bearing.

Mukesh shahu et al [2] presented thermodynamic study of the 3 dimensional plain journal bearing using CFD. In this paper, author found out pressure distribution on journal surface not only circumferentially but also axially, with and without considering temperature effect. 3–dimensional bearing geometry and meshing generated in Gambit and investigate the performance of bearing using fluent 6.3.26 software. From this it is clear that increasing frictional force increases the temperature and reduces viscosity as well as maximum pressure of lubricant present inside the plain journal bearing.

Amit Chauhan et al [3] have presented thermo-hydrodynamic analysis of plain journal bearing. During the analysis, deviation of pressure and temperature is considered on the fluid film. From result it is observed that putting constant viscosity during analysis may give incorrect prediction about the bearing. So the present paper gives future prediction of bearing performance.

Amit singla et al[4] have used computational fluid dynamic (CFD) for analyze the hydrodynamic performance of circular journal bearing. They presented results for pressure and temperature distribution throughout the bearing by considering variable viscosity, constant viscosity, and variable viscosity with cavitations. From result it is found out that when the viscosity is put constant , temperature as well as pressure increases is more in lubricant but in practical concept increasing temperature reduces the lubricant viscosity and it affect the bearing loading capacity hence at constant viscosity may gives wrong prevision, so the analysis is helpful for considering the working condition of bearing.

Priyanka tiwari [5] analyzed the performance of infinitely long journal bearing using CFD and FSI approach. In this paper, required data for analytical calculation is considered from design data book. The objectives of this paper have to found out pressure and temperature variation of journal bearing under steady state condition. It is found that maximum pressure occurred nearer to the region of minimum film thickness. During analysis, developed analytical model, and it is compared with simulation results of ansys and found that CFD results validated with analytical solution.

S. Baskar and G. Sriram[6] observed pressure distribution on hydrodynamic journal bearing using SAE20W40, rapeseed oil and soybean oil for loading condition such as 300N and 450N and speed ranges such as 1500rpm and 1750rpm. The Bearing is tested using journal bearing test rig.(JBTR) for different vegetable oils and compared the results with SAE20W40. And it is calculated that only 10% to 20% and 50% to 75% pressure distribution variation occurred in rapeseed oil and soybean oil. Hence Soybean oil generated more heat as compared to rapeseed oil, so the soybean oil is not suitable as a lubrication purpose for journal bearing applications.

Hu Yong et al[7] have presented CFD simulation of journal bearing with dimples under lubrication behaviors. The focus of the study is to calculated pressure distribution, friction force, friction coefficient under different dimple and comparing the textured surface sliding with smooth surface sliding. The effect of lubrication performance is identified by considering different dimple – depth, density, and profile. From result it is found that dimple is useful for lubrication performances and reduces friction force but there is loss of load capacity.

D. M. Nuruzzama et al[8] have calculated pressure distribution and load capacity of journal bearing by analytical method and finite element method. To check the validity, both the results were compared. During

calculation isothermal analysis was considered. By comparing both the results it is identified that at low eccentricity ratio rise the dimensionless load steadily and rise with high eccentricity ratio.

Nabarun Biswas and Prasun Chakraborti[9] worked on unsteady transient analysis of 3lobe journal bearing. Author used physical properties SAE-50 for analysis purpose in journal bearing. They considered surface roughness as 0.9 and motion of shaft at 6000 rpm for analysis various flow parameters. Gambit is used for design and analysis is done with the help of fluent .They study six time steps 10, 30, 50, 70, 90, and 110 sec for unsteady analysis and found out after 110 sec the flow becomes steady. At minimum oil film thickness maximum pressure is observed with increasing value of roughness.

Peeyush vats et al[10] have done case study on heat transfer through journal bearing. This paper presented thermal analysis of journal bearing. The author has used FEM analysis to found out heat generated, temperature distribution and heat dissipation throughout the journal bearing. Theoretical as well as FEM analysis have done for journal bearing. From results it is showed that difference between heat dissipated and heat generated in oil film was very large, because of this temperature of the bearing rises and damaged the bearing pads.

K. M. Panday et al[11] have done unsteady analysis for thin film lubricated journal bearing with different L/D ratios such as 0.25, 0.5, 1, 1.5, and 2. During the analysis, author observed maximum pressure present at minimum oil film thickness. Also they found out that shear stress on surface of bearing and journal is reduced with increase in L/D ratio, but the turbulent viscosity of lubricant rises with increase in L/D ratio.

Arjun Panthi et al [12] have studied pressure and temperature effects on viscosity also found out effect of L/D ratio, rotational speed and eccentricity ratio on pressure distribution on bearing. The analysis has done using CFD tool and results obtained from the software validated with numerical results got from using Raimondi and Boyd chart method. From results, it is predicted that increasing temperature raises pressure but decreases of attitude angle.

Chaitanya K. Desai et al[13]have done experimental as well as theoretical analysis of pressure distribution for various loading conditions and working parameters in hydrodynamic journal bearing. From results it is concluded that maximum pressure generated where fluid film thickness is minimum and at cavitations zone zero pressure occurred, also increasing speed and load on bearing increases the pressure.

Dr. Suwarna Torgal et al[14] have worked on steady state thermal analysis of hydrodynamic journal bearing using ANSYS. Authors found out equivalent oil film temperature of bush type journal bearing using ansys and MATLAB software, because it is one of the important parameter which influences the operation of journal bearing. From results, it is showed that around 12% variations observe between two methods. But Ansys gave more exact solution than numerical method.

Ravindra M. Mane et al[15] have presented pressure distribution in 3D model of plain journal bearing using COMSOL Multiphysics and analytical model developed using reynold equation. Pressure distribution is found out on infinitely short and infinitely long hydrodynamic bearing under steady state condition. From results it predicted that increasing pressure is proportional to eccentricity ratio and pressure increases along the direction of eccentricity.

3.2 Bearing Surface Deformation

A.Ouadoud et al [1] have done thermo-hydrodynamic and thermo-elastohydrodynamic analysis of full journal bearing using numerical methods that is CFD and FSI. In this paper finite volume and finite element method is used to determine the pressure, temperature and velocity distribution in the fluid film, and bearing surface deformation under static load condition respectively. They found out that the distortion due to pressure plays vital role in determine the behavior of bearing, also due to elastic effects minimum film thickness is affected.

Dinesh Dhande et al [16] have used fluid structure interaction method to found out deformation of the hydrodynamic journal bearing. During analysis, models are developed for different eccentricity ratios and speeds to investigate interaction between elastic behavior of bearing and fluid, also observed amount of deformation of the bearing. It is found that CFD-FSI method is useful to observed influence of hydrodynamic and elastic behavior of the bearing. And this technique developed accurate performance of the bearing.

B.S. Shenoy et al[17] have used computational structural dynamics (CSD) and computational fluid dynamics(CFD) to observe the elasto-hydrodynamic lubrication behavior of full 360 journal bearing. The main focus of this paper was to found out deformation and stress distribution in the bearing liner occurred due to resulting forces. To calculated stress distribution finite element method (FEM) was used. The simulation of elasto-hydrodynamic lubrication have validated with standard lubrication result. The paper presented, these techniques is effectively used for finding the surface deformation of bearing under static load.

K. P. Gertzos et al[18] have presented three dimensional CFD analysis of journal bearing with bingham fluid. The results found from fluent software compared with

previously investigation experimental and theoretical results of Newtonian as well as Bingham lubricants and it shows good agreement. In this paper, the journal bearing performance checked in electro-rheological and magneto-rheological fluids. From results it is concluded that the effect of yield stress is small for low eccentricity ratio on the journal bearing.

S. Chaitanya Kumar et al[19] have worked on CFD analysis of hydrodynamic journal bearing. During the analysis they state that oil film pressure is one of the important parameter to describing the working condition of hydrodynamic journal bearing. The author focused on to the modeling of journal bearing for various L/D and eccentricity ratios, and analysis is done by using FSI approach to find out pressure, stress and deformation of hydrodynamic journal bearing. In this paper, author found out pressure distribution by sending the lubricant in between bearing and journal. Then use the FSI technique to identify stresses and deformation of the journal bearing. Hence this technique has been effectively used to finding out the performance of the bearing.

3.3 Load Carrying Capacity

The load carrying capacity is a function of pressure distribution around the journal and surface, due to fluctuation in fluid film thickness. The load carrying capacity affected by the rising in shaft speed and eccentricity ratio.

B. Manshoora et al [20] have found out that 3 directional numerical investigation of thin film lubricated journal bearing for three turbulent models. For analysis purpose considered different L/D ratio of 0.25, 0.5, 1.0, 1.5 and 2.0 to find out result in terms of static pressure, wall shear stress and dimensionless load carrying capacity of the thin film journal bearing. In this paper, Standard k-€ model, Relizable k-€ model and Reynolds Stress Model (RSM) is used for simulation work of thin film lubricated journal bearing. The comparison concluded that all models generate equivalent results. Therefore, from this paper, it was showed that, k-€ model was good to do the simulation because it was simplest model and faster as compared to RSM and K-€ Relizable.

Jamaluddin Md Sheriff et al[21] have investigated CFD analysis to predict load carrying capacity of linear journal bearing and groove surface waviness with bio-based lubricant. From results it is concluded that load carrying capacity of sinusoidal wavy surface is better than linear journal bearing. But high load carrying capacity obtained in linear journal bearing keeping small eccentricity ratio and it is the optimum operation of linear journal bearing.

Marco Tulio C. Faria et al[22] have used finite element method for dynamic as well as steady state analysis of oil – lubricated journal bearing. From results it is clear that hydrodynamic long journal bearing model must be evaluated because it can rises large errors in the bearing performance.

Huixia jin et al[23]have carried out numerical simulation of central circumferential groove of hydrodynamic journal bearing with the help of CFD software. From result it is found out that groove depth affect the load zssone, bearing carrying capacity, cavitations zone and vapour fraction.

Samuel Cupillard et al[24] have performed CFD analysis of journal bearing with smooth and textured surface. The focus of this study is to determine the influence surface texture on eccentricity ratio and frictional force. During the analysis considered the flow is laminar and isothermal at unsteady condition. From this study it is found out that for light loading condition increased the minimum film thickness and reduced frictional force and for high loading conditions increasing pressure zone decreases the frictional force.

Amit Solanki et al [25]have optimized the design parameter such as load carrying capacity of hydrodynamic journal bearing using Genetic Algorithm. From results it concluded that the load carrying capacity is proportional to rotational speed of journal, L/D ratio, length and radial clearance of journal.

4. Discussion

This literature review presents various researchers' work on journal bearing to improve the performance of the bearing. Various analyses is done on different parameter of the bearing such as load carrying capacity, deformation and stress distribution on surface of bearing, pressure and temperature distribution on the journal bearing. Also analysis is done for different L/D ratios and eccentricity ratios to find out their effect on the journal bearing. The analysis is done by using various software available in this days such as computational fluid dynamic(CFD), Fluid structure interaction(FSI), computational structural dynamics(CSD), finite element method (FEM) also analytical and experimental analysis have completed. But still problem remains unsolved in film of fluid film journal bearing. So it's need to identify solution on other parameters such as lubricant used in fluid film journal bearing that is to find out optimize solution for journal bearing.

5. Conclusion

1) From literature, it is shows that CFD solutions get validated with experimental as well as analytical results.
2) Oil pressure and temperature in bearing depend on various factors such as bearing geometry, properties of fluid, rotational speed and force developed during working condition. These are the important elements, while considering the design of bearing.
3) It is recommended to identify thermo-hydrodynamic analysis of journal bearing, because it gives actual performance parameter of the bearing.
4) Various researchers have done remarkable investigation on different parameters of journal bearing, but still problem remains unsolved in film of fluid film journal bearing during the operation of bearing.
5) The failure of fluid film related with lubricant used in fluid film journal bearing.
6) Hence it is needed to optimize the material of film used in fluid film journal bearing.

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