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### RESEARCH ARTICLE

#### A CRITICAL REVIEW ON PARAMETRIC INFLUENCE OF JOURNAL BEARING

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#### Abstract

The innovatory modifications in the field of journal bearing are at quite slow speed. In the field of tribology tools requires high stiffness to improve accuracy. Thus it is necessary for the designer to study the parametric influence of journal bearing quantitative as well as qualitative. This article provides a brief review for journal bearing from available literature in recent years. Since there have been lot of developments in design, the parametric optimization has been performed by many researchers. Numbers of researchers have been working on different aspects of performance of the journal bearing, ranging from temperature rise, geometry of grooves, damping, eccentricity ratio and clearance etc. Based on the state of art in bearing identification, valuable discussions are made with future directions.

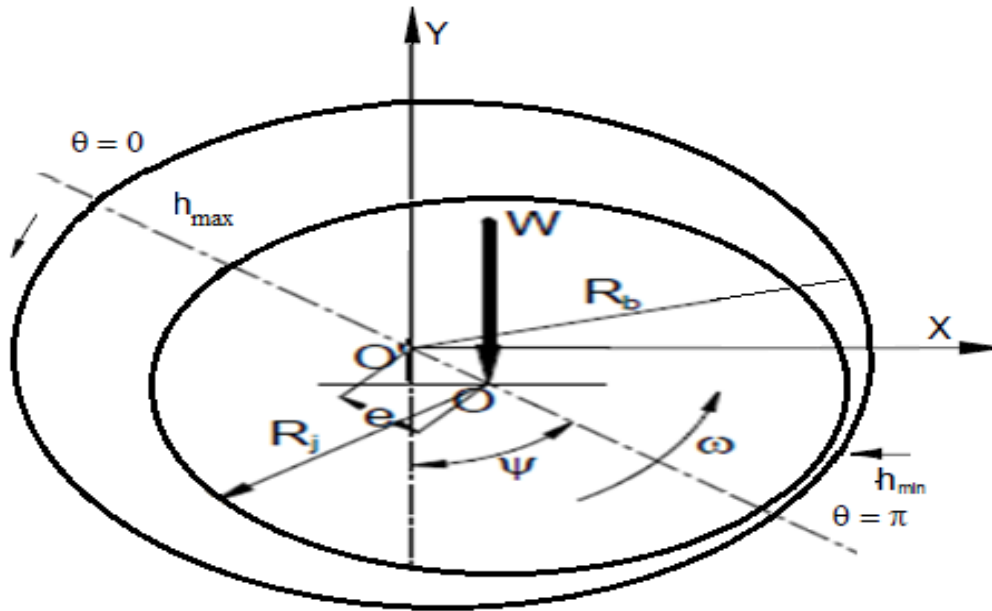
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#### Introduction:-

Now a days, hydrodynamic journal bearing are in high demand for their excellent properties such as long-term performance, negligible friction and almost zero wear particularly in Diesel engine, centrifugal compressors, pumps, motors, etc. Now a day, hydrodynamic journal bearing are in high demand for their excellent properties such as long-term performance, negligible friction and almost zero wear particularly in Diesel engine, centrifugal compressors, pumps, motors, etc. This type of bearing works on hydrodynamic principle, which involves with the rotation of shaft, creates an oil wedge that supports the shaft and relocates it within the bearing clearances. The shaft spinning within a journal bearing is actually separated from the journal bearing's metal facing by an extremely thin film of continuously supplied oil that prohibits metal to metal contact. In other words the hydrodynamic journal bearing works on hydrodynamic lubrication theory, which is concerned with separation of two surfaces in relative motion.

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**Figure 1:-** Journal bearing geometry

Journal bearings shown in figure 1 have many designs to compensate for varying load requirements, machine speeds, cost, or dynamic properties. A stable bearing design holds the rotor at a fixed attitude angle during transient periods such as machine start-ups/shutdowns or load changes. The performance of a hydrodynamic journal bearing is governed by a number of bearing parameters, such as radial clearance length, diameter, viscosity, groove geometry, location, etc. There are few assumptions regarding hydrodynamic journal bearing as the flow is laminar and isothermal with a constant vertical load  $W$  is applied on the journal. Geometry and co-ordinate system of the journal bearing is shown in fig 1. The journal rotates with angular velocity  $\omega$  and remains in equilibrium position under the action of external load,  $W$ . The journal centre  $O$  is eccentric to bearing centre  $O'$ . The film thickness  $h(\theta)$  varies from its maximum value  $h_{max}$  at bearing angle  $\theta = 0$  to its minimum value,  $h_{min}$  at  $\theta = \pi$ .

In this article, we present a review of hydrodynamic journal bearing from literature available in recent years. Since there have been a lot of developments in design, the parametric optimization has been performed by many researchers. Numbers of researchers have been working on different aspects of performance of the journal bearing, ranging from temperature rise, geometry of grooves, damping, eccentricity ratio and clearance etc. Based on the state of art in bearing identification, valuable discussion is made and future directions are suggested.

### Literature Review:-

First a remarkable work on Thermo-hydrodynamic study of journal bearing was done by Hughes and Osterle [1] and describes a relation between viscosity as a function of temperature and pressure of the lubricant inside the journal bearing for adiabatic conditions with examples Basri and Gethin [2] have investigated the thermal aspects of various noncircular journal bearing using adiabatic model. Cupillard et al. [3] have presented an analysis of lubricated conformal contact to study the effect of surface texture on bearing friction and load carrying capacity using computational fluid dynamics. The authors have reported that the coefficient of friction can be reduced if a texture of suitable geometry is introduced. Gertzos et al. [4] have investigated journal bearing performance with a Non-Newtonian fluid i.e. Bingham fluid considering the thermal effect. Huiping Liu et al. [5] studied hydrodynamic journal bearings with elastic insert and found that the elastic deformation of the bearing had a significant influence on the rotor-bearing system, particularly for the polymeric-based materials. Jaw-Ren Lin et al. [6] numerically calculated oil film pressure by using Fourth Runge-Kutta method and this pressure is utilized to evaluate the load carrying capacity and the friction parameter. A comparison of the results between the Darcy model and Brinkman model is made to show the viscous shear effects provide an increase in the load capacity, as well as a decrease in the friction parameter. Nabhan et al. [7] solved Navier-Stokes equation with the aid of Simpson rule and calculated the pressures, drags and load carrying capacities by taking binary fluid mixture with different viscosity ratio. Hassan E.

Rasheed [8] theoretically presented the effects of circumferential, axial and combined surface waviness on the performance of the hydrodynamic journal bearings by using Reynolds equation for Newtonian isoviscous lubricant. It was observed that when waviness number is approximately below nine, then circumferential waviness increases the load carrying capacity and decreases the friction variable. But the axial waviness is to always have an opposite effect on the load carrying capacity and friction variable. S.k.guha [9] analyzed the effect of isotropic roughness on the steady-state characteristics of hydrodynamic journal bearings terms of load capacity, attitude angle, end leakage flow rate, misalignment moment and friction coefficient are estimated for different values of roughness parameter, eccentricity ratio and degree of misalignment at unit slenderness ratio. Finite difference method is also used to measure steady-state oil film pressures by using Reynolds equation. Myung-Rae Cho et al.[10] presented the effects of circumferential groove on the minimum oil film thickness in engine bearings and used mobility method for journal locus analysis. It was observed that the circumferential  $360^\circ$  groove only decreases the magnitude while  $180^\circ$  half groove affects the shape and position of the minimum oil film thickness. NabarunBiswas and PrasunChakraborti[11] used physical properties of SAE-50 lubricant for analysis purpose in journal bearing. They involve with six time steps 10, 30, 50, 70, 90, and 110 sec for unsteady analysis and found out that after 110 sec the flow becomes steady. It was also observed that maximum pressure is observed at minimum oil film thickness with increasing value of roughness.

Sep et al.[12] analysed new design of the journal bearing with two-component surface layer and experimentally proved its usefulness in the case, where oil is contaminated by hard particles. In this new design the helical grooves are made on the bearing journal surface that should enable to eliminating contaminants from the frictional contact zone and concluded that if soft material is placed in the immediate vicinity of the grooves it will restrict the hard particles driving into the bearing surface which also decreases sensitivity. Byoung-Hoo Rho et al. [13] investigated acoustical properties of hydrodynamic journal bearing. The universal Reynolds equation is solved at each step of time using the finite difference method and the nonlinear transient motion of the journal centre is obtained by numerical integration of its acceleration using fourth order Runge-Kutta method. Byoung-Hoo Rho et al [14] investigated the effects of design parameters on the noise of rotor-bearing system supported by oil lubricated journal bearing. The Reynolds equation for finite width bearing under unsteady condition is applied for calculating pressure. It was observed that the radial clearance, mass eccentricity of the rotor and the width of the bearing considerably affect the A-weighted sound pressure level of the bearing. Wu et al.[15] studied wall slip problem by parametric quadratic programming method and generalized Reynolds equation with wall slip for two-dimensional flow is applied. It is observed that if limiting shear stress at bearing surface should be more than that at the journal surface, the wall slip avoided. Nikolakopoulo et al.[16] developed an analytical modal which shows the relationship among the friction force, wear depth and misalignment angles The Reynolds equation is used to calculate the friction force in equilibrium condition and found that friction function dependent on wear and misalignment of the bearing. Singh et al [17] theoretically performed steady-state thermodynamic analysis of an axial groove bearing by using Reynolds equation, energy equation and heat conduction equation with appropriate boundary conditions in the journal bearing. It was found that the fluid film temperature increases due to frictional heat resulting viscosity and load carrying capacity decreases. It was also observed that groove angle of  $360^\circ$  and groove length (Half of the bearing length) promoted to decrease the maximum temperature and increase the load carrying capacity. Ron A.J. Van Ostayen [18] presented a mathematical optimization procedure to find the optimal film height distribution for a hydrodynamic bearing. Firstly this methodology is applied for a bearing with constant load and sliding speed. Then subsequently applied for a bearing with periodic load and sliding speed. Slider bearings with different shapes, loads and speeds are analyzed by new heuristic load optimization procedure along with Reynolds equation and found more efficient than general purpose optimization routine. Andras Z. Szeri [19] modified the structure of lubricant film by using double layer of lubricant into clearance space of bearing surfaces in place of single layer of lubricant. Basic Reynolds equation was used for composite films under the restrictive assumptions by applying boundary conditions. The low-viscosity lubricant reduced viscous dissipation, while the high-viscosity lubricants maintained the desirable thickness to separate out the bearing surfaces. It was also found that composite-film bearings have considerably lower frictional losses in comparison to other traditional bearings. Lui et al.[20] designed and fabricated a test rig to investigate the stability nature of the JRHB. It was found that the rolling bearing plays a protective role under IHP condition. K. M. Panday et al [21] analysis thin film lubricated journal bearing with different L/D ratios such as 0.25, 0.5, 1, 1.5, and 2. It was observed that maximum pressure present at minimum oil film thickness. Also reported that shear stress is reduces on bearing and journal surface with increase in L/D ratio whereas turbulent viscosity of lubricant rises with increase in L/D ratio. NacerTala-Ighil et al [22] developed a numerical model based on finite difference method by using Reynolds equation to study the cylindrical textures shape effect on the performance of hydrodynamic journal bearing. Based on geometric arrangement of textures on the bearing surface, a comparison of

considered twenty five cases is conducted. It was found that the minimum oil film thickness increased approximately by 1.8% and friction torque is decreased approximately by 1.0%. Meybodi et al [23] developed a general methodology, to design the proper bearing in order to eliminate the deviation of final product in extrusion process. Three smooth curved dies with non-symmetric T-shaped sections at different off-centricities have been taken and for each die proper bearing has designed. It was found that the deviation of final product is eliminated to a great extent. McAllister and Rohde [24] optimized the load-carrying capacity of one-dimensional journal bearings for a given minimum film thickness by using a long bearing approximation, which is inaccurate in most practical design ranges. Hashimoto [25] presented an optimum study for high speed short journal bearings using successive quadratic programming. For Eccentricity  $> 0.8$  and  $L/D > 0.3$ , the short bearing approximation predicts highly unreliable results. Peeyush vats et al [26] presented thermal analysis of journal bearing by using FEM analysis. Parameters like heat generated, temperature distribution and heat dissipation are studied. From results it is reported that difference between heat dissipated and heat generated in oil film was very large, which causes increase in temperature of the bearing and damaged the bearing pads.

Currently, due to advancement in computer technology, many researchers trying to use commercial computational fluid dynamics (CFD) programs in their investigations. The CFD code is differ from other relevant codes because full Navier–Stokes equations is used with provides a solution to complex flow problem, whereas finite difference codes are based on the Reynolds equation. Moreover, the CFD packages are applicable in very complex geometries. Authors used different computational codes to study the parametric influence of hydrodynamic journal bearing are listed below with their outcomes.

Ref.	Technique used	Bearing type	Parameter	Analysis /Results
[27 ]	CFD	journal bearing with smooth and textured surface	Surface texture on eccentricity ratio and frictional force	Light loading condition increased minimum film thickness and reduced frictional force and for high loading conditions increasing pressure zone decreases the frictional force.
[28]	CFD	Central circumferential groove of hydrodynamic journal bearing	Bearing carrying capacity, cavitations zone and vapour fraction.	Groove depth affect the load zone, bearing carrying capacity, cavitations zone and vapour fraction.
[29]	CFD	Hydrodynamic journal bearing	L/D and eccentricity ratios, pressure	FSI approach is used to find out pressure, stress and deformation of hydrodynamic journal bearing
[30]	CFD	Journal bearing with bingham fluid.	Eccentricity ratio, yield stress	Fluent software compared with experimental and theoretical results of Newtonian as well as Bingham lubricants and found good agreement. It is also concluded that the effect of yield stress is small for low eccentricity ratio on the journal bearing
[31]	CSD and CFD	Full 360° journal bearing.	Deformation and stress distribution	The paper presented, these techniques is effectively used for To finite element method (FEM) was used to calculate stress distribution .finding the surface deformation of bearing under static load.effect of resulting forces is also discussed. The simulation of elasto-hydrodynamic lubrication have validated with standard lubrication result
[32]	CFD-FSI	Journal bearing	Deformation, eccentricity ratios and speeds	Investigate interaction between elastic behavior of bearing and fluid by developing models for different eccentricity ratios and speeds. this technique developed accurate performance of the bearing
[33]	CFD and	Thermo-	Pressure,	Finite volume and finite element method is used

	FSI.	hydrodynamic and thermo-elastohydrodynamic analysis of full journal bearing	temperature and velocity distribution in the fluid film, and bearing surface deformation	to determine the characteristics under static load condition. Distortion due to pressure is important factor for determining the behavior of bearing.
[34]	COMSOL models	Hydrodynamic bearing	Pressure distribution, eccentricity ratio	Pressure distribution is found out on infinite (short as well as long) bearing under steady state condition. It was predicted that increasing pressure is proportional to eccentricity ratio and pressure increases along the direction of eccentricity
[35]	ANSYS. MATLAB software	Bush type journal bearing	Temperature	It is showed that around 12% variations observe between two methods. But Ansys gave more exact solution than numerical method.
[36]	CFD	Journal bearing	Pressure, temperature viscosity, L/D ratio, rotational speed, Eccentricity ratio, pressure distribution	Software results validated with numerical results got from Raimondi and Boyd chart method. It is predicted that increasing temperature raises pressure but decreases of attitude angle
[37]	CFD (Gambit and using fluent 6.3.26 )	Plain journal bearing	Pressure distribution, temperature and viscosity	It is observed that increasing frictional force increases the temperature and reduces viscosity as well as maximum pressure of lubricant
[38]	CFD	Circular journal bearing	Pressure and temperature distribution	When the viscosity is put constant , temperature as well as pressure increases
[39]	CFD and FSI	Infinitely long journal bearing	Pressure and temperature variation	It is found that maximum pressure occurred nearer to the region of minimum film thickness
[40]	CFD	Journal bearing	Pressure distribution, friction force, friction coefficient	It is observed that dimple is useful for lubrication performances and reduces friction force but there is loss of load capacity.

### Common observations:-

From the available literature it is clear that researchers have listed almost all aspects regarding performance characteristics of journal bearing, however there is a need to develop new mathematical models based on behaviour of rotor-bearing systems. Similarly more experimental work also needed to study the influencing parameters on performance of hydrodynamic journal bearings. CFD code set new level of precision in the research of journal bearing with accuracy. New experiments can be used available data more effectively, especially with the inherent practical constraints for measurements and development of new identification techniques. The load carrying capacity, fluid film thickness and eccentricity ratio of journal bearing are discussed briefly but the effect of time duration is also hidden in the available literature which may influence performance characteristics of journal bearing.

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