A Review of Optimization of Hydrodynamic Journal Bearing Parameters

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ABSTRACT

The journal bearing is widely used in gasoline and diesel fueled piston engine in motor vehicle and allowed parts to move together smoothly. Journal bearing are considered to be sliding bearing as opposed to rolling bearing such as ball bearing. The hydrodynamic journal bearings are required and suitable for low temperature and speed. The starting resistance is much greater that running resistance due to slow build-up of lubricant film round the bearing surface. The main problem is identified in the journal bearing is that there is no provision for wear and adjustment on account of wear, and the shaft must be passed into the bearing axially, i.e. endwise. In this bearing limited load on shaft and speed of shaft is low.

Keywords: *Journal Bearing, Hydrodynamic, Taguchi, RSM, Optimization.*

1. Introduction

Tribology is the branch of science which deals the surfaces, that are rub together or we can say that it is a scientific and systematic method to deal with interacting surfaces so that characteristics of the system can be improved. Tribology contains the study of chemistry, physics and mechanics of rubbing surfaces which include friction wear and lubrication of materials. From the ancient civilization various attempts have been made to minimize friction and wear so that we can transport men and materials from one place to another place in an economical way. This was the biggest challenge faced from past till now. In the nineteenth and the twentieth century lubrication came into picture which is usually put between interacting surfaces to minimize friction and wear.

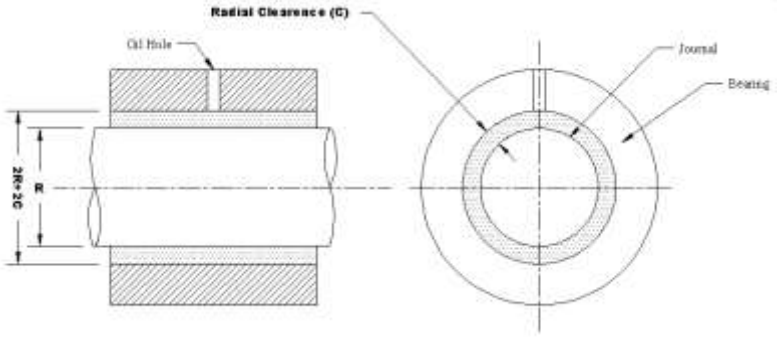

Figure 1. Full Journal Bearing

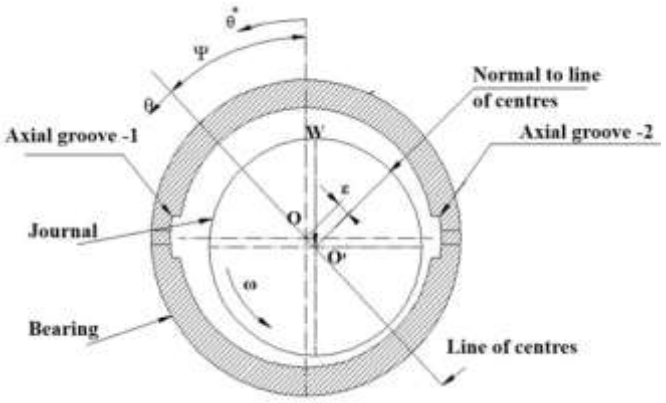

Figure 2. Schematic geometry of journal bearing

2. Literature Review

Over the past few decades effort have been made by researchers to obtained the best design of journal bearing system.

Sherbiny et al (1984), formulated optimization problem to maximize the load-carrying capacity of hydrostatic journal bearings. Optimization process is based on the well-known Rosenbrock method and from results concludes that precision bearings with small clearances and low-pressure ratios are recommended for applications involving low supply pressures, while bearings with large clearances and pressure ratios close to 0.5 are recommended for applications involving high supply pressures.

Hashimoto (1998), has optimized the design procedure of high-speed, short journal bearings under laminar and turbulent flow conditions developed based on Successive Quadratic Programming, Genetic Algorithm and Direct Search method. Short bearing assumption to the modified turbulent Reynolds equation, simplified closed form design formulae are obtained for the eccentricity ratio, friction force, film temperature rise, supply lubricant quantity and whirl onset velocity as a function of design variables such as radial clearance, slenderness ratio and averaged viscosity of lubricants. Design variables, which optimize the objective function given by a linear summation of temperature rise and supply lubricant quantity with respective weighting factor, are determined for a wide range of journal rotational speeds under various constraints.

Cho et al (2000), presented the effects of circumferential groove on the minimum oil film thickness in engine bearings. The fluid film pressures are calculated by using the infinitely short bearing theory for the convenience of analysis. Journal locus analysis is performed by using the mobility method. A comparison of minimum oil film thickness of grooved and un grooved bearing is presented. It is found that circumferential 360° groove only reduces the absolute magnitude of the oil film thickness, but 180° half groove affects the shape of film thickness curve and position of minimum oil film thickness.

Matsumoto and Hashimoto (2001), have described the optimum design methodology, hybrid optimization technique combining the direct search method and the successive quadratic programming and is applied effectively for the optimum solutions. It determines to minimize the objective function defined by the weighted sum of maximum averaged oil film temperature rise, leakage flow rate, and the inversion of whirl onset speed of the journal under many constraints.

Boedo and Eshkabilov (2003), implemented a genetic algorithm scheme to optimize the shape of fluid film general bearings under steady journal rotation. They considered only one objective function, namely the maximization of load capacity. However, the optimum design of a journal bearing is a multi-objective problem which must be solved with multiple objectives taking into consideration design constraints. Each objective function (i.e. minimization of temperature rise, minimization of oil feed flow, minimization of power loss) has a different individual optimal solution. Multiple optimal solutions exist because no one solution can be optimal for multiple conflicting objectives.

Hirani and Sut (2005), have presented the optimum design methodology for improving operating characteristics of fluid-film steadily loaded journal bearings. A finite difference mass conserving algorithm is used to provide relatively accurate power loss and flow rate. Pareto optimal concept to avoid subjective decision on priority of objective functions, a genetic algorithm to deal with multimodal nature of hydrodynamic bearing

and develop a Pareto optimal front, fitness sharing to maintain genetic diversity of the population used in genetic algorithm, and axiomatic design to provide inside of objective functions and design variables. Algorithm for the optimum design of short journal bearings. The optimized results were compared with those of genetic algorithm and successive quadratic programming. All the results have the same tendency. The artificial life algorithm only uses the function value and doesn't need derivatives calculated analytically or numerically and so it has a strong possibility for being used for other optimization problems.

Ghoneam and Strzelecki (2006), derived operation of plain circular journal bearing at high speed is restricted by the excessive temperature that is generated in the oil film and by the loss of stability. However, low costs of machining and high transmitted loads are the advantages of these types of bearings. The operation of bearing and its thermal state are affected by modifications of bearing design. These modifications should result in the higher speeds of operation and better thermal state of bearing. There is small effect of axial profile variation coefficient on the Somerfield numbers and the static equilibrium position angles. Axial profile variation coefficient causes the small decrease in the oil film temperatures.

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Matsuda et al (2007), suggested clearance configuration of fluid-film journal bearings and optimized in a sense of enhancing the stability of the full circular bearing at high rotational speeds. A performance index is chosen as the sum of the squared whirl-frequency ratios over a wide range of eccentricity ratios, and a Fourier series is used to represent an arbitrary clearance configuration of fluid-film bearings. An optimization problem is then formulated to find the Fourier coefficients to minimize the index. The designed bearing has a clearance configuration similar to that of an offset two-lobe bearing for smaller length-to-diameter ratios. The load capacity of the designed bearings is nearly in the same magnitude as that of the full circular bearing for smaller length-to-diameter ratios. The designed bearings successfully enhance the stability of a full circular bearing and are free from the whirl instability.

Tala-Ighil et al (2007), developments in microscopy have a profound effect on the resurgence of tribological applications at the microscopic level. Using surfaces with controlled microgeometry may prove an effective approach to improving bearing performance. It is consequently of interest to study the lubrication of journal bearing systems taking into consideration the effect of surface geometry design. A numerical approach is used in the analysis of texture effects on bearing characteristics. The results from investigating the performance of bearing surfaces with spherical dimple textures suggest that contact characteristics such as minimum film thickness, maximum pressure, axial oil film flow, and friction torque may be improved through an appropriate surface texture geometry and appropriate textures distribution on the contact surface. The main purpose of our work is to model and understand the evolution of journal-bearing characteristics with textures. A rigorous methodology is recommended. The work is divided into two steps. The first one serves to quantify the evolution of the characteristics with the texture parameters and to deduce their optimized values. The second step enhance the performance of the journal bearing by progressively considering the optimized values of texture parameters, especially the textures disposition.

Cupillard et al (2008), an analysis of a lubricated conformal contact is carried out to study the effect of surface texture on bearing friction and load carrying capacity using computational fluid dynamics. The work focuses on a journal bearing with several dimples. Two- and three-dimensional bearing geometries are considered. The full Navier—Stokes equations are solved under steady-state conditions with a multi-phase flow cavitation model. The coefficient of friction can be reduced if a texture of suitable geometry is introduced. This can be achieved either in the region of maximum hydrodynamic pressure for a bearing with high eccentricity ratio or just downstream of the maximum film for a bearing with low eccentricity ratio. An additional pressure build-up produced as a result of the surface texture has been shown at low eccentricity ratios.

Bhuptani and Prajapati (2012), done an evolution optimization methodology for full journal bearing has been applied. The effect of minimizing temperature rise, minimizing oil flow, minimizing the weighted summation of oil flow and temperature rise, and linear combinations of minimizing oil flow and power loss under different

constraints are demonstrated. The results lead to the recommendation of using simultaneous minimization of oil flow and power loss. Pareto-optimal concepts are utilized to help the win-win situation between power loss and oil flow. Optimization studies with three design variables are performed. An orthogonal array is used in selection and setting of the values of design variables and tolerances. The results indicate that the oil viscosity is of the highest importance. Therefore, during bearing design special attention should be given to lubricant viscosity.

Kalakada et al (2012), In this paper, the static and dynamic performance characteristics of journal bearing in terms of load capacity, attitude angle, end leakage, frictional force, threshold speed and damped frequency are presented when the bearing operating under lubricants, which contain nanoparticles and viscosity of these lubricants varies with temperature. The nanoparticles used for the present work are copper oxide (CuO), cerium oxide (CeO_2) and aluminum oxide (Al_2O_3). Viscosity models for the lubricants are developed with the available experimental data. The modified Reynolds and energy equations are used to obtain pressure and temperature distribution across the lubricant film and these equations are solved by using the finite element method and a direct iteration scheme. The static and dynamic performance characteristics of journal bearing are computed for various values of eccentricity ratios for isoviscous and thermoviscous lubricants. The computed results show that in isoviscous case, addition of nanoparticles does not change performance characteristics considerably but in thermoviscous case, changes are significant.

Kango et al (2013), had been concluded that, Different types of negative texture (microcavities) have been considered on journal bearing surface at different locations and the influences of cavity width and that of cavity depth on bearing performance have been investigated. The presence of negative texture helps in increasing the lubricant film thickness, which causes to decrease the friction force.

Binu et al (2014), Influence of TiO2 nanoparticle lubricant additive on the load carrying capacity of a journal bearing is studied. Increase in lubricant viscosity due to presence of TiO2 nanoparticles is modelled using a modified Krieger-Dougherty viscosity model. Validity of modified Krieger-Dougherty model in simulating the viscosities of TiO2 nanoparticle dispersions in engine oil is experimentally verified. The pressure distribution and load carrying capacity are theoretically evaluated using a modified Reynolds equation for various TiO2 nanoparticle concentrations and aggregate sizes. Results reveal an increase in load carrying capacity of journal bearing using TiO2 nanoparticle lubricant additive as compared to plain oils without nanoparticle additive.

Gropper et al (2016), understanding the influence of surface properties (roughness, grooves, discrete textures/dimples) on the performance of hydrodynamically lubricated contacts has been the aim of numerous studies. A variety of different numerical models have been employed by many researchers in order to find optimal texturing parameters (shape, size, distribution) for best performance enhancement in terms of load carrying capacity, film thickness, friction and wear. However, the large number of different modeling techniques and complexity in the patterns make finding the optimum texture a challenging task and have led to contrary conclusions. This article outlines the research effort on surface texturing worldwide, reviews the key findings and, in particular, provides a comparative summary of different modeling techniques for fluid flow, cavitation and micro-hydrodynamic effects.

Shinde and Pawar (2017), work out a multi-objective optimization approach is used to determine the optimal surface texturing parameters to improve performance of journal bearing. The numerical attempts are made using Taguchi's orthogonal array L27. Initially, static performance analysis is carried out for plain bearing system using thin film analysis by COMSOL Multiphysics and the results are validated with the literature. In the later part, analysis of load carrying capacity and frictional torque is carried out for different parameters of surface texturing. The bearing performance is studied for various groove parameters viz. groove location, groove height, groove width, number of grooves and spacing between grooves. Grey relational analysis is used to find an optimal set of parameters which gives maximum load carrying capacity and minimum frictional torque.

3. Conclusion

From the study, is the identify the plain journal bearing is not suitable for heavy performance or required to modified them. Many literatures are work in textured and grooved journal using theoretically, analytically and numerically. And some are optimized plain or modified bearing using different optimization tool like; Taguchi method. In this present study, the Response surface methodology has been taking for carried out the optimum results with respect to control factors. The RSM tool help in visualizing the effect of parameters on response in the entire range specified whereas Taguchi method gives the average value of response at given level of

parameters. Thus, RSM is a promising analytical tool to predict the response which suits the range of parameters studies.

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