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Performance Analysis of Virgin Polytetrafluoroethylene (PTFE) Hydrodynamic Journal Bearing using CFD

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Abstract - *This work focuses on study of tribological behavior of a commercially available polytetrafluoroethylene (PTFE) hydrodynamic journal bearing. The purpose of selection of this material is due to its low coefficient of friction and enhancement of the self lubricating properties. Performance parameters like pressure distribution, load carrying capacity of bearing are studied for various eccentricity ratios and speeds. Computational fluid dynamics (CFD) approach is used to get numerical results which are compared with experimental results. It is observed that CFD method provides a useful platform to study the combined effect of hydrodynamics and elastic behavior of the bearing. It is concluded that the deformations of the bearing are significant and should be considered in order to predict accurate performance of the hydrodynamic journal bearings.*

Keywords: *Composite bearing, fluid structure, hydrodynamic journal bearing, PTFE.*

1. INTRODUCTION

The application of hydrodynamic journal bearing is widely used in various applications due to its simplicity and superior load carrying capacity along with high precision while operating at higher speeds as compared to its counterpart rolling element bearings. Besides various parameters like speed, lubricant viscosity, temperature, eccentricity and load, material used for bearing plays important role as its deformation due to generated hydrodynamic forces modifies the flow domain. Now-a-days use of polytetrafluoroethylene (PTFE) is becoming popular due to itself lubricating properties, lower friction coefficient, excellent corrosion resistance and significant reduction in maintenance but have high wear rate, poor thermal conductivity and lower stiffness. M.Conte carried out the experiments to enhance these properties, filler materials like glass fiber; bronze fillers and graphite are used. Past research shows that uses of these materials also improves the load carrying capacity [1], hardness and wear resistance. Jaydeep Khedkarsuggest the wear process generally depends upon thermal considerations and properties of filler material. [2]. the comparison between tribological behavior dry sliding and water lubricated polyetheretherketone (PEEK) composite journal bearing and pressure distribution has been investigated in the literature [3].The tests were carried out at different speeds and pressures to investigate wear rate. Computational fluid dynamics (CFD) analysis of hydrodynamic and hydrostatic bearing simulation using CFX-Tascflow is studied for various geometry fluid films bearing for static and dynamic conditions [4]. Qiyin Lin developed the tool for lubrication problem and the effect of cavitations on pressure distribution of water lubricated journal bearing is analyzed using CFD with thermal and Cavitations effects. The relationship between eccentricity ratio and dimensionless Somerfield number is also investigated [5-6].The effect of PTFE lining on plain journal bearing characteristics is studied. The thermodynamic and mechanical properties are considerably influenced as compared to the plane journal bearing [7].Recently fluid-structure interaction approach is becoming popular which takes into account the combined effect of hydrodynamic and elastic behavior of bearing [8-9].

In this work, PTFE bearings are analyzed using fluid structure interaction approach along with study of microstructure of composite material and heat absorbing capacity using scanning electron microscopy (SEM) and Differential scanning calorimeter (DSC) respectively.

2. Hydrodynamic journal model

Hydrodynamic journal bearing (fig. 1) is defined as a mechanical element which supports high load due to wedge shape geometry formed during the relative motion between journal and bearing surface. Hydrodynamic journal bearing is widely used due to its high load carrying capacity and good damping properties. It is vital component in any manufacturing industry because whole plant efficiency greatly depends on it. The bearing supports the shaft of any transmission device which transfers energy or motion. Journal bearings have been widely used in rotating machinery. The bearing supports rotor weight, operating speed and dynamic behavior. The bearing carries higher loads which reduces film thickness and also increase temperature of bearing due to fluid film temperature increment. Both in the case of load capacity estimations (static performance) and dynamic analysis, the pressure distribution on the journal are important. Both theoretical and analytical thermo hydrodynamic problem of a finite length journal bearing is studied. The analysis takes into account load transfer between the film and both the shaft and the bearing. In the present work, hydrodynamic journal bearing model (mixture) model is used in order to take cavitations into account and deformation phenomenon also taken. In hydrodynamic journal bearing analysis using fluid-structure interactions need to compute the performance taking into consideration of cavitations as well as deformation in the bearing caused by hydrodynamic forces. In this work the geometry considered is as shown in fig.1. O' is the bearing centre and O is the journal or shaft centre, 'e' is the eccentricity of the bearing and L is the bearing length. The external load F is assumed as acting vertically along Y axis and is constant. The hydrodynamic pressure developed in the convergent region separates the bearing from shaft with a fluid film and balances the external force acting on the shaft. In this region the fluid properties remain constant. As the fluid enters in the divergent region, the fluid pressure falls and reaches to saturation pressure. In this region, liquid is converted into vapour form and as the fluid advances, oil vapour expands and more vapour bubbles are released.

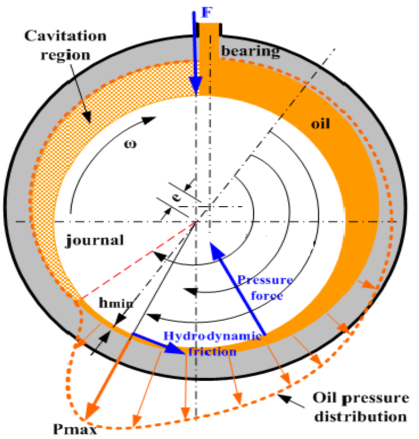

Fig-1: Schematic of Journal bearing geometry

2.1 Geometrical Model and Mesh Generation

The CFD model is developed using ANSYS Design modeler.The pre-processor of ANSYS (MESH) is used for mesh generation. Since clearance is much smaller than bearing diameter and length, the hexahedral mesh use in CFD analysis.

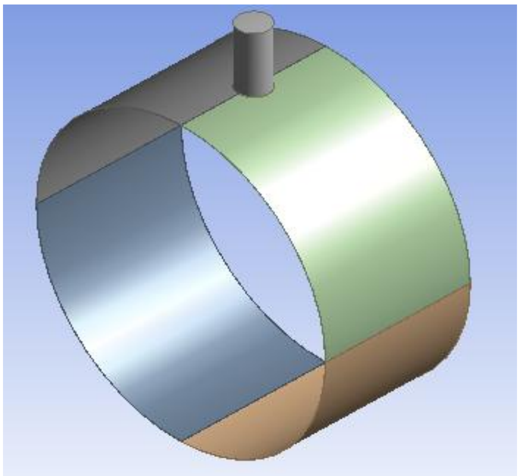

Fig-2: FLUENT CAD Model

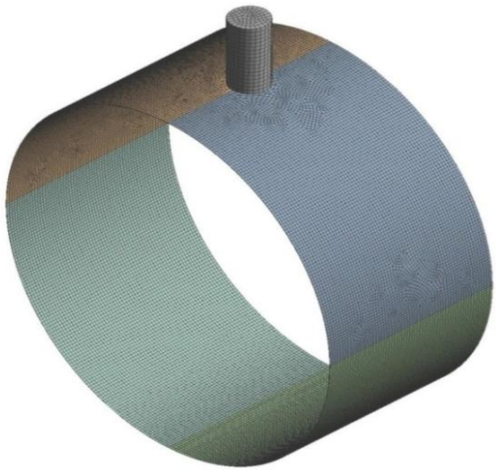

Fig-3: FLUENT Mesh Model

2. 2 Assumptions and boundary conditions

The governing equations are solved in steady state, taking no account of gravity force, and the operating pressure is set to 101,325 Pa. According to the dimensional parameters and the working condition of the journal bearings, the viscous model is set to the laminar model and enhanced wall treatment. To simplify the geometry, one side of the oil film clearance is used as an inlet and the other as an outlet. The boundary conditions of the inlet and outlet are respectively "pressure inlet" and "pressure outlet" with gauge pressure at zero Pascal. The outer surface of the oil film is modeled as a "stationary wall" and the inner surface is modeled as a "moving wall" with an absolute rotational speed which equals the angular velocity of the journal. The pressure-based solver is chosen for the numerical analysis in the paper. A converged solution can be obtained more quickly using SIMPLEC compared to SIMPLE.

3. Journal Bearing Parameter and Material Properties

Table -1: Journal Bearing Parameter and Material Properties

Parameter	Values
Journal Radius	24.95mm
Bearing Inner Radius	25mm
Bearing Length	25mm
Bearing Outer Radius	25mm
Radial Clearance	50 µm
Rotational Speed	1000rpm 2000rpm 3000rpm 4000rpm 5000rpm
Eccentricity Ratio(ε)	0.2 0.4 0.6 0.8
Lubricant viscosity	0.0125 Pa-Sec
Lubricant Density	850 kg/m³
PTFE young's modulus	8.496Mpa
PTFE Poisson's ratio	0.46
PTFE density	2150 kg/m³
steel young's modulus	210 GPa
Steel Poisson's ratio	0.3
Steel density	7850 kg/m³

4. Result and Discussion

The results obtained for a bearing with the following parameter here i.e. ε=0.8 and N=3000RPM radial clearance is 0.05mm. The pressure distribution of oil pressure is studied.

The maximum pressure developed in the bearing for Eccentricity ratio 0.8 and at 3000rpm is 5.762Mpa **(Fig.4),** as the rotational speed of journal increases; the maximum pressure developed in bearing also increases.

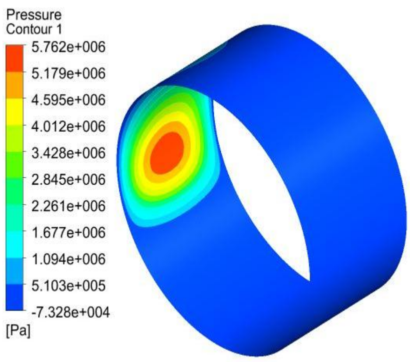

Fig-4: Pressure contour at ε=0.8 and 3000RPM

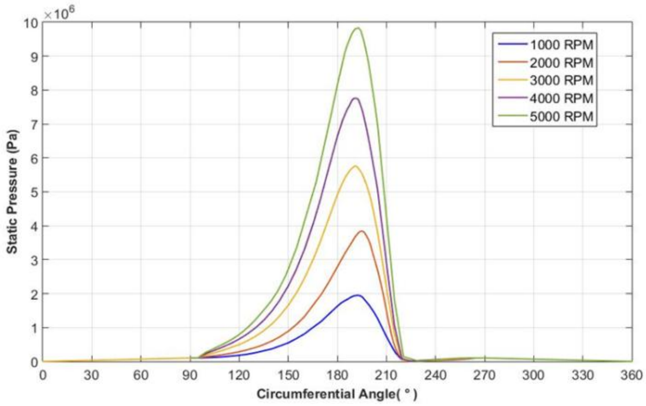

Chart-1: The film pressure distribution in the circumferential direction

(Chart-1) shows the pressure distribution on shaft for different speed of journal. It is also observed that the negative pressure negligible compared to the positive pressure. In addition, the positive pressure significantly different with different speed of journal (N).

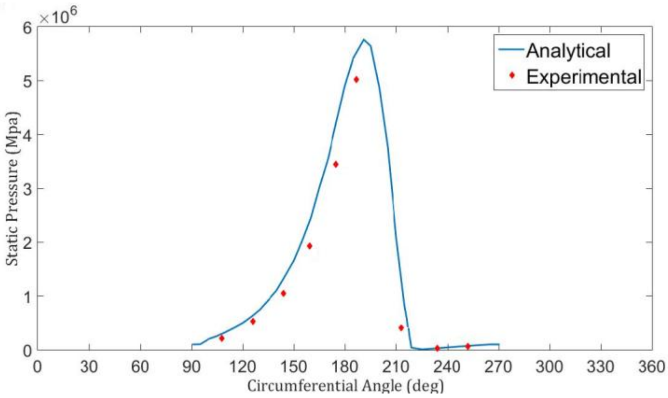

Chart-2: Comparison of analytical and experimental pressure profile at ε=0.8 and N=3000RPm

From experimental results **(Chart-2)** it was observed that the pressure is maximum at pressure sensor number six for the bearing. The negative pressure is observed at sensors seven and eight. This negative pressure is nothing but the Cavitations occurring inside the bearing due to load and speed. At lower speed and load the pressure on bearing is comparatively lower than higher speed and load.

Table -2: Comparison of analytical value and Experimental value

Bearing Parameter	Analytical	Experimental
Maximum pressure at ε=0.8 and N=3000RPM	5.76 Mpa	5.31 Mpa

Table-2 shows the results of the finite element analysis compared with the experimental results; similar characteristic static pressure curves are obtained. However, the analytical results are obtained by the finite element analysis show relatively high pressure in comparison with the experimental results. The results obtained by the CFD analysis are found to be in very good agreement with experimental results.

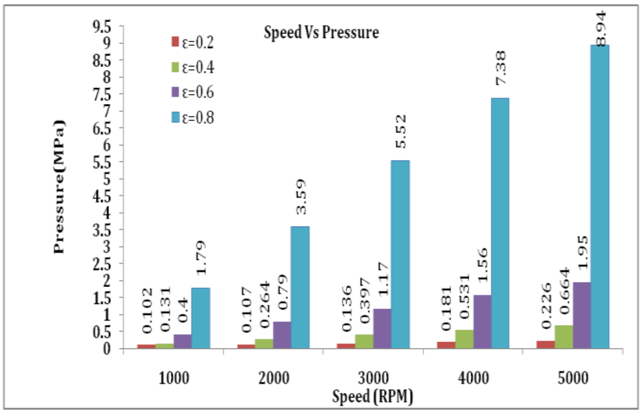

Chart-3: Variation of pressure distribution for various eccentricity ratio and speed

The pressure developed in the bearing for different eccentricity ratios and different speeds are tabulated in the above table **(Chart-3)** from the above Graph, as the eccentricity ratio increases from 0.2 to 0.8, the pressure developed in the bearing increases. At the 1000rpm 2000rpm, 3000rpm, 4000rpm, 5000rpm. Pressure developed increases from 0.102Mpa to 1.79Mpa, 0.107Mpa to 3.59Mpa, 0.136Mpa to 5.76Mpa, 0.181Mpa to 7.38Mpa, 0.226Mpa to 8.94Mpa respectively

5. Conclusions

The behavior of polymer material like PTFE hydrodynamic journal bearing is studied using CFD approach. Overall efficiency of material was good for application journal bearing. The lubricant film is generated in the CFD module of the software. The overall elastohydrodynamic lubrication analysis of plain journal bearing has been conducted using sequential application of computational fluid dynamics. 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. The deformations in PTFE bearings are significant as compared to metal a bearing which justifies the use of filler material for strengthening the polymer bearing characteristics.

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