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INVESTIGATION OF THERMAL PROPERTIES OF A LUBRICANT IN JOURNAL BEARING USING CFD

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Abstract

Modern industry increasingly relies on machinery that rotates at high speeds and handles substantial rotor loads. In these applications, hydrodynamic journal bearings are employed. At high speeds, a bearing generates heat from significant shearing within the lubricant film, increasing its temperature and reducing the lubricant's viscosity, which subsequently impacts its performance. Therefore, thermo-hydrodynamic analysis should be conducted to accurately determine the bearing's performance characteristics, as several THD studies have already been performed on journal bearings. Most of the analyses employed two-dimensional energy equations to determine the temperature distribution in the fluid film, assuming no temperature variation along the axial direction, and a two-dimensional Reynolds equation was used to calculate the pressure distribution in the lubricant flow, neglecting pressure changes across the film thickness. This study employs the Computational Fluid Dynamics technique to precisely forecast the performance characteristics of a plain journal bearing. Three-dimensional studies have been conducted to forecast pressure distribution around the journal surface both circumferentially and axially.

Keywords: *Thermal Properties, Thermo Hydrodynamic, Lubricant, Journal Bearing, Computational Fluid Dynam-ics.*

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1. Introduction

A journal bearing operates as a hydrodynamic load-bearing component. In a journal bearing, the lubricant situated between the journal and the bearing rotates along with the journal and helps carry the load. Because of the physical structure of the journal, a wedge-shaped fluid film is formed, as illustrated. CFD stands for Computational Fluid Dynamics, which involves using computers to simulate fluid flow. Conceptual approaches to solving ODEs or PDEs using numerical methods date back to Newton's era. However, without computers available at that time, applying these techniques was impossible. Today's computers, however, make numerical methods for solving differential equations easily accessible. This paper presents a numerical method capable of accurately predicting the performance characteristics of a plain journal bearing. The three-dimensional momentum equations along with the continuity equations that govern the flow field within the positive pressure fluid film region in the clearance space of the finite bearing are employed to determine the velocity and pressure fields in the fluid flow. The three-dimensional energy equation is employed to determine the temperature distribution within the fluid film.

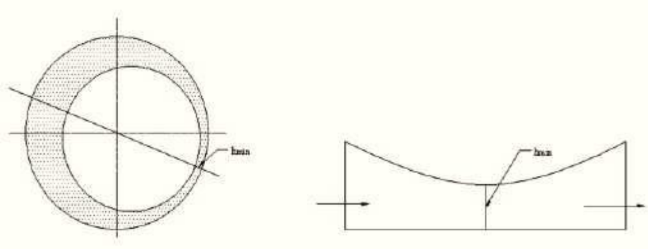

Figure 1. Fluid film development in a journal bearing

2. Problem Formulation

In this paper journal bearing has been analyzed with a 3-Dimensional geometry. In this analysis pressure distribution on the journal surface has been calculated considering the temperature effect and then temperature distribution also has been calculated. The pressure distribution has been compared then with the work of S. Cupillard and M. J. Cervantes [1]. In this paper a journal bearing having dimensions mentioned in the following section has been analyzed with the help of Fluent 6.3.26, a CFD software.

The following assumptions are made:

1) The inertia and body force terms are negligible relative to viscous and pressure forces.
2) The pressure remains uniform throughout the fluid film.
3) There is no slip at the fluid-solid boundaries 4) No external forces are acting on the film.
5) The flow is viscous and laminar 6) Because of the fluid film's geometry, the derivatives of u and w with respect to y are significantly greater than the derivatives of other velocity components.
7) The film thickness is much smaller than the bearing length ℓ. A typical value of h/ l is around 10−3.

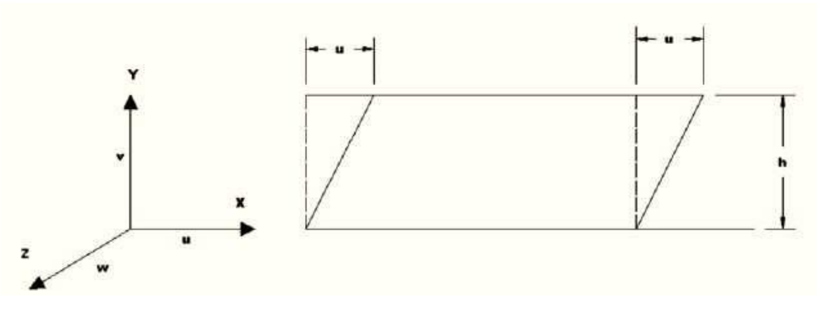

Figure 2. Fluid film depicting the Shear

3. Methodology

Journal Bearing Modeling

The smooth journal bearing which have been analyzed first is having following dimensions.

Length of the bearing (L)	133mm
Radius of Shaft (Rs)	50mm
Radial Clearance (C)	0.145mm
Eccentricity ratio(ε)	0.61
Angular Velocity (ω)	48.1 Rad/sec
Lubricant density (ρ)	840 Kg/m3
Viscosity of the lubricant (η)	0.0127 Pas [Kg/m.Sec]

Based on the above topological data, other derived values would include

I. Bearing Radius (Rb): (Rs + C) = 50.145 mm

II. Attitude angle (φ): 68.4°. (as per reference [7])

III. Eccentricity (e): (ε × C) = (0.61 × 0.145) = 0.08845 mm. Now, the details of the cavitation model are as follows:

Lubricant vapour saturation pressure	20 KPa.
Ambient pressure	101.325 KPa.
Density of lubricant vapour	1.2 kg/m3
Viscosity of lubricant vapour	2×10-5 Pas.
Assumed vapour bubble dia	1×10-5 m

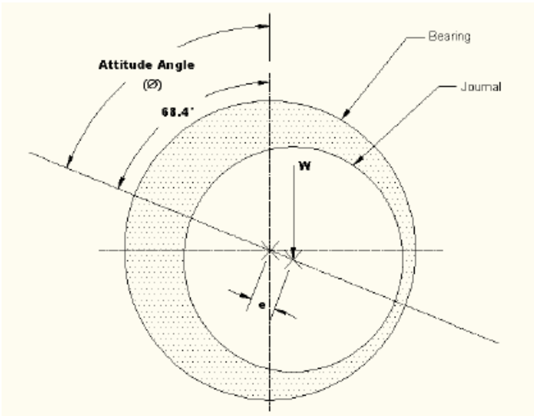

Figure 3. Schematic diagram of a smooth journal bearing

To begin this analysis, a 3-dimensional bearing was first created using GAMBIT 2.3.16. The figures below illustrate the 3D geometry and its meshed version as used in the GAMBIT CFD analysis with ANSYS.

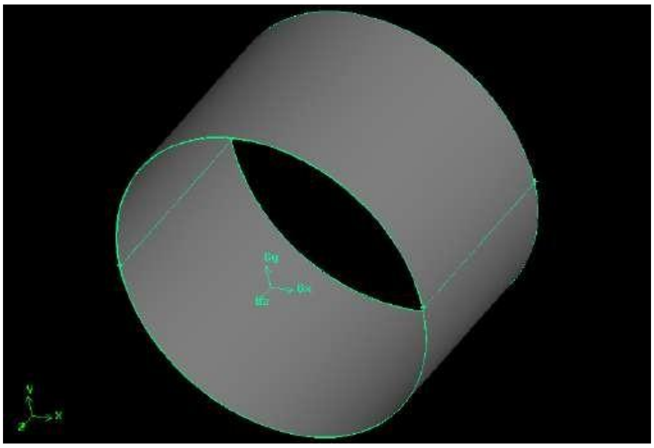

Figure 4. 3-dimensional representation of a smooth journal bearing in GAMBIT

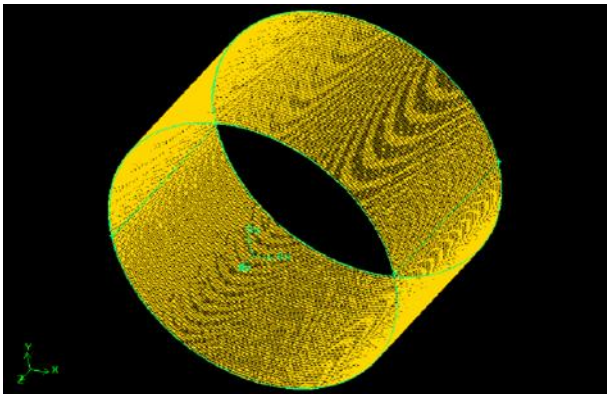

Figure 5. Meshed volume of a smooth journal bearing in GAMBIT

Following the generation of the meshed volume in GAMBIT, the next set of boundary conditions has been applied.

S.N.	BOUNDARY NAME	BOUNDARY TYPE
1	Middle cross-sectional plane	SYMETRY
2	End plane of the bearing	PRESSURE OUTLET
3	Journal surface	WALL
4	Bearing surface	WALL

After defining the boundary names and flow region types, the file was exported in „ .msh" format and subsequently imported into the „ Fluent" software for CFD simulation.

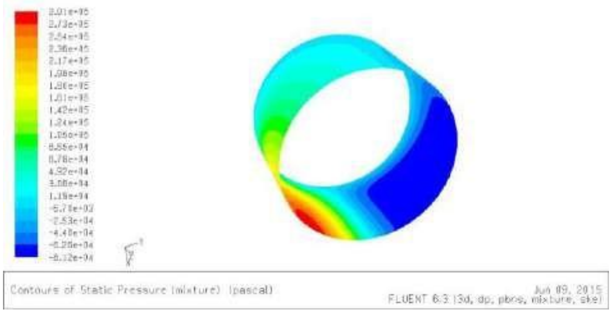

Figure 6. Pressure contour on Journal surface starting from plane of symmetry.

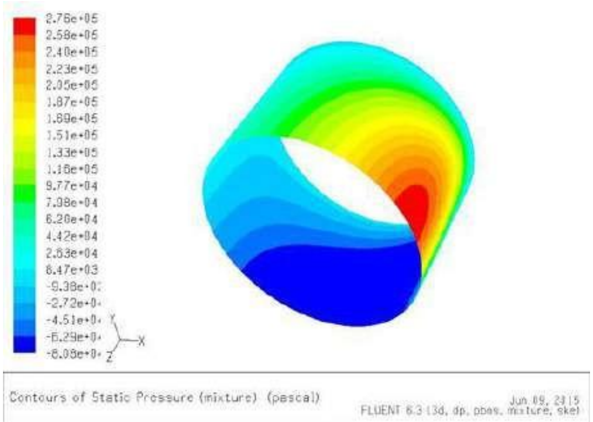

Figure 7. Pressure contour on Journal surface starting from a plane 10% of length

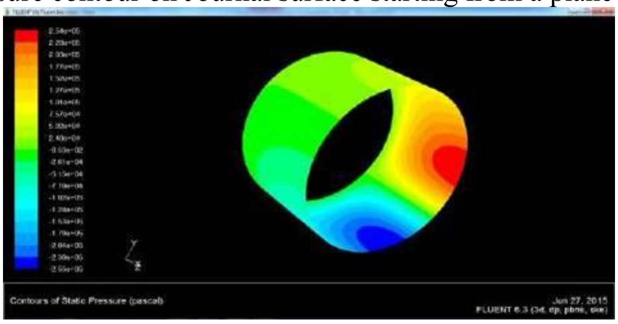

Figure 8. Pressure distribution on journal surface considering temperature effect

Once the thermal analysis is completed, the temperature distribution across the journal surface has been determined. The figure below illustrates how the oil temperature changes across the journal surface.

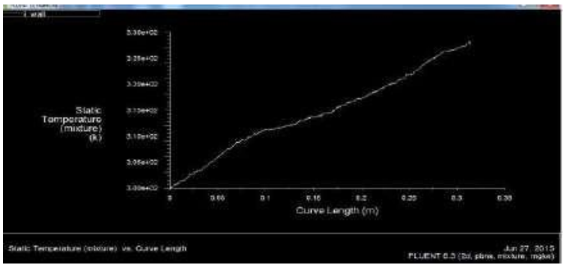

Figure 9. Temperature distribution on journal surface

4. Conclusion

In this study a work of Cupillardet. al. has been reassessed, who have done some modification on Journal bearing and done a CFD study of lubricant of that modified Journal Bearing. In their work Cupillardet. al first analyzed a plain Journal Bearing and evaluated pressure distribution on the circumference of Journal at the mid plane. Cupillard et al did this investigation without considering temperature effect on lubricant's physical and chemical properties and also they did it with a 2-Dimensional geometry. In this work a 3-Dimensional study of a plain journal bearing of dimension as per Cupillardet. al[1] has been done with a consideration of temperature as well as pres-sure effect on lubricants viscosity. The investigation carried out in this paper leads to a very important conclusion. Thermo hydrodynamic analysis of bearing gives the actual prediction of different performance parameters correctly. So whatever modification done on a bearing and then CFD simulation is done, it is mandatory to con-sider thermal effects on the chemical properties of the lubricant in the flow region.

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