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CFD Analysis of Two Lobe Hydrodynamic Journal Bearing

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***Abstract*— Hydrodynamic journal bearing is a vital component in the rotating machinery since efficiency of the machine greatly depends on the performance of the bearing. The journal bearing performs well for medium speed, but at high speed fluid starts to whip around the journal due to which constant wedge shape is not form. Hence journal becomes unstable and starts vibrating. To avoid this for high speed hydrodynamic journal bearing, shape of inner diameter of the bearing is changed such that it will try to avoid oil whip. One of the such method is providing lobes on inner surface of the bearing. Two lobe and multi lobe (more than two lobe) are the two methods to provide lobe on the bearing. The present paper is the validation of the theoretical results obtained by them using Computational Fluid Dynamics (CFD) software package ANSYS 14.5. Also comparison of variation of pressure around bearing surface of Two Lobe and Simple Hydrodynamic Journal Bearing is compared.**

I. Introduction

Hydrodynamic journal bearing 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 failure of the bearing may stop the whole production line and loss of money and material. The major problem with hydrodynamic bearing is failure of fluid film during the operation which may cause metal to metal contact between journal and bearing surface which leads to wear and friction which overheats the surfaces. Hence the power loss increases. One of the most important causes of fluid film failure is oil whip at high speed due to which constant wedge is not form between the surfaces which causes uneven displacement of the journal and leads to bearing vibration. Lot of research has done across the world to increase the stability of the fluid film. Changing the bearing profile is one of the methods to increase the stability of the fluid film. Amit Chauhan and Rakesh Sehgal [1] has studied two lobe bearing in the paper "Thermohydrodynamic Analysis of Two Lobe Journal Bearing with Different Grade Oils" puplished in the Tribology International. The present work is validation of the paper[1] as well as study of stability of Two Lobe Journal Bearing and effect of increase in elliptical ratio by using CFD tool.

II. THEORETICAL BACKGROUND

The hydrodynamic journal bearing consist of journal rotating relative to bearing. The two surfaces are separated by thick fluid film of lubricating oil due to which converging shape zone is created during the rotation of the journal. High pressure is created due to this converging zone and velocity of the journal which supports the load. As the speed of rotation of the journal increases maximum pressure developed also increases. Maximum pressure developed in a fluid film is also dependent of viscosity of the oil.

Circular Hydrodynamic Journal Bearing

The hydrodynamic journal bearing consist of journal rotating relative to bearing. The two surfaces are separated by thick fluid film of lubricating oil due to which converging shape zone is created during the rotation of the journal. High pressure is created due to this converging zone and velocity of the journal which supports the load. As the speed of rotation of the journal increases maximum pressure developed also increases. Maximum pressure developed in a fluid film is also dependent of viscosity of the oil.

Construction of Circular and 2 Lobe Hydrodynamic Journal Bearing

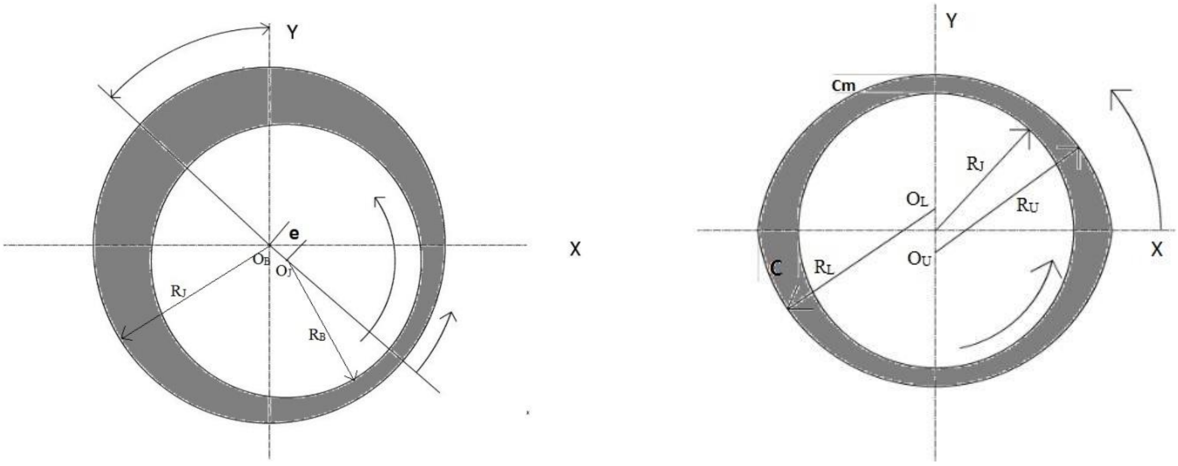


Fig. 1 Circular Hydrodynamic Journal Bearing

Reynolds equation is used to analyze journal bearing For steady state and incompressible flow the Reynolds Equation is

$$\frac{\partial}{\partial x}\left(\frac{h^3}{\mu}\frac{\partial p}{\partial x}\right)+\frac{\partial}{\partial z}\left(\frac{h^3}{\mu}\frac{\partial p}{\partial z}\right)=6U\frac{\partial h}{\partial x} \qquad (1)$$

Two Lobe Hydrodynamic Journal Bearing

Lemon bore bearing is a variation on the plain bearing where the bearing clearance is reduced in one direction and this bearing has a lower load carrying capacity than the plain bearings, but is more susceptible to oil whirl at high speeds.

Reynold's equation for two lobe journal bearing is obtained by modifying equation (1)
Minimum flude film Thickness for two lobe journal bearing is give by sehgal and chauhan[1]

$$h = c_m[1 + E_M + \varepsilon_1 \cos(\theta + \emptyset - \emptyset_1)],\ for\ 0 < \theta < 180 \qquad (2)$$

$$h = c_m[1 + E_M + \varepsilon_2 \cos(\theta + \emptyset - \emptyset_2)],\ for\ 180 < \theta < 360 \qquad (3)$$

Different parameters used in equation are given as

$$\varepsilon_1 = \left({E_M}^2 + \varepsilon^2 - 2E_M\varepsilon\cos\emptyset\right)^{\frac{1}{2}};\ \varepsilon_2 = \left({E_M}^2 + \varepsilon^2 + 2E_M\varepsilon\cos\emptyset\right)^{\frac{1}{2}}$$

$$\emptyset_1 = \pi - \tan^{-1}\left(\frac{\varepsilon\sin\emptyset}{E_M - \varepsilon\cos\emptyset}\right)\ ;\ \emptyset_2 = \tan^{-1}\left(\frac{\varepsilon\sin\emptyset}{E_M + \varepsilon\cos\emptyset}\right)$$

III. METHODOLOGY

For analysis in fluent a 3-D model of fluid film is created in GAMBIT by using the following dimensions

Table 1 Two Lobe Jornal Bearing parameters

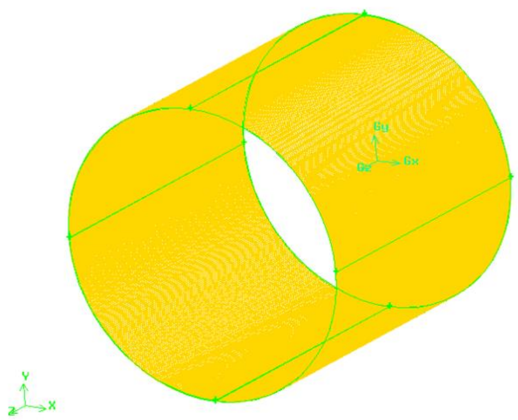
Parameter	**Dimension**
Length, L	100mm
Length to Diameter (L/D) ratio	1
Diameter of the Journal D	100mm
Maximum inner diameter of the bearing D_{imax}	100.4mm
Minimum inner diameter of the bearing D_{imin}	100.24mm
Radial Clearance, C	200µm
Minimum Clearance, C_m	120µm
Oil Inlet Temperature	33^0C

Table 2 Names and types of boundaries of flow region boundary flow region

Geometrical boundary	**CFD boundary condition**
Journal surface	Wall
Bearing surface	Wall
Fluid zone side 1	Pressure Outlet
Fluid zone side 2	Pressure Outlet

Model of lubricant in the clearance space is modeled in GAMBIT and meshed with grid details as Number of mesh elements (hexahedral) are 63200. Different boundary conditions are set for different zones and surfaces. The mesh file is imported in ANSYS Fluent solver for CFD simulation. In Fluent after conforming quality of mesh, data related to chemical and physical properties of the lubricant oil used is applied. The bearing is modeled as 'moving wall' with absolute motion at an angular speed of 0 RPM. Rotation axis coordinates for the bearing are X=0, Y=0, Z=0 and rotation axis direction X=0, Y=0, Z=1.The journal is modeled as moving wall with angular velocity 3000 RPM, rotation axis is shifted according to eccentricity assumed (i.e. if eccentricity ratio is 0.7 then rotation axis of the journal is shifted to (X=0.098, Y=0, Z=0) and rotation axis direction is same as that of bearing.

In fluid cell zone condition define motion type as moving reference frame for journal with rotational velocity 0 RPM and direction of rotation is as direction of journal. The translational velocity in all three coordinate directions was set equal to zero. The various parameters are specified associated with the solution method to be used in the calculation. The segregated solver is used for finding the solution and flow is assumed to be laminar and steady. The discritisation used is ‘PRESTO’ for pressure, ‘second order’ for momentum, ‘second order’ for energy and ‘simple’ for P-V coupling. After simulation
3-dimentional pressure distribution around the journal surface is presented in the form of contour.



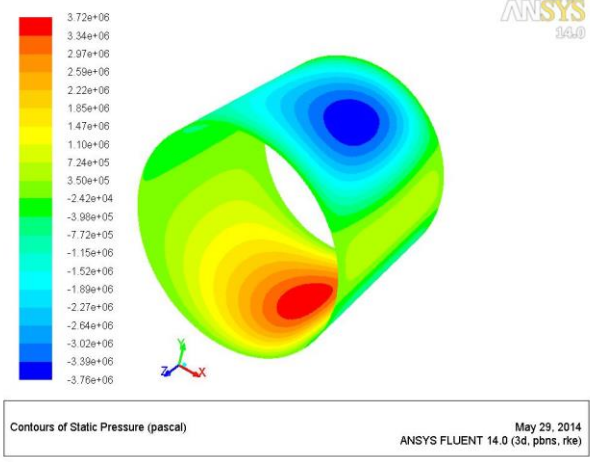
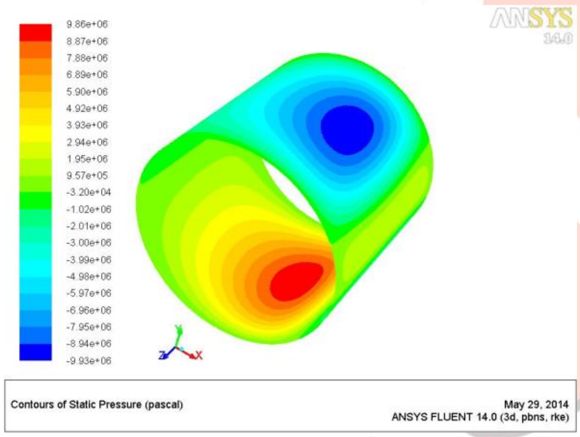


Fig.3 Meshed Model of Two Lobe Journal Bearing
Fig.4 Counters of Static pressure at Eccentricity ratio 0.7 and Speed 3000 RPM For Oil Hydrol 68



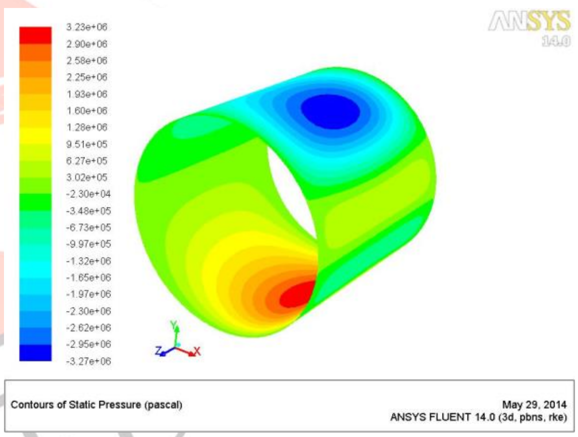


Fig.5 Counters of Static Pressure at Eccentricity Ratio 0.7 and Speed 3000 RPM For Oil Mak 2T
Fig.6 Counters of Static Pressure at Eccentricity Ratio 0.7 and Speed 3000 RPM For Oil Mak Multigrade

Properties of Oils under study

Table 4: Properties of the lubricating oil used in the analysis

Properties	Oil 1 Mak 2T	Oil 2 Hydrol 68	Oil 3 Mak Multigrade	Servo Prime 46
Density, ρ	868 kg/m^3	880 kg/m^3	886 kg/m^3	867 kg/m^3
Specific Heat, C_p	2000 J/kg-^{0}C	2000 J/kg-^{0}C	2000 J/kg-^{0}C	2000 J/kg-^{0}C
Thermal Conductivity, K_{oil}	0.126 W/m-^{o}C	0.126 W/m-^{o}C	0.126 W/m-^{o}C	0.126 W/m-^{0}C
Viscosity, μ (at T=33^{0}C)	0.065 Pa-s	0.075 Pa-s	0.200 Pa-s	0.0326 Pa-s

IV. VALIDATION

The graph of static pressure versus angular coordinates is plotted and it is compare with graph obtained theoretically by Sehgal and Chauhan[2]

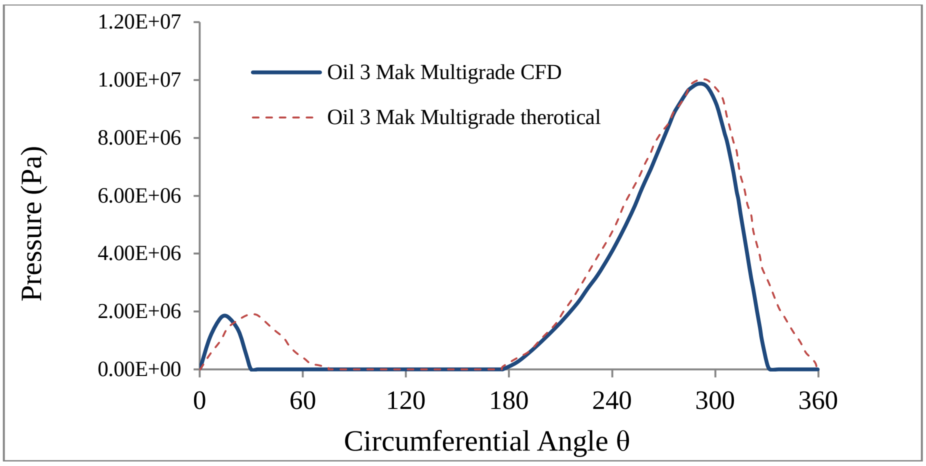


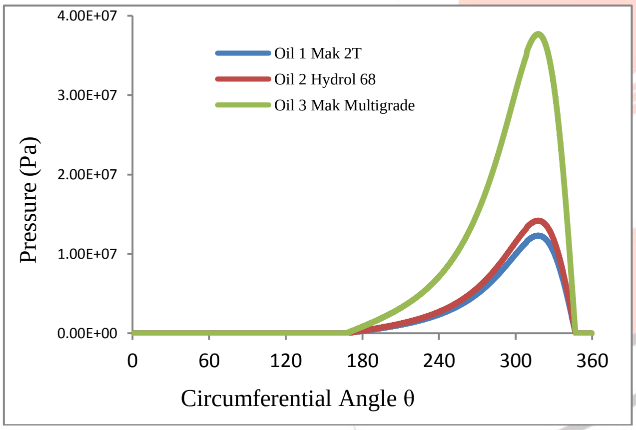
Fig 7 Graph showing validation of results obtained for Maximum pressure at eccentricity ratio 0.7 and 300 rpm speed of

The maximum pressure obtained is 9.92E+06 by CFD tool which is nearly same to 10E+06 obtained theoretically for oil 3 which is Mak Multigrade oil. Also pressure obtained for oil with different viscosity has approximate same values as that of theoretically obtained.

V. RESULT AND DISCUSSION

Comparison of Circular and Two Lobe Journal Bearing

Simple journal bearing with clearance equal to minimum clearance of two lobe journal bearing which is equal to 0.12mm is considered for comparison with two lobe journal bearing. The variation of pressure around bearing surface is obtained from CFD too for both bearings are shown in graphs below.



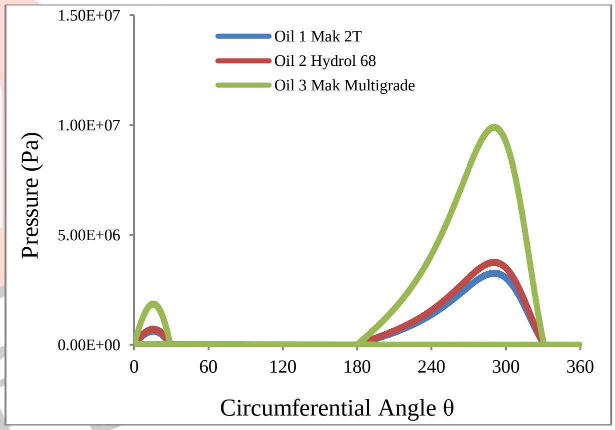


Fig 8 Variation of Pressure With Respect to Circumferential Angle for Simple Journal Bearing at 3000 RPM speed and Eccentricity Ratio 0.7

Fig 9 Variation of Pressure With Respect to Circumferential Angle for Two Lobe Journal Bearing at 3000 RPM Speed and Eccentricity Ratio 0.7

Load Carrying Capacity

Load carrying capacity of both Simple Bearing and Two Lobe Bearing is compared at the speed 1000, 2000, 3000, 4000 and 5000 revolutions per minute. Oil used for this analysis is Servo Prime 46 with Viscosity 0.0325 kg/m-s Specific heat 2041.8 J/Kg-C, thermal conductivity 0.1254 W/m-s and Density 861 kg/m^3

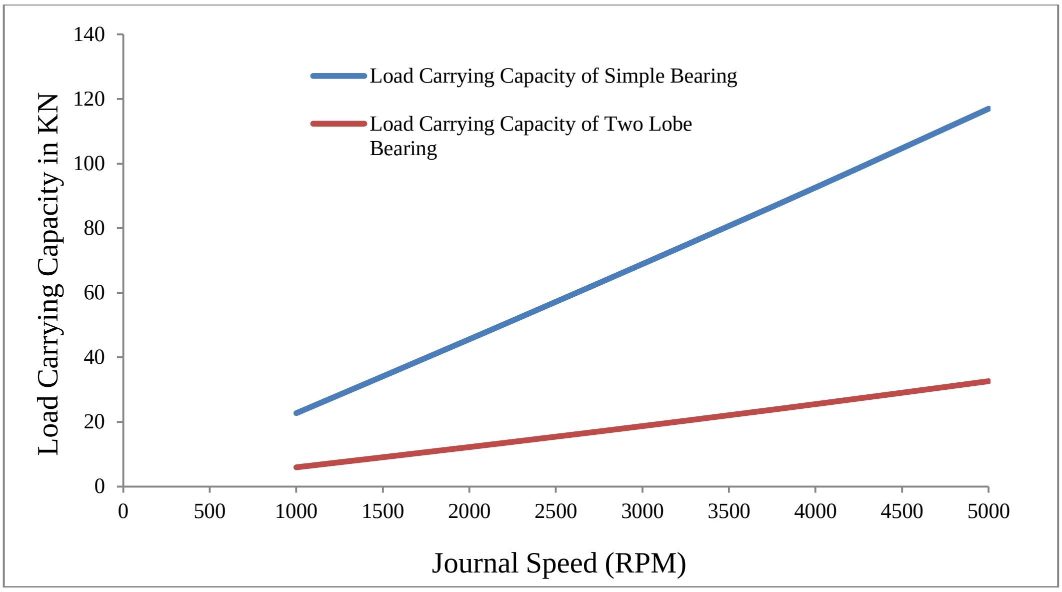


Fig 10 Load carrying capacity of Two Lobe and Simple Journal Bearing at different Speed for Oil Servo Prime 46

From the graph it can be seen that at high speed load carrying capacity of the bearing increases drastically due to sudden change of maximum pressure. For Two Lobe Hydrodynamic Journal Bearing variation of the maximum pressure is very slow compared to Cylindrical Hydrodynamic Journal Bearing, hence its load carrying capacity increases slowly with respect to increase in speed.

Variation of pressure with respect to Elliptical Ratio E_M

When elliptical ratio is increased it refers to increase in non-circularity of the bearing. The elliptical ratio is increased from 0.5 to 3 for Two Lobe Journal Bearing with eccentricity ratio 0.7 at 3000 RPM speed with lubricating oil Servo Prime 46. The Elliptical ratio is increase by keeping minimum clearance same and by changing only maximum clearance. The graphs of variation of Pressure around circumference of the Bearing surface are obtained as below

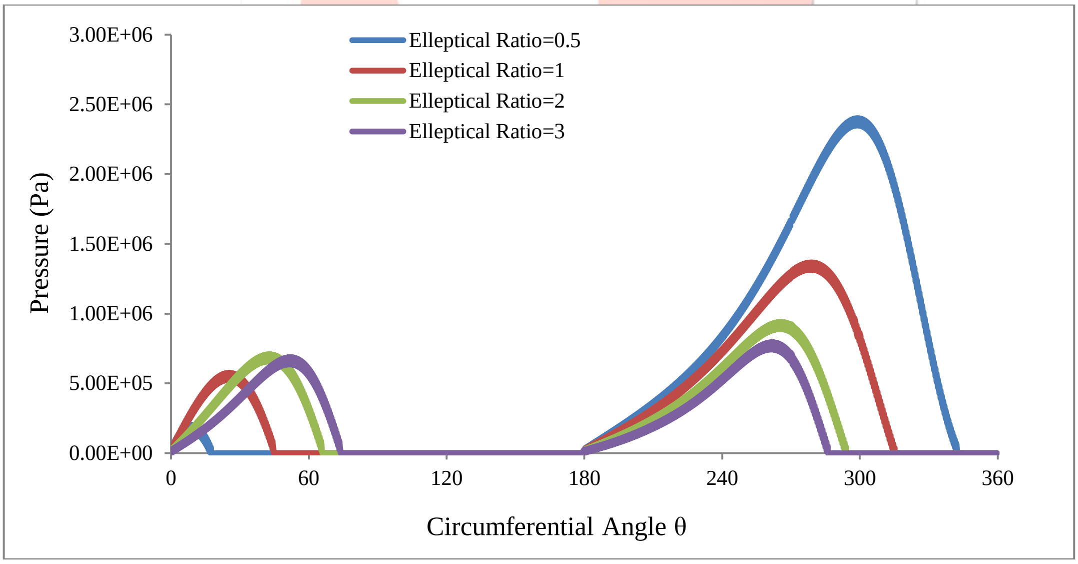


Fig. 10 Variation of pressure along the Bearing surface with varying Elliptical ratio E_M

From the graph it can be seen that with increasing elliptical ratio maximum pressure decreases but stability of the bearing increases since pressure distribution in both lobes (Upper & lower) tends to be equal.

VI. CONCLUSION

The present work is analysis of Two Lobe Journal Bearing by using CFD tool ANSYS 14.5. The Variation of pressure along the circumference of the bearing surface is studied and compared with Simple Hydrodynamic Journal Bearing and it is found that maximum pressure for Two Lobe Hydrodynamic Journal Bearing is much less than Simple Hydrodynamic Journal Bearing. From the results it can be seen that at high speed Cylindrical bearing shows drastic change in maximum pressure in the fluid film which increases tendency of journal to fall in the low pressure zone. This cycle is repeated again and again which setups vibration in the bearing. On the other hand Two Lobe Journal Bearing shows very less variation of maximum pressure at high speed which indicates that two lobe journal bearing is more stable than Cylindrical Journal Bearing. But load carrying capacity of the two lobe journal bearing is much less than Cylindrical Hydrodynamic Journal bearing. Also with increasing elliptical ratio E_M maximum

Pressure decreases but pressure in upper and lower lobe tries to be equal with increasing elliptical shape which indicates that stability of the Two Lobe Journal Bearing increases with increasing elliptical ratio.

Abbreviations and Acronyms

C	Radial clearance, µm
C_m	Minimum clearance when journal center is coincident with geometric center of bearing, µm
C_p	Specific heat of lubricating oil, J/kg ^{0}C
D	Inner Diameter of the bearing
E	Eccentricity in mm
E_m	Elliptical ratio
H	Film thickness for elliptical journal bearing in mm
K_{oil}	Thermal conductivity of lubricating oil, W/m^{0}C
N	Journal speed in rpm
O_B	Bearing centre
O_J	Journal centre
O_L	Lower lobe centre
O_U	Upper lobe centre
P	Film Pressure, Pa
R_U	Radius of upper lobe
R_L	Film Pressure, Pa
T	Lubricating Fluid temperature, ^{0}C
Ta	Ambient temperature, ^{0}C
u, w	Velocity components in X and Z direction, m/s
ε	Eccentricity ratio
$\varepsilon_1, \varepsilon_2$	Eccentricity ratio from 0-180^0 and 180-360^0, respectively
$\emptyset$	Attitude angle
$\emptyset_1, \emptyset_2$	Attitude angles from 0-180^0 and 180-360^0, respectively
θ	Angle Measured from Horizontal split axis
μ	Absolute viscosity, Pa-s
ρ	Density of lubricating oil, kg/m^3
ω	Angular Speed of Shaft in RPM

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