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Analysis of Hydrodynamic Journal Bearings using Fluid Thermal Structural Interaction

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Abstract **- Hydrodynamic journal bearings are critical power transmission components that are carrying increasingly high loads because of the increasing power density in various machines. Therefore, knowing the true operating conditions of hydrodynamic journal bearings is essential to machine design. Oil film pressure is one of the key operating parameters describing the operating conditions in hydrodynamic journal bearings.**

In this thesis, the CFD analysis, Thermal analysis is done on liquid lubricated cylindrical journal bearing. In order to find temperature distribution in the bearing structure, satisfying the boundary conditions are analyzed for some geometric and operating parameters, such as journal eccentricity ratio. Journal bearings for L/D ratio and different eccentricity ratios are modeled in 3D modeling software Pro/Engineer. The L/D ratios considered is 0.8 and eccentricity ratios considered are 0.2, 0.4, 0.6 and 0.8. The liquid lubricants are SAE30.

Journal bearing models are developed for speed of 5000 rpm to study the interaction between the fluid and elastic behaviour of the bearing. The speed is the input for CFD analysis and the temperature obtained from the CFD analysis are taken as input for thermal analysis.

Index Terms: **Journal Bearings, CFD analysis and Lubrication.**

I. INTRODUCTION

A surprisingly large number of bearings can be found all around us. Take automobiles, for example: there are 100 to 150 bearings in a typical car. Without bearings, the wheels would rattle, the transmission gear teeth wouldn't be able to mesh, and the car wouldn't run smoothly. A plain bearing is the simplest type of bearing, comprising just a surface and no rolling elements. Therefore the journal slides over the bearing surface. The simplest example of a plain bearing is a shaft rotating in a hole. A simple linear bearing can be a pair of flat surfaces designed to allow motion; e.g., a drawer and the slides it rests on or the ways on the bed of a lathe. Plain bearings, in general, are the least expensive type of bearing. They are also compact and lightweight, and they have a high load-carrying capacity.

The design of a plain bearing depends on the type of motion the bearing must provide. The three types of motions possible are: journal bearing, linear bearing and thrust bearing. Materials: Babbitt and Bi-material.

Figure: Babbit & Bi-Materials

Bearings enhance the functionality of machinery and help to save energy. Bearings do their work silently, in tough environments, hidden in machinery where we can't see them. Nevertheless, bearings are crucial for the stable operation of machinery and for ensuring its top performance. The word "bearing" incorporates the meaning of to bear in the sense of to support and to carry a burden. This refers to the fact that bearings support and carry the burden of revolving axles.

Figure: Rolling Bearing

Figure: Outer Ring

Figure: Inner Ring

Figure: Rolling elements

II. LUBRICATION

Lubrication is the process or technique employed to reduce friction between, and wear of one or both, surfaces in close proximity and moving relative to each other, by interposing a substance called a lubricant between them. The lubricant can be a solid, (e.g. Molybdenum disulfide MoS_2) a solid/liquid dispersion, a liquid such as oil or water, a liquid-liquid dispersion (a grease) or a gas with fluid lubricants the applied load is either carried by pressure generated within the liquid the due to the frictional viscous resistance to motion of the lubricating fluid between the surfaces, or by the liquid being pumped under pressure between the surfaces.

The types of lubrication system can be categorized into three groups:

- **Class I** — bearings that require the application of a lubricant from an external source (e.g., oil, grease, etc.).
- **Class II** — Bearings that contain a lubricant within the walls of the bearing (e.g., bronze, graphite, etc.,). Typically these bearings require an outside lubricant to achieve maximum performance.
- **Class III** — bearings made of materials that are the lubricant. These bearings are typically considered "self-lubricating" and can run without an external lubricant.

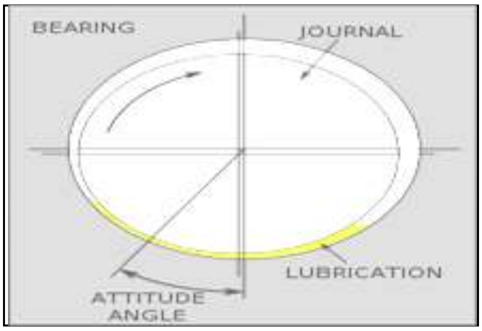


Figure: Fluid Lubrication

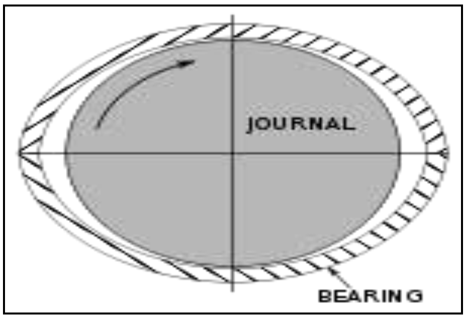


Figure: A lemon bore

III. LITERATURE REVIEW

In the paper by B. S. Shenoy[1], Conventional method of performing an EHL analysis on a bearing involves development of complex codes and simplification of actual physical model. This paper presents a methodology to model and simulate the Overall Elasto-Hydrodynamic Lubrication of a full journal bearing using the sequential application of Computational Fluid Dynamics (CFD) and Computational Structural Dynamics (CSD). Here, the coupled field analysis uses the capabilities of commercially available Finite Element Software ANSYS/FLOTRAN incorporating the technique of Fluid Structure Interaction (FSI). The pressure field for a full journal bearing operating under laminar flow regime with various L/D ratios is obtained by CFD. Stress distribution and deformation in the bearing liner due to resulting pressure force is evaluated using FEM, satisfying the boundary conditions. The stress distribution indicates the critical points in the bearing structure.

In the paper by PriyankaTiwari[2], Hydrodynamic journal bearings are analyzed by using Computational fluid dynamics (CFD) and fluid structure interaction (FSI) approach in order to find Pressure profile and temperature distribution in the bearing structure, satisfying the boundary conditions. The Journal bearing is designed in ANSYS software, the journal is modeled as a moving wall with an absolute rotational speed of 3000rpm and bearing is modeled as a "stationary wall". Design parameters like pressure distribution and temperature distribution are considered for the analysis. It is assumed that the flow of lubricant is laminar and steady. Also cavitations effects in the bearing are neglected by setting all negative pressures to ambient pressures. Design data like journal diameter, clearance, L/D ratio, minimum film thickness, and journal speed and oil viscosity are taking by machine design data book for making analytical calculation.

In the paper by S. Sharma [4], experimental study out-of-roundness and radial clearance of journal bearings were measured with high precision and the impact of their metrology was examined on the specific oil film thickness of the bearing. Some metrological issues were emerged and these should be taken into account when bearings are designed.

IV. BOUNDARY CONDITIONS

CYLINDRICAL JOURNAL BEARING

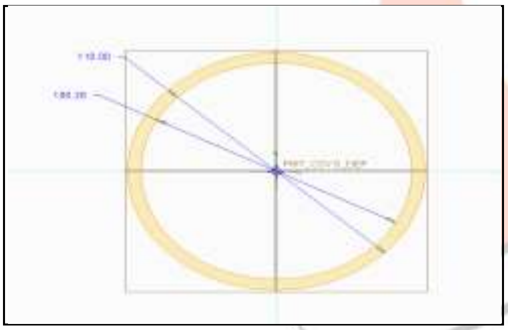


Figure: 2-D Sketch for bearing

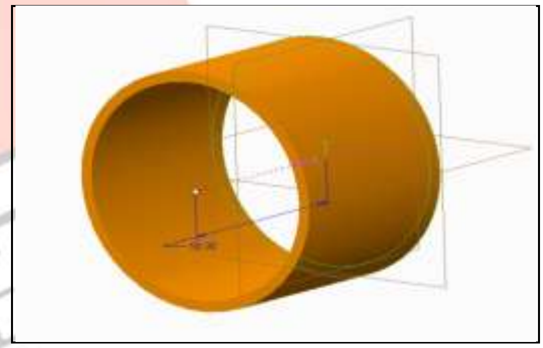


Figure: 3D MODEL

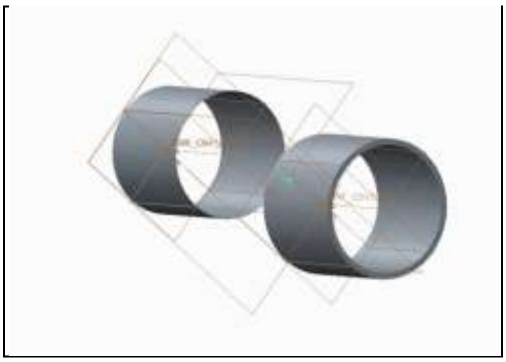


Figure: Assembly of bearing and lubrication

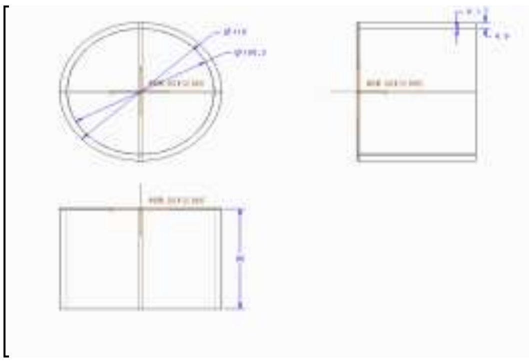


Figure: 2D Drafting

Figure: Assembly of bearing and lubrication

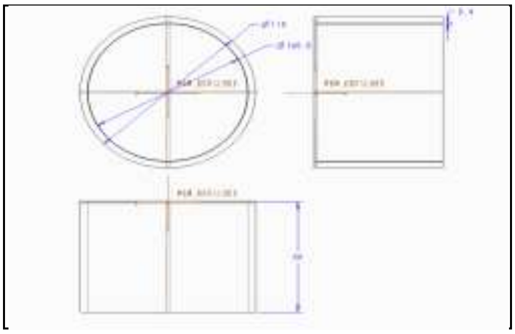


Figure: 2D Drafting

V. THERMAL ANALYSIS

ECCENTRICITY = 0.2
MATERIAL – STEEL

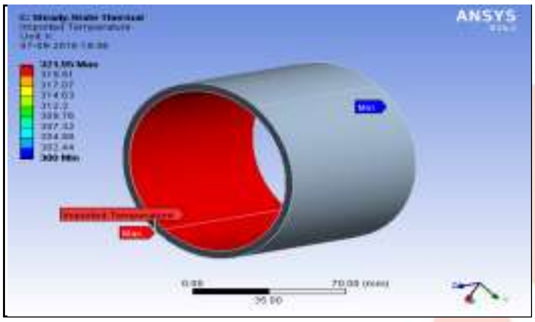


Figure: Imported temperature

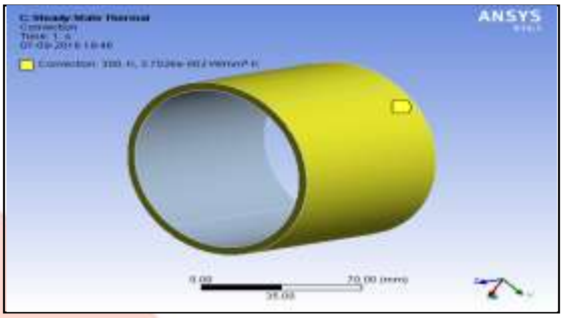


Figure: convection

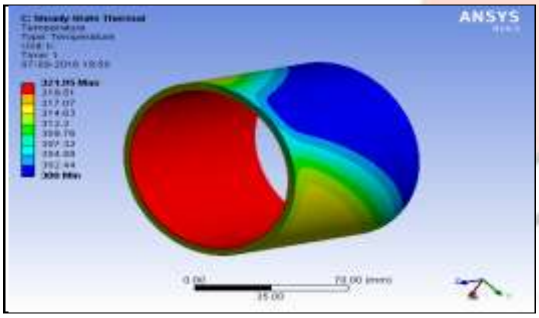


Figure: Temperature

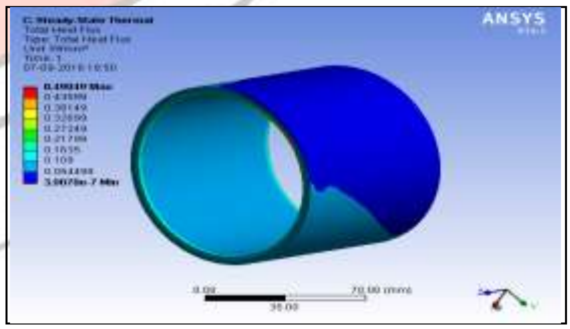


Figure: Total heat flux

MATERIAL - ALUMINIUM ALLOY

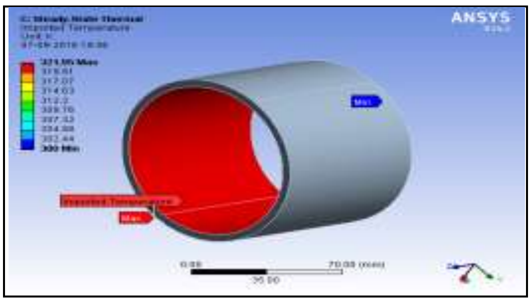


Figure: Imported Temperature

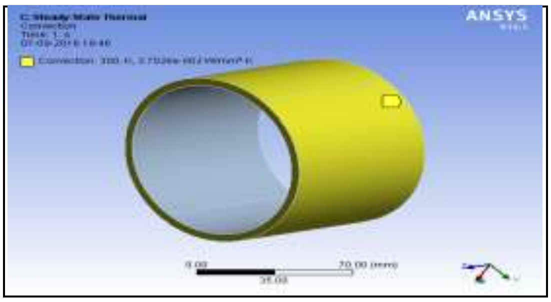


Figure: convection

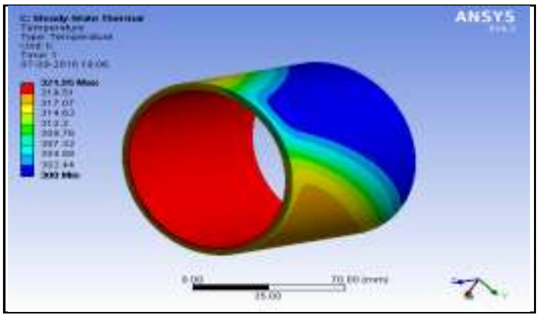


Figure: Temperature

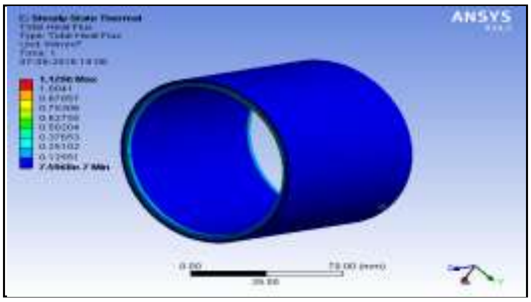


Figure: Total heat flux

ECCENTRICITY - 0.4
MATERIAL - STEEL

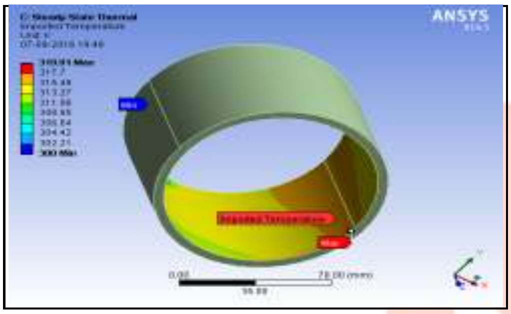


Figure: Imported temperature

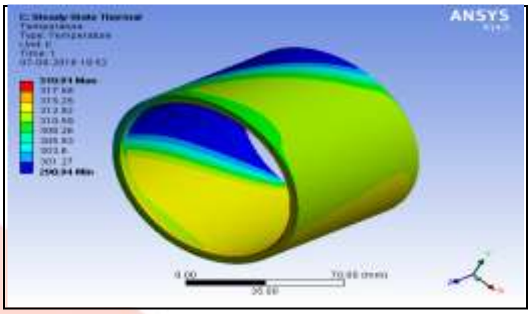


Figure: Temperature

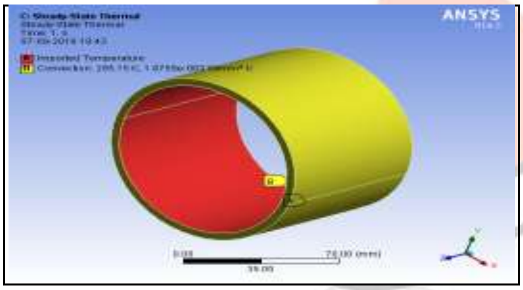


Figure: Convection

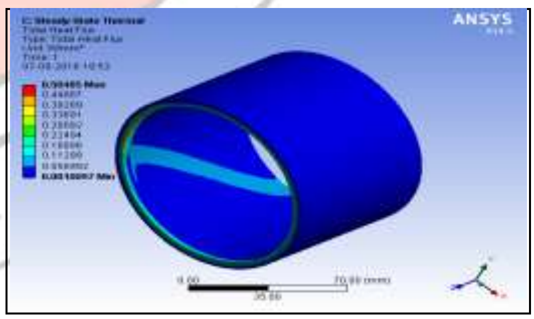
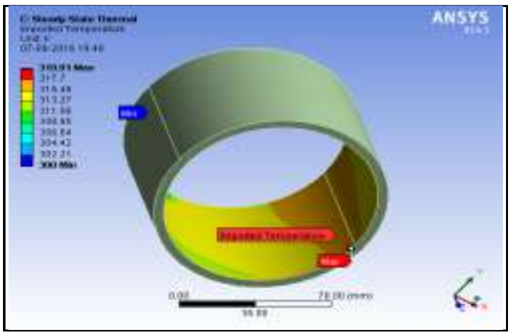


Figure: Heat flux

MATERIAL - ALUMINIUM ALLOY



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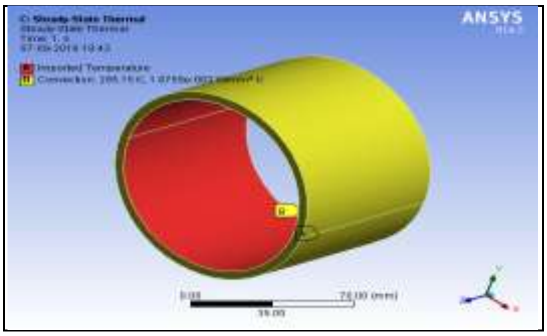


Figure: Convection

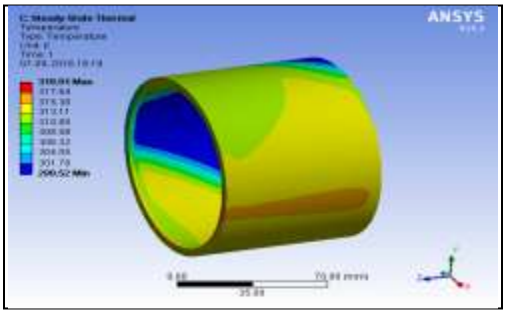


Figure: Temperature

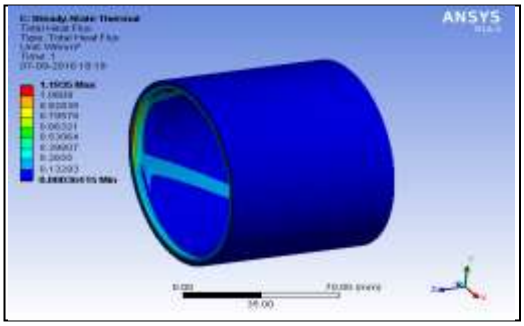


Figure: Heat flux

ECCENTRICITY - 0.6

MATERIAL – STEEL

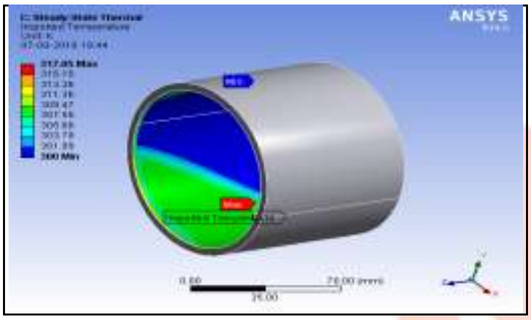


Figure: Imported Temperature

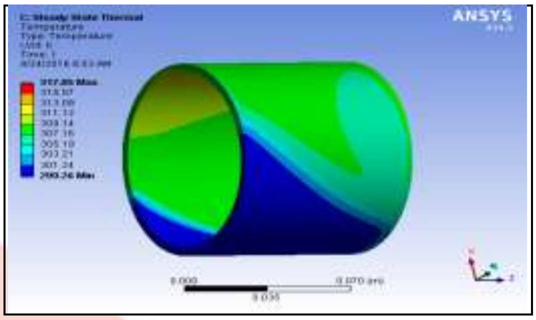


Figure: Temperature

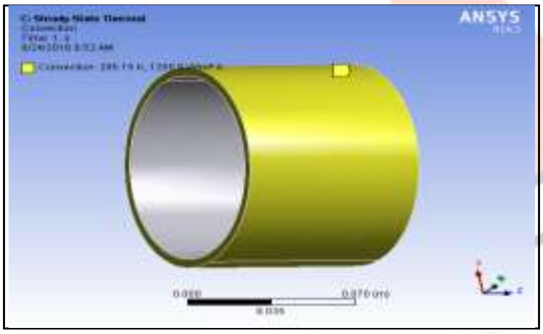


Figure: Convection

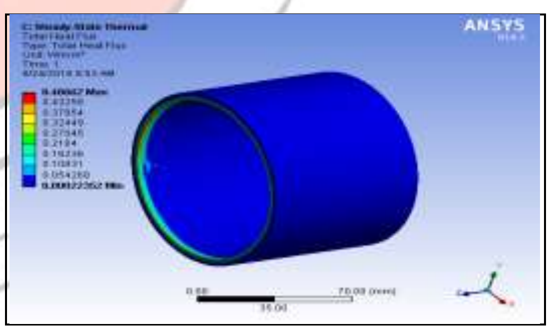
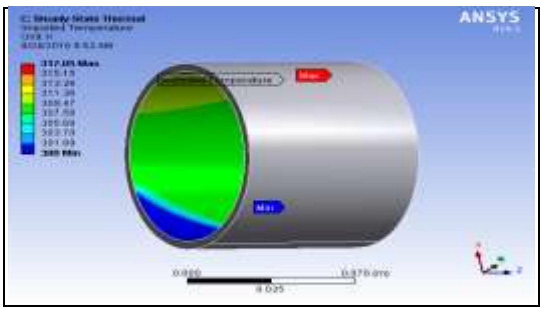


Figure: Heat flux

MATERIAL - ALUMINIUM ALLOY



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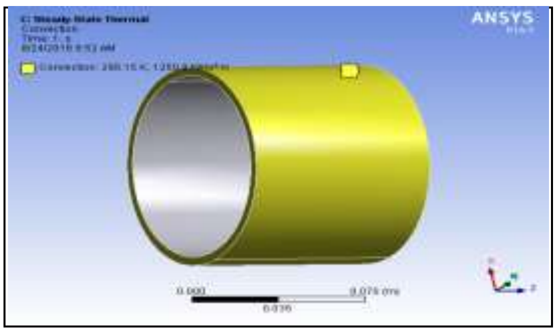


Figure: Convection

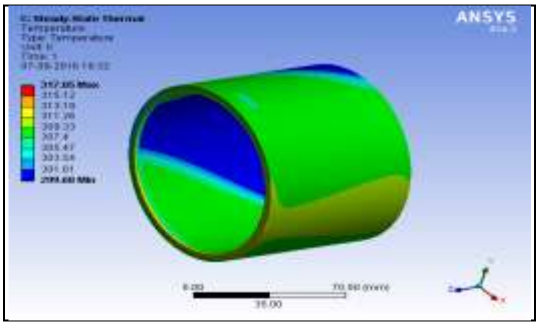


Figure: Temperature

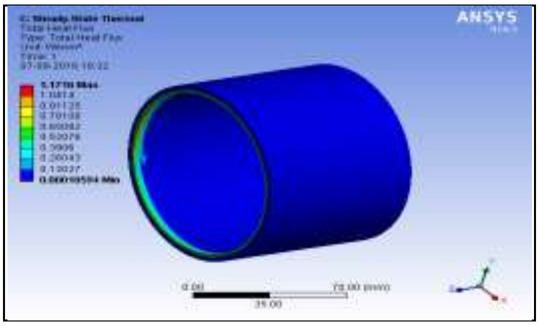


Figure: Heat flux

ECCENTRICITY = 0.8

MATERIAL – STEEL

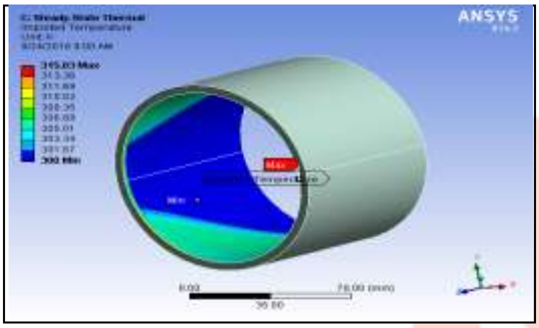


Figure: Imported temperature

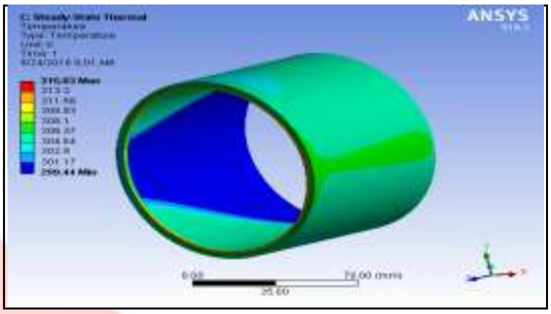


Figure: Temperature

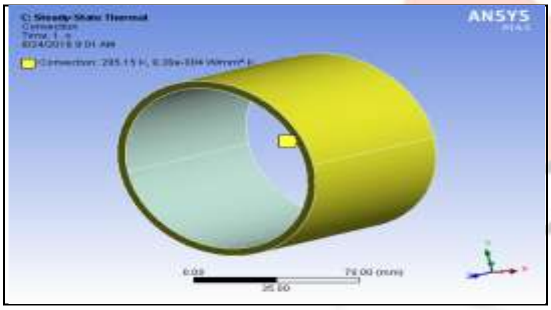


Figure: Convection

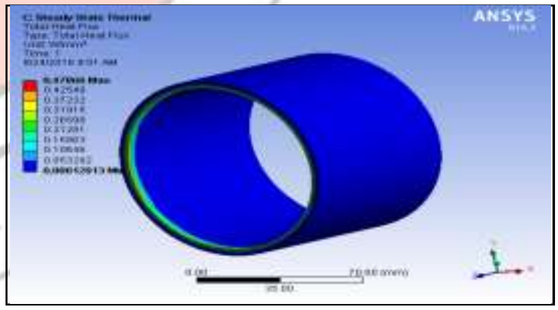
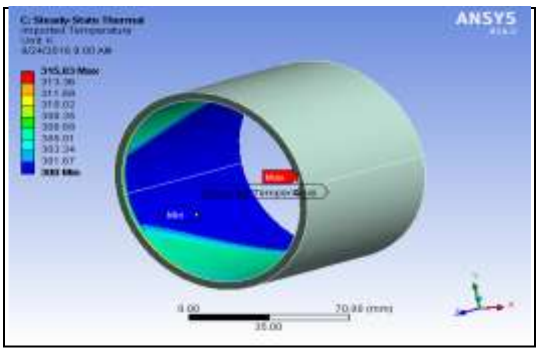


Figure: Heat flux

MATERIAL - ALUMINIUM ALLOY



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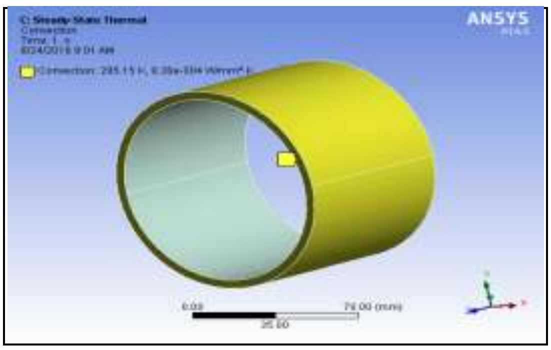


Figure: Convection

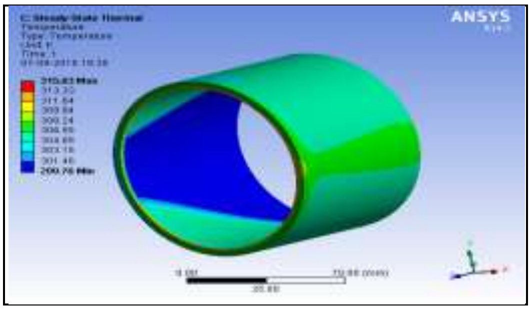


Figure: Temperature

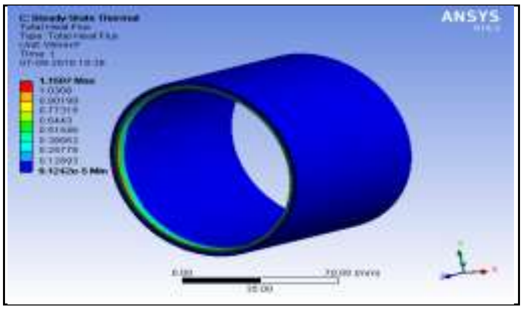


Figure: Heat flux

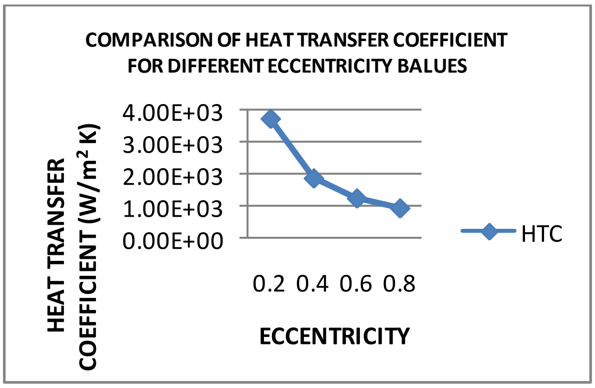
VI. RESULTS

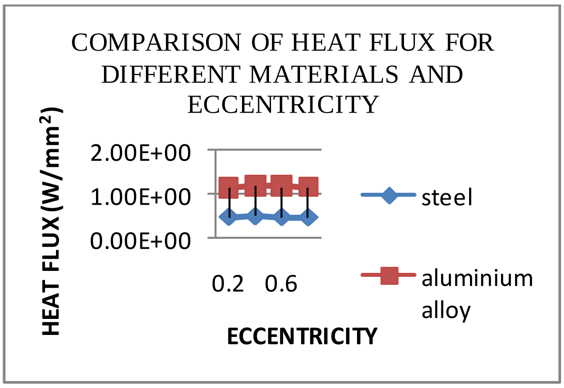
MATERIAL – STEEL

L/D Ratio	Eccentricity	Temperature (K)		HEAT FLUX (W/mm^2)
		Min	max	
0.8	**0.2**	300	321.95	0.49049
	0.4	298.94	319.91	0.50485
	0.6	299.26	317.05	0.48662
	0.8	300	315.03	0.47866

MATERIAL - ALUMINIUM ALLOY

L/D Ratio	Eccentricity	Temperature (K)		Heat flux
		Min	max	
0.8	**0.2**	300	321.95	1.1296
	0.4	299.52	319.91	1.1935
	0.6	299.68	317.05	1.1716
	0.8	299.76	315.03	1.1597





VII. CONCLUSIONS & FEATURE SCOPE

CONCLUSIONS

In this thesis, Hydrodynamic journal bearings are analyzed by using Computational fluid dynamics (CFD) and fluid thermal structure interaction approach on different models by varying eccentricity ratios using Ansys in order to evaluate the fluid pressures, Stress distribution and deformation in journal bearing. Journal bearings for L/D ratio 0.8 and eccentricity ratios 0.2, 0.4, 0.6 and 0.8.

By observing the CFD analysis results, the pressure is decreasing by increasing the eccentricity ratios. The temperature and heat transfer coefficient also are is decreasing by increasing the eccentricity ratios

In the thermal analysis, the temperature and heat transfer coefficient from CFD analysis are taken as input to determine heat flux values for two materials Steel and Aluminum alloy. By observing the results, the heat flux values are slightly varying by increasing the eccentricity ratios. The heat flux values are more for Aluminum alloy that is the heat transfer rates are more for Aluminum alloy.

By this thesis, heat transfer rates, of the bearing due to action of hydrodynamic forces developed which is important for accurate performance of the bearings operation under severe conditions can be evaluated.

FEATURE SCOPE

In the present thesis, the analytical investigations are made on the journal bearing for single L/D ratio and single lubricant. This work can further be extended by varying the L/D ratios for different bio lubricants like Jatropha oil, Castor oil, Neem oil.

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