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Fluid Structural Thermal Analysis of Cylindrical Journal Bearing

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ABSTRACT

In this paper journal bearings for L/D ratio and different eccentricity ratios are modeled in 3D modeling software Pro/Engineer. The L/D ratio considered is 0.8 and eccentricity ratios considered are 0.2, 0.4 and 0.5 and 0.6. The liquid lubricant considered is SAE 30 oil. Journal bearing models are developed for speed of 600 rpm to study the interaction between the fluid and elastic behavior of the bearing. The speed is the input for CFD analysis and the pressure obtained from the CFD analysis is taken as input for structural analysis. The temperature values obtained from structural analysis are taken as input for thermal analysis. Computational fluid dynamics (CFD) and fluid structure and thermal interaction is done in ANSYS.

INTRODUCTION

A plain bearing (sometimes called a solid bearing) is the simplest type of bearing, comprising just a surface and no rolling elements. Therefore the journal (i.e., the part of the shaft in contact with the bearing) 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[1-5].

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. The results show reasonable agreement in general. In the paper by Priyanka Tiwari [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, journal speed and oil viscosity are taking by machine design data book for making analytical calculation. The CFD results were compared in order to validate the model with the analytical results and good agreements were found.

3D MODELS OF CYLINDRICAL JOURNAL BEARING FOR DIFFERENT ECCENTRICITY RATIOS

Eccentricity - 0.2

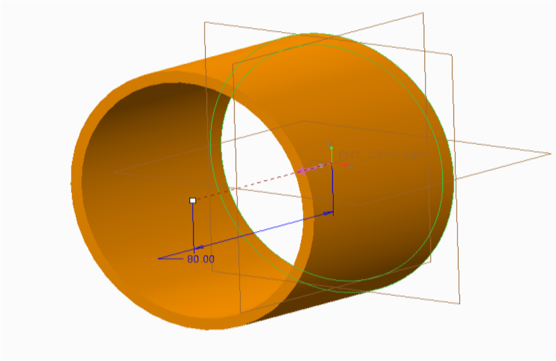


Fig1 – 3D Model of bearing for eccentricity ratio 0.2

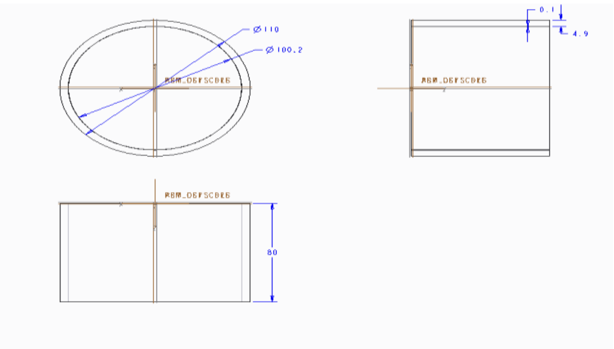


Fig2 – 2D drafting of bearing for eccentricity ratio 0.2

ANALYSIS OF JOURNAL BEARING - FSI (FLUD STRUCTURE THERMAL INTERFACE)

L/D RATIO=0.5

ECCENTRICITY RATIO (Ɛ) =0.2, 0.4, 0.6 &0.8

FLUID - SAE 30

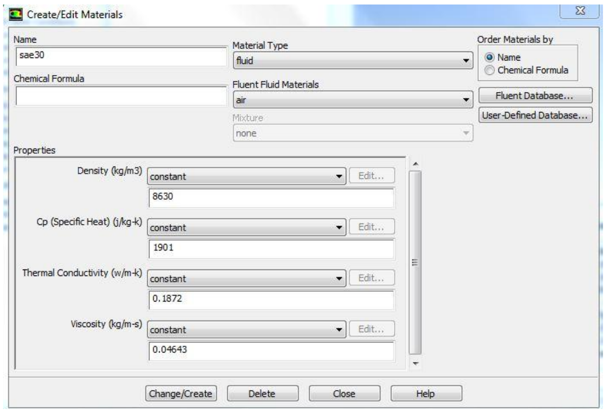
BEARING MATERIAL – BABBIT

BOUNDARY CONDITIONS

For CFD analysis, velocity and pressure are applied at the inlets. For structural analysis, the boundary conditions are the pressure obtained from the result of CFD analysis and displacement. For thermal analysis, the boundary conditions are the temperatures obtained from the result of CFD analysis.

ECCENTRICITY=0.2

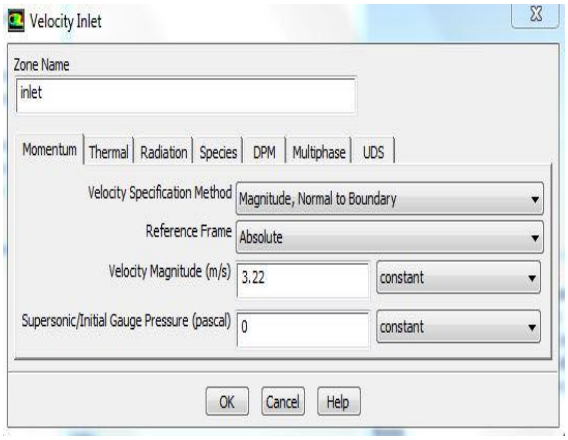
SAE 30 properties


Create/Edit Materials

Name: sae30
Material Type: fluid
Order Materials by: ● Name ○ Chemical Formula
Chemical Formula:
Fluent Fluid Materials: air
Mixture: none

Properties
Density (kg/m3): constant — 8630
Cp (Specific Heat) (j/kg-k): constant — 1901
Thermal Conductivity (w/m-k): constant — 0.1872
Viscosity (kg/m-s): constant — 0.04643

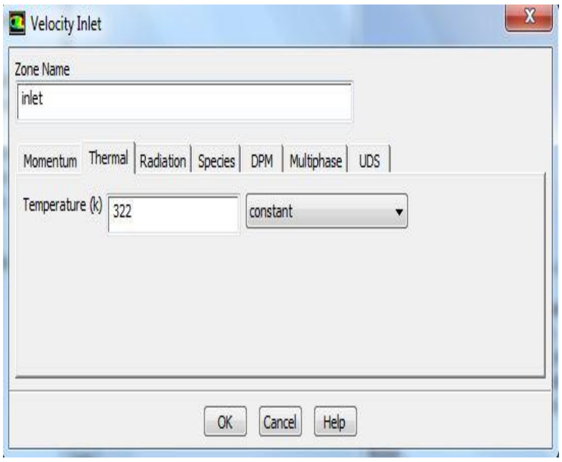
Fig 3 - SAE 30 properties


Velocity Inlet

Zone Name: inlet

Velocity Specification Method: Magnitude, Normal to Boundary
Reference Frame: Absolute
Velocity Magnitude (m/s): 3.22 — constant
Supersonic/Initial Gauge Pressure (pascal): 0 — constant

Fig 4 – Velocity Inlet


Velocity Inlet

Zone Name: inlet

Temperature (k): 322 — constant

Fig 5 – Inlet Temperature

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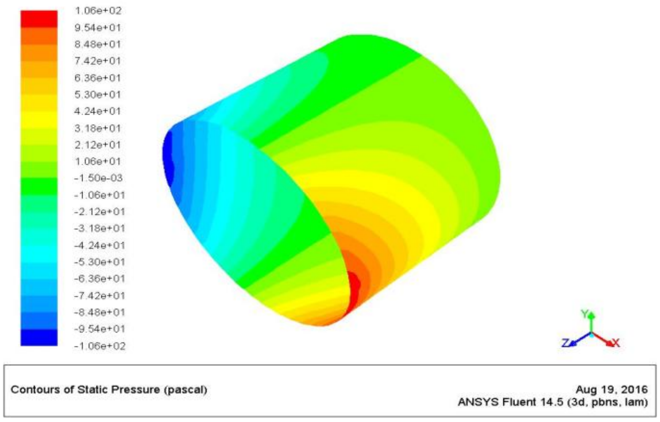


Fig 6 – Contours of Static Pressure

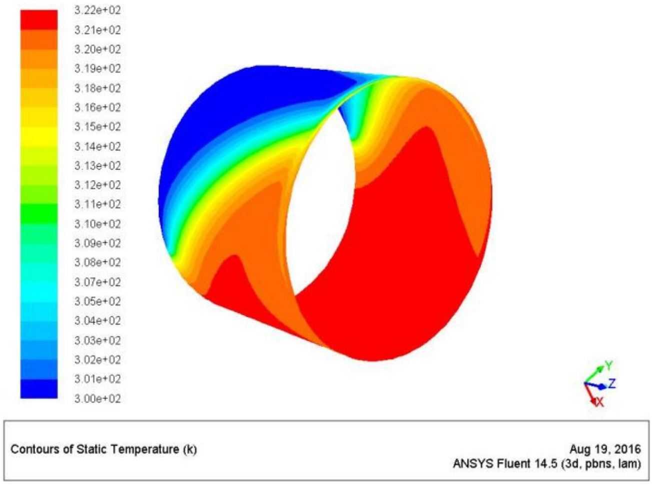


Fig7 – Contours of Static Temperature

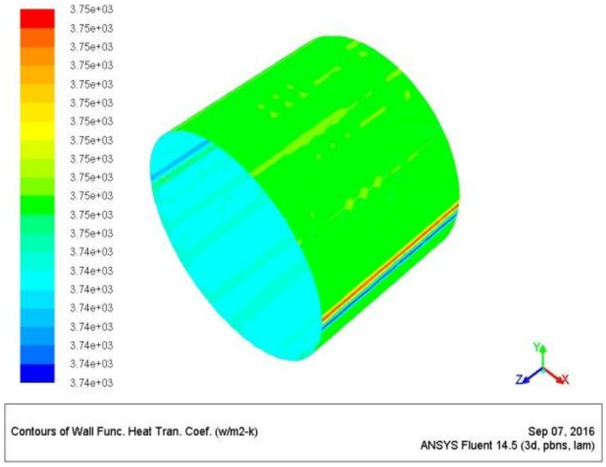
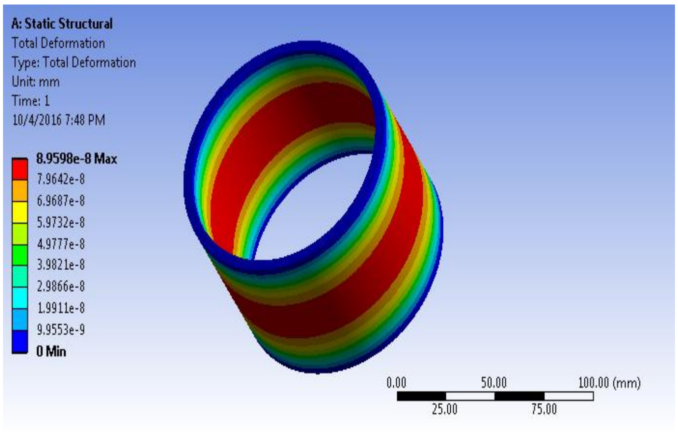


Fig 8 – Contours of Wall Function Heat Transfer Coefficient

STRUCTURAL ANALYSIS OF CYLINDRICAL JOURNLING BEARING

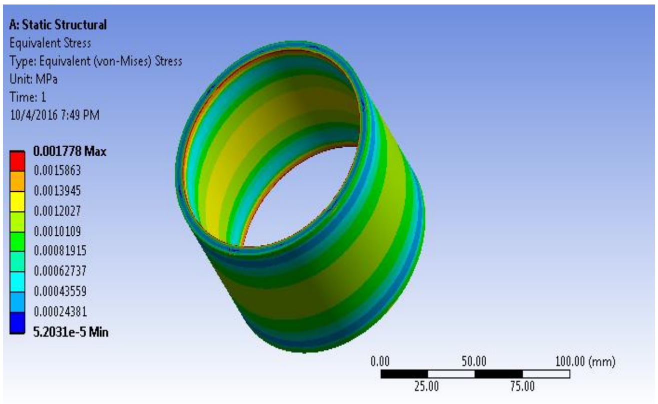
ALUMINUM ALLOY

Deformation



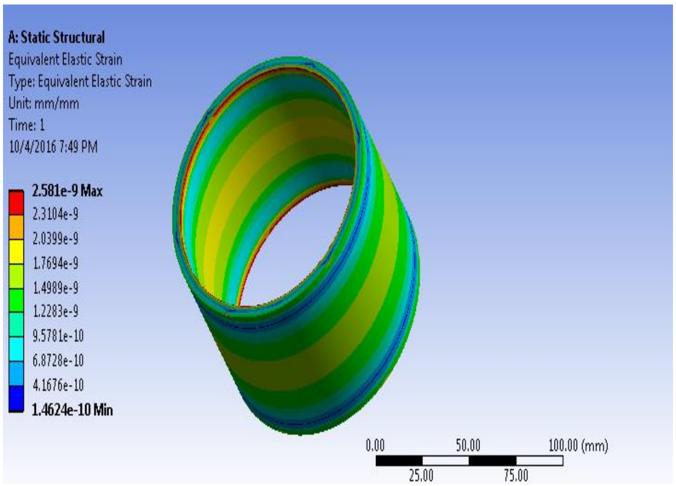
A: Static Structural
Total Deformation
Type: Total Deformation
Unit: mm
Time: 1
10/4/2016 7:48 PM

Stress



A: Static Structural
Equivalent Stress
Type: Equivalent (von-Mises) Stress
Unit: MPa
Time: 1
10/4/2016 7:49 PM

Strain



A: Static Structural
Equivalent Elastic Strain
Type: Equivalent Elastic Strain
Unit: mm/mm
Time: 1
10/4/2016 7:49 PM

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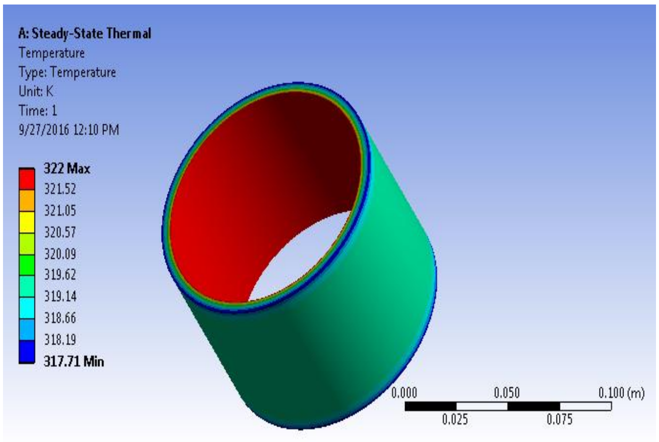
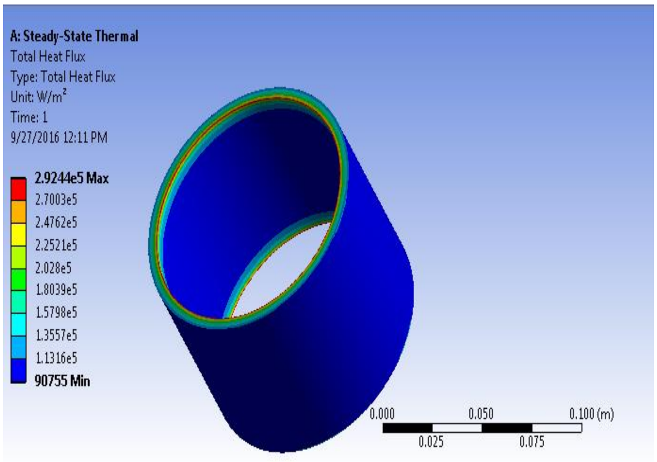
THERMAL ANALYSIS
MATERIAL - ALUMINIUM ALLOY
Temperature

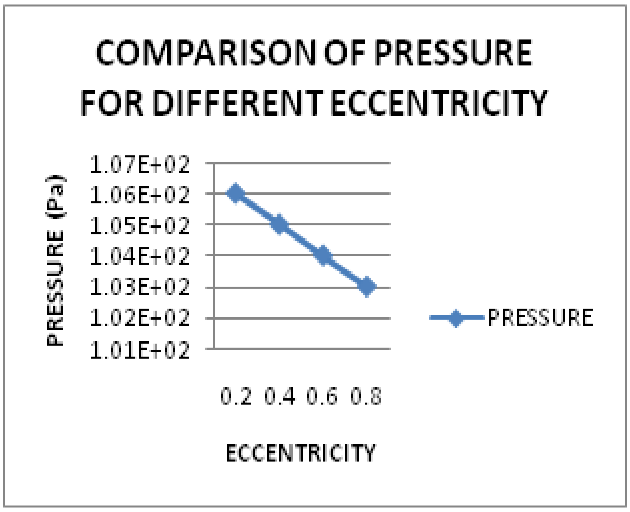


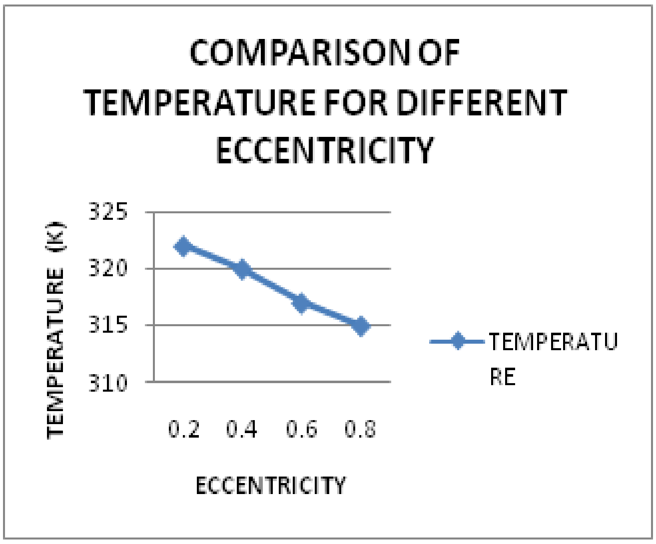
Heat flux

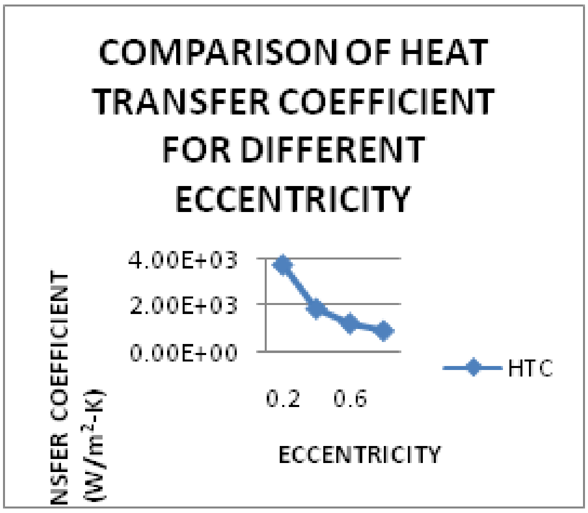


RESULTS TABLES
CFD ANALYSIS

L/D Ratio	Eccentricity	Pressure (Pa)	Temperature (K)	Heat transfer coefficient (W/m^2-k)
0.8	0.2	1.06e+2	322	3.75e+3
	0.4	1.05e+2	320	1.88e+3
	0.6	1.04e+2	317	1.25e+3
	0.8	1.03e+2	315	9.39e+2







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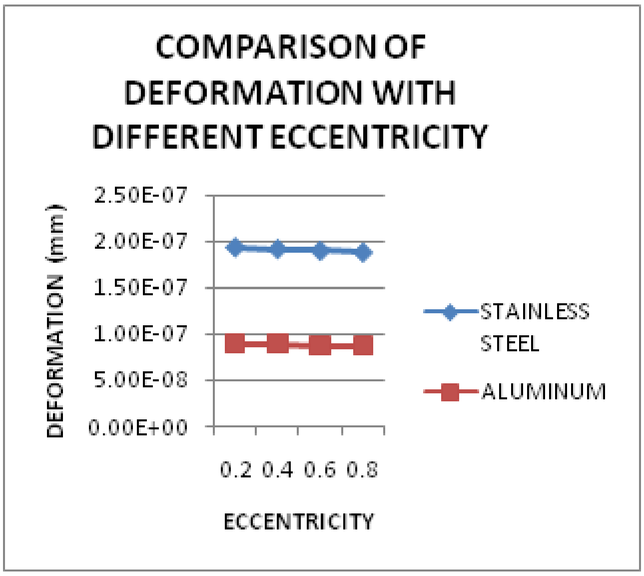
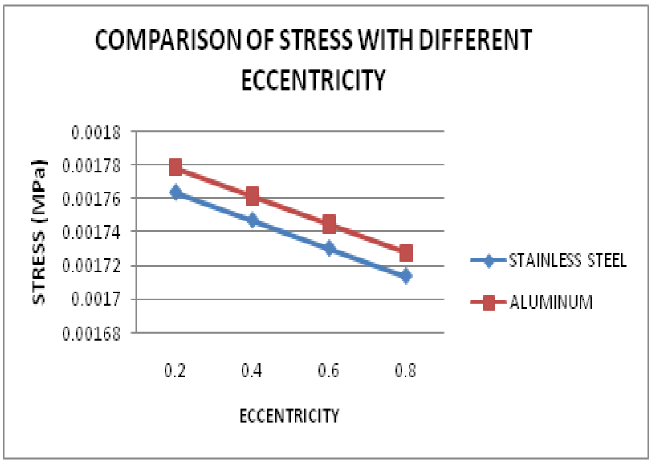
STRUCTURAL ANALYSIS
MATERIAL - STAINLESS STEEL

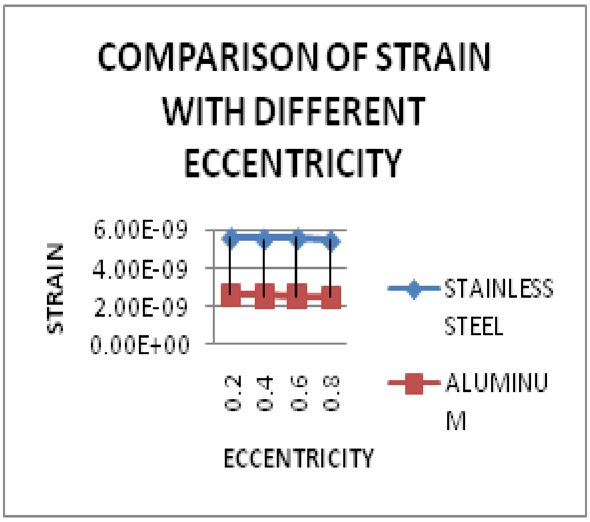
L/D Ratio	Eccentricity	Deformation (mm)	Stress (MPa)	Strain
0.8	0.2	1.9358e-7	0.0017636	5.5641e-9
	0.4	1.9175e-7	0.0017469	5.5116e-9
	0.6	1.8993e-7	0.0017303	5.54592e-9
	0.8	1.881e-7	0.0017137	5.4067e-9

Material - Aluminum alloy 6061

L/D Ratio	Eccentricity	Deformation (mm)	Stress (MPa)	Strain
0.8	0.2	8.9598e-8	0.001778	2.581e-9
	0.4	8.8753e-8	0.0017613	2.5566e-9
	0.6	8.7907e-8	0.0017445	2.5323e-9
	0.8	8.7062e-8	0.00172777	2.5079e-9





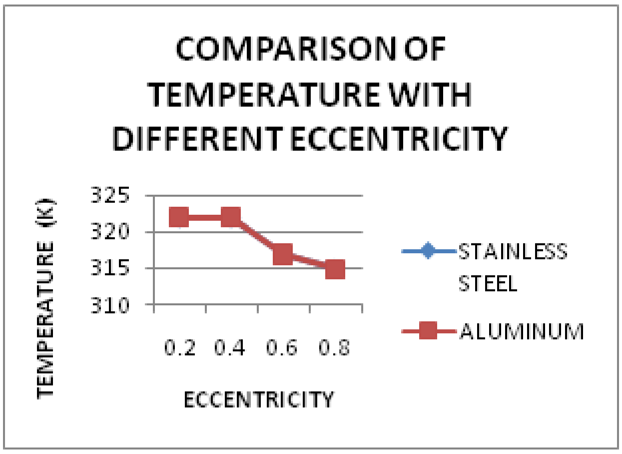


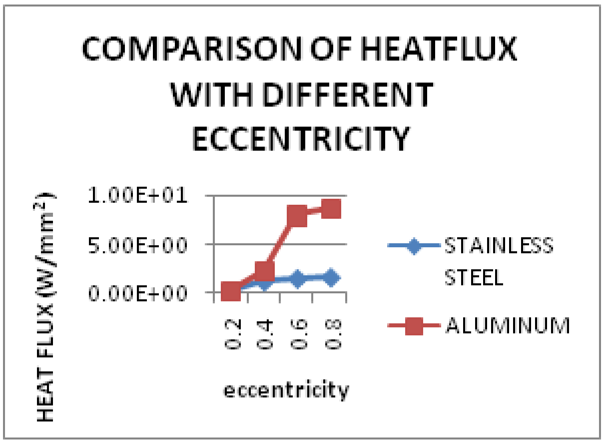
THERMAL ANALYSIS
MATERIAL - STAINLESS STEEL

L/D Ratio	Eccentricity	Temperature (K)		Heat flux (W/mm^2)
		Min	max	
0.8	0.2	307.72	322	0.2167
	0.4	289.33	322	1.2312
	0.6	290.26	317	1.5152
	0.8	292.06	315	1.6463

MATERIAL - ALUMINIUM ALLOY6061

L/D Ratio	Eccentricity	Temperature (K)		Heat flux (W/mm^2)
		Min	Max	
0.8	0.2	317.71	322	0.29244
	0.4	289.33	322	2.3466
	0.6	290.27	317	7.9491
	0.8	292.07	315	8.6341





CONCLUSION

By observing the CFD analysis results, the pressure is decreasing by increasing the eccentricity ratio thereby decreasing the displacements and stress values for cylindrical journal bearing in Structural analysis. The stress values for both materials Stainless Steel and Aluminum alloy are less than the respective allowable strength values. Comparing the results between materials Stainless Steel and Aluminum alloy, the deformation and stress values are less for Stainless Steel than Aluminum alloy. By comparing the results in thermal analysis, the heat flux values are increasing by increasing the eccentricity ratio. The heat flux values are more for Aluminum alloy than Stainless Steel. So the heat transfer rate is more when Aluminum alloy is used. So it can be concluded that increasing eccentricity ratio and using Aluminum alloy is better for cylindrical journal bearing.

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