FLUID STRUCTURE INTERACTION ON JOURNAL BEARINGS AT DIFFERENT L/D AND ECCENTRICITY RATIOS

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ABSTRACT

Journal bearings have the longest history of scientific study of any class of fluid film bearings. In a fluid film bearing, the pressure in the oil film satisfies the Reynolds equation which intern is a function of film thickness. Structural distortion of the housing and the development of hydrodynamic pressure in a full journal bearing are strongly coupled thus require a combined solution. Oil film pressure is one of the key operating parameters describing the operating conditions in hydrodynamic journal bearings. Hydrodynamic journal bearings are analyzed by using Computational fluid dynamics (CFD) and fluid structure interaction (FSI) approach in order to find deformation of the bearing.

In this thesis journal bearings for different L/D ratios and eccentricity ratios are modeled in 3D modeling software Pro/Engineer. The L/D ratios considered are 0.5, 1.0, 1.5 and eccentricity ratios considered are 0.3, 0.5, 0.7 and 0.9.

Journal bearing models are developed for speed of 2000 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. Computational fluid dynamics (CFD) and fluid structure interaction (FSI) is done in Ansys.

Keywords: Different L/D ratios and eccentricity ratios to design plain bearngs ,CFD Analysis in fluid structure interaction (FSI) technique.

INTRODUCTION

A **PLAIN BEARING** (in railroading 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.

Design :The design of a plain bearing depends on the type of motion the bearing must provide. The three types of motions possible are:

Journal (Friction, Radial or Rotary) Bearing:

This is the most common type of plain bearing; it is simply a shaft rotating in a bearing. In locomotive and railroad car applications a journal bearing specifically referred to the plain bearing once used at the ends of

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the axles of railroad wheel sets, enclosed by journal boxes (axle boxes). Axle box bearings today are no longer plain bearings but rather are rolling-element bearings.

***Linear bearing*:** This bearing provides linear motion; it may take the form of a circular bearing and shaft or any other two matching surfaces (e.g., a slide plate).

***Thrust bearing*:** A thrust bearing provides a bearing surface for forces acting axial to the shaft.

Materials:

Plain bearings must be made from a material that is durable, low friction, low wear to the bearing and shaft, resistant to elevated temperatures, and corrosion resistant. Often the bearing is made up of at least two constituents, where one is soft and the other is hard. The hard constituent supports the load while the soft constituent supports the hard constituent. In general, the harder the surfaces in contact the lower the coefficient of friction and the greater the pressure required for the two to seize.

Babbitt: Babbitt is usually used in integral bearings. It is coated over the bore, usually to a thickness of 1 to 100 thou (0.025 to 2.540 mm), depending on the diameter. Babbitt bearings are designed to not damage the journal during direct contact and to collect any contaminants in the lubrication

PROBLEM STATEMENT:

Problem Solving Methodology:

In this thesis journal bearings for different L/D ratios and eccentricity ratios are modeled in 3D modeling software Pro/Engineer. The L/D ratios considered are 0.5, 1.0, 1.5 and eccentricity ratios considered are 0.3, 0.5, 0.7 and 0.9.

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Journal Bearing Model Calculations

L=Length of journal, mm
D=diameter of journal, mm

Length Of Journal

Cases	D(mm)	L/D	L(mm)
1	100	0.5	50
2	100	1.0	100
3	100	1.5	150

Eccentricity calculations:

Ɛ =eccentricity ratio,

C= radial clearance, mm C=0.145mm

e = eccentricity (mm)

$$\varepsilon = e/c$$

Eccentricity Calculation at different eccentricity ratio:

Cases	C	Ɛ	e= Ɛ×C
1	0.145	0.3	0.0435
2	0.145	0.5	0.0725
3	0.145	0.7	0.1015
4	0.145	0.9	0.1305

Models and 2d Drawings of Journal Bearing In Pro-Engineer

L/D ratio	Eccentricity ratio			
0.5	0.3	0.5	0.7	0.9
1.0	0.3	0.5	0.7	0.9
1.5	0.3	0.5	0.7	0.9

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Theoretical Calculations of Journal Bearing With Different L/D Ratios

STRESS CALCULATIONS

F=force N

D=diameter of the journal bearing mm=100mm

μ =coefficient of friction

L=length of the journal bearing mm=50mN=speed rpm=2000rpm

C=clearance mm=0.25mm

$$F=\frac{\pi 2\times D2\times L\times N}{30\times C}\times \mu$$

$$\sigma =\frac{F}{A} N/mm^2$$

Stress Calculation table:

cases	L/D	F(N)	σ(N/mm^2)
1	0.5	1314613.33	41.84
2	1.0		83.6906
3	1.5		125.5360

Note :caluculate stress at L/D and Ɛ.

PRESSURE CALCULATIONS:

R=radius of journal bearing

L=length of the journal bearing

F=shaft carrying load=8000N (taken from journal)

$$P=\frac{F}{2\pi rl}$$

Pressure Calculation table :

Cases	L/D	L	F	R	P(Pa)
1	0.5	50	8000	50	509554.1401
2	1.0	100	8000	50	254777.0701
3	1.5	150	8000	50	169851.38

MODELING AND ANALYSIS

Modeling:

Introduction to CAD

Computer-Aided Design (**CAD**), also known as **Computer-Aided Design and Drafting** (**CADD**), is the use of computer technology for the process of design and design-documentation. Computer Aided Drafting describes the process of drafting with a computer. CADD software, or environments, provides the user with input-tools for the purpose of streamlining design processes; drafting, documentation, and manufacturing processes. CADD output is often in the form of electronic files for print or machining operations. The development of CADD-based software is in direct correlation with the processes it seeks to economize; industry-based software (construction, manufacturing, etc.) typically uses vector-based (linear) environments whereas graphic-based software utilizes raster-based (pixilated) environments.

Introduction to Pro/Engineer

Pro/ENGINEER Wildfire is the standard in 3D product design, featuring industry-leading productivity tools that promote best practices in design while ensuring compliance with your industry and company standards. Integrated Pro/ENGINEER CAD/CAM/CAE solutions allow you to design faster than ever, while maximizing innovation and quality to ultimately create exceptional products.

Customer requirements may change and time pressures may continue to mount, but your product design needs remain the same - regardless of your project's scope, you need the powerful, easy-to-use, affordable solution that Pro/ENGINEER provides.

Different types modules In Pro/Engineer

- Sketcher
- Part design
- Assembly
- Drawing
- Sheet metal

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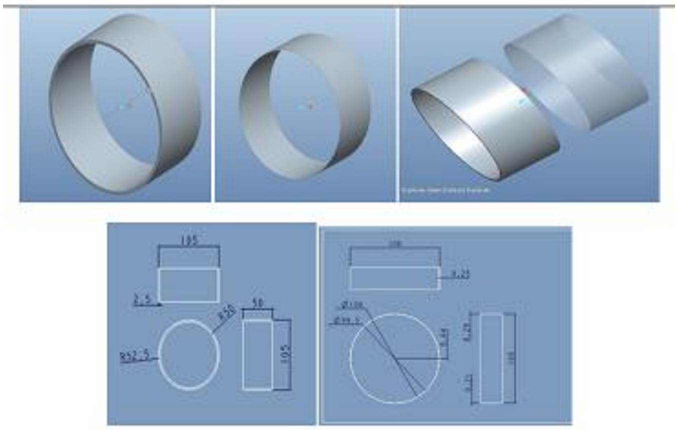
TO DESIGN THE JOURNAL BEARING DIFFERENT L/D RATIOS AND ECCENTRICITY RATIOS:

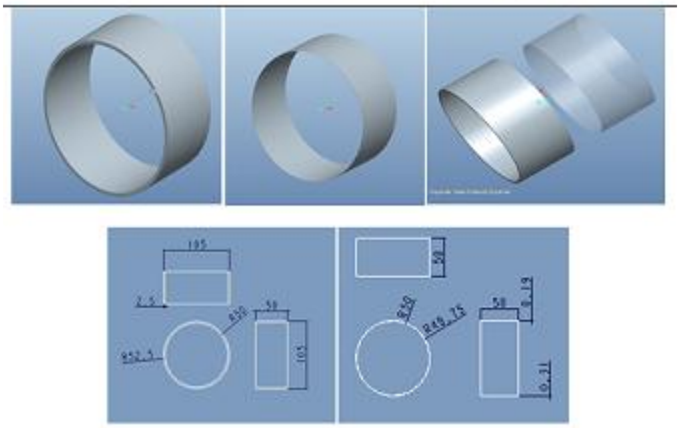
case 1.1: when L/D=0.5;Ɛ=0.3

Solid model fluid model assembly model



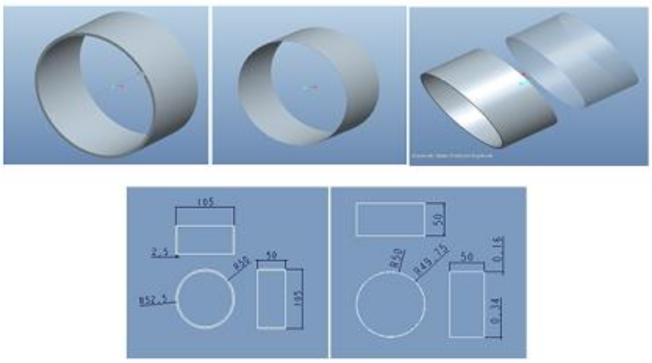
case 1.2 when L/D ratio=0.5; eccentricity ratio=0.5

Solid model fluid model assembly model



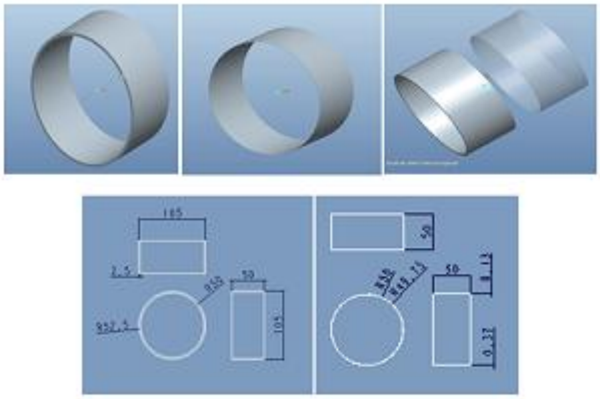
case 1.3 when L/D ratio=0.5; eccentricity ratio=0.7

Solid model fluid model assembly model



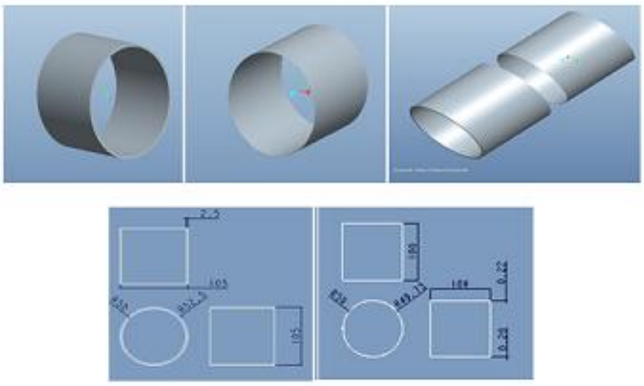
Case 1.4 when L/D ratio=0.5; eccentricity ratio=0.9

Solid model fluid model assembly model



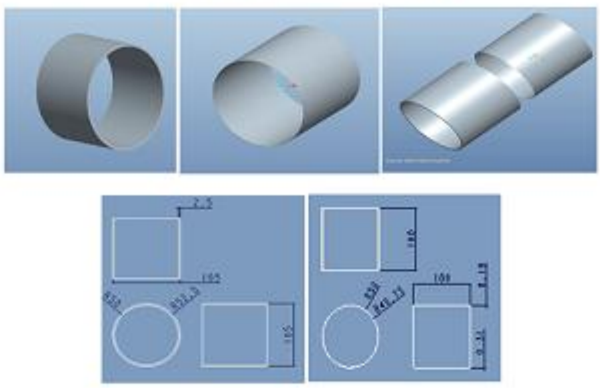
case 2.1 when L/D ratio=1.0; eccentricity ratio=0.3

solid model fluid model assembly model



case 2.2 when L/D ratio=1.0; eccentricity ratio=0.5

Solid model fluid model assembly model



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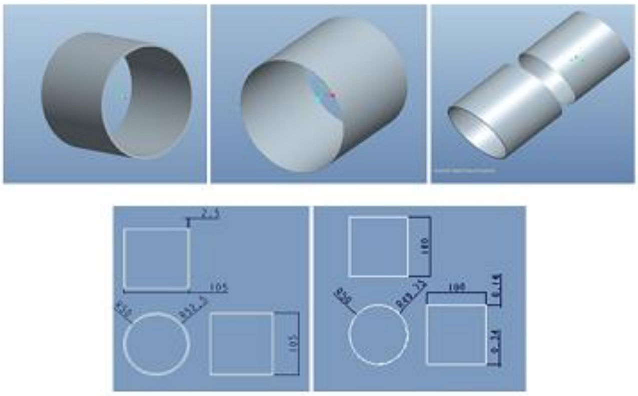
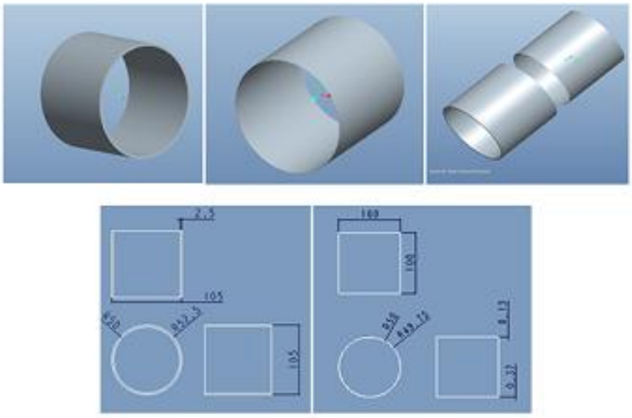
case 2.3 when L/D ratio=1.0; eccentricity ratio=0.7

Solid model fluid model assembly model



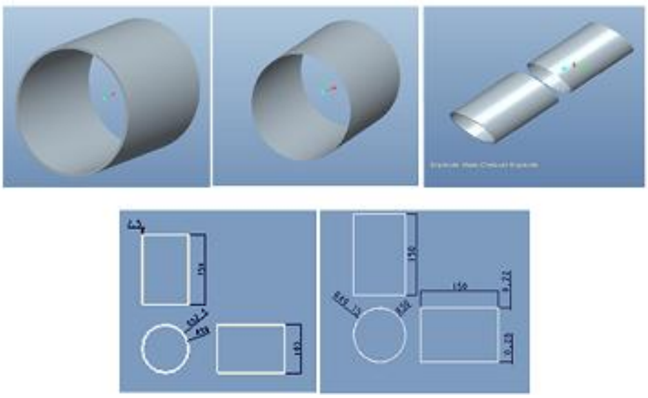
case 2.4 when L/D ratio=1.0; eccentricity ratio=0.9

Solid model fluid model assembly model



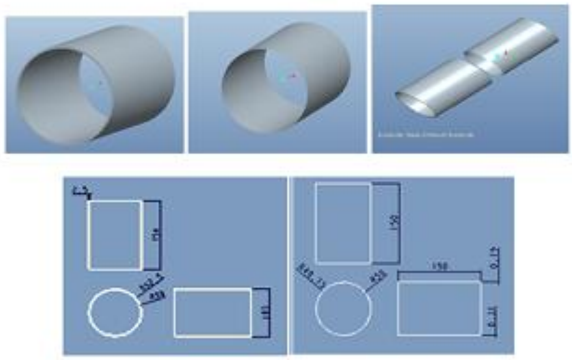
case 3.1 when L/D ratio=1.5; eccentricity ratio=0.3

Solid model fluid model assembly model



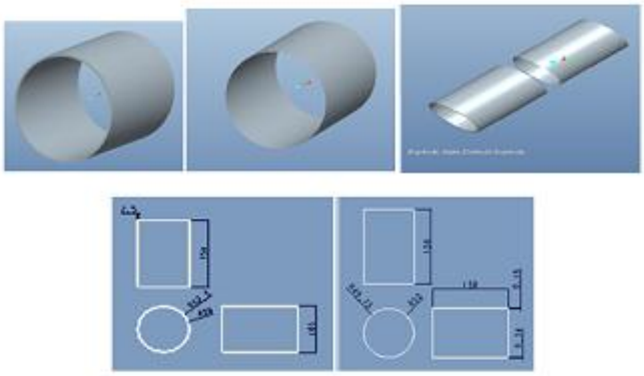
case 3.2 when L/D ratio=1.5; eccentricity ratio=0.5

Solid model fluid model assembly model



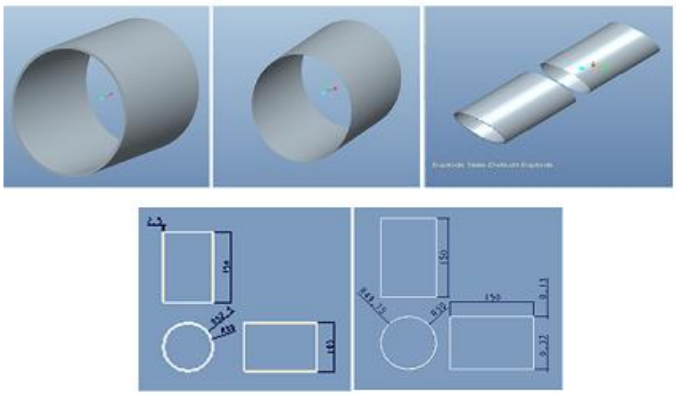
case 3.3 when L/D ratio=1.5; eccentricity ratio=0.7

Solid model fluid model assembly model



case 3.4 when L/D ratio=1.5; eccentricity ratio=0.9

Solid model fluid model assembly model



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ANALYSIS:

INTRODUCTION TO CFD

Computational fluid dynamics, usually abbreviated as CFD, is a branch of fluid mechanics that uses numerical methods and algorithms to solve and analyze problems that involve fluid flows. Computers are used to perform the calculations required to simulate the interaction of liquids and gases with surfaces defined by boundary conditions. With high-speed supercomputers, better solutions can be achieved.Ongoing research yields software that improves the accuracy and speed of complex simulation scenarios such as transonic or turbulent flows.

Initial experimental validation of such software is performed using a wind tunnel with the final validation coming in full-scale testing, e.g. flight tests.

Material properties:

Fluid: *SAE-20 OIL:*

Density =872 kg/m^2
Thermal conductivity=0.136 w/mk
Specific heat = 19252.96 J/kg k
Viscosity= 0.0256 kg/ms
Density =872 kg/m^2

Solid: Babbitt material

Density=7272 kg/m^3
Young's modulus=50000MPa
Poisson's ratio=0.35

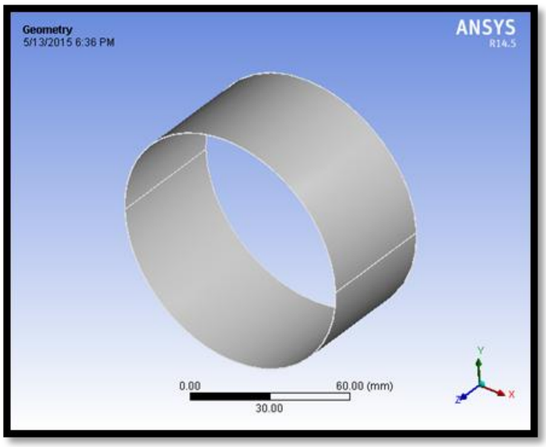
Open **Ansys** Workbench 14.5, It opens a project Schematic window with tool box graphical User Interface with some other important tools.

Use import tool to import the geometry with IGES or STEP file format. After importing the geometry file, we do the Analysis. Now on our Analysis of Journal Bearing - FSI (Fluid Structure Interaction) done. Imported Model in the ANSYS work bench looks as shown below.

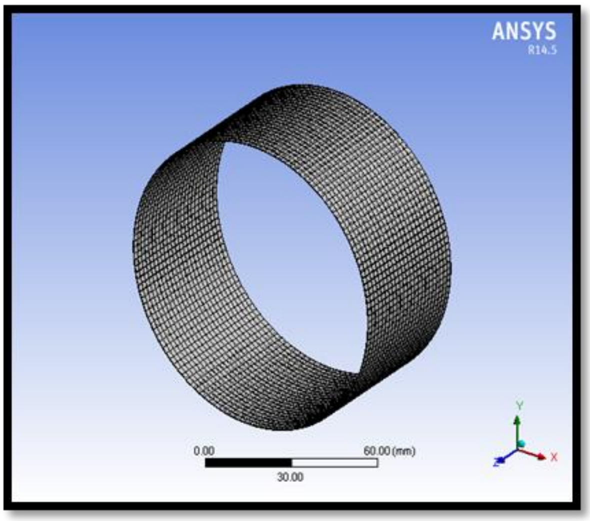
Case 1.1 When L/D =0.5 & Eccentricity=0.3

→→Ansys → workbench→ select analysis system → fluid flow fluent → double click →Select geometry….

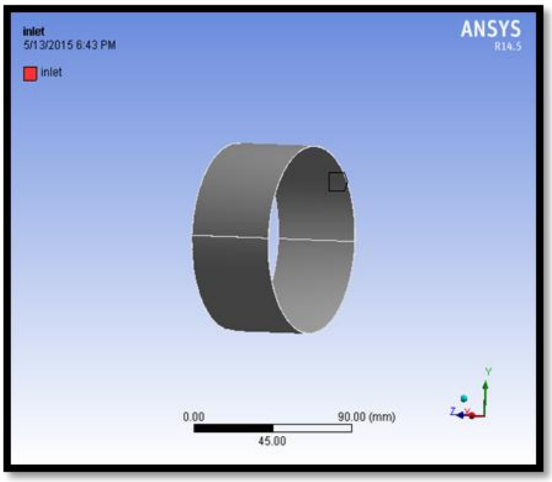
Geometry model:



Meshed model:



Naming the Lubricant Inlet Section:



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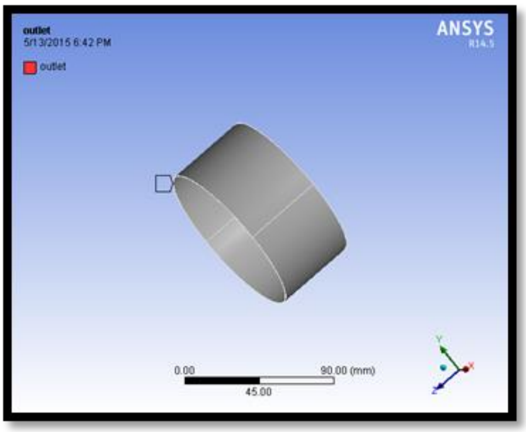
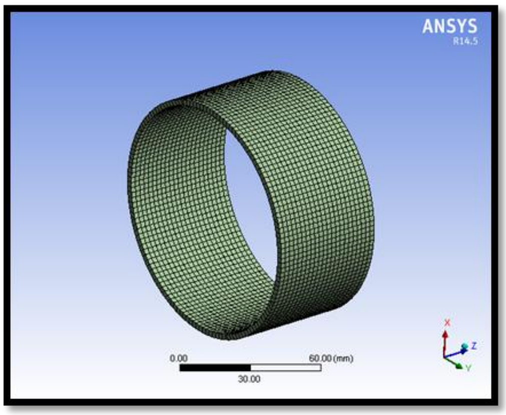
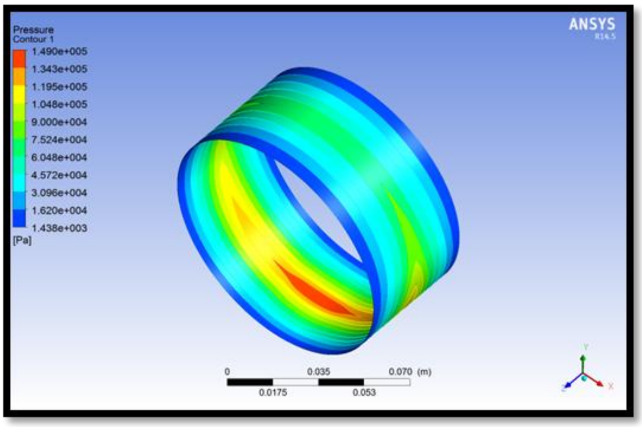
Naming the Lubricant Outlet Section:



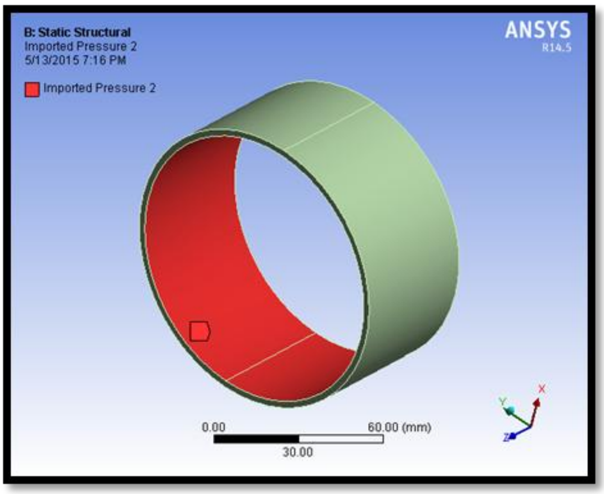
Meshed Model:



Pressure contours:

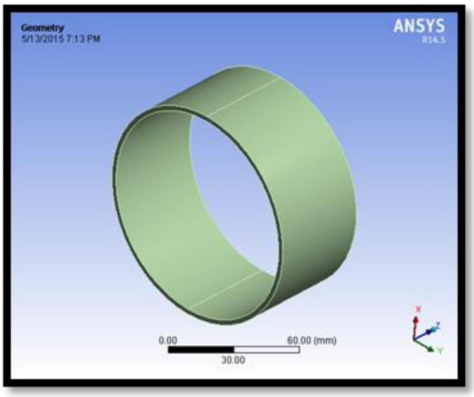


Selecting The Displacement Area

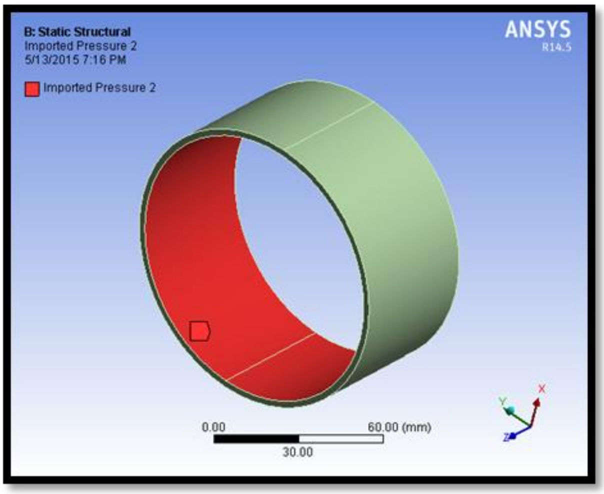


the model in static structural>geometry…..

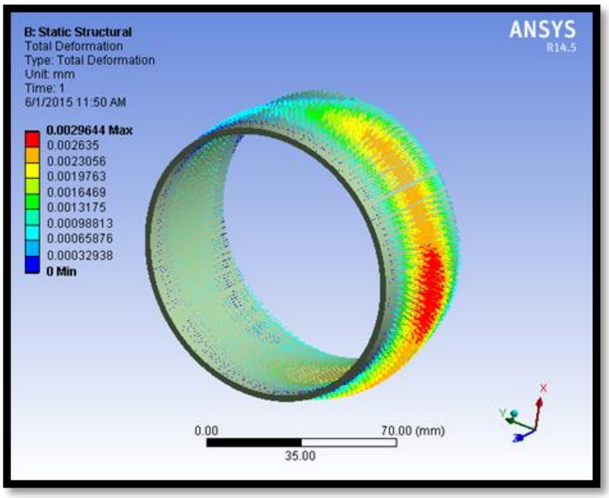
Geometry Model:



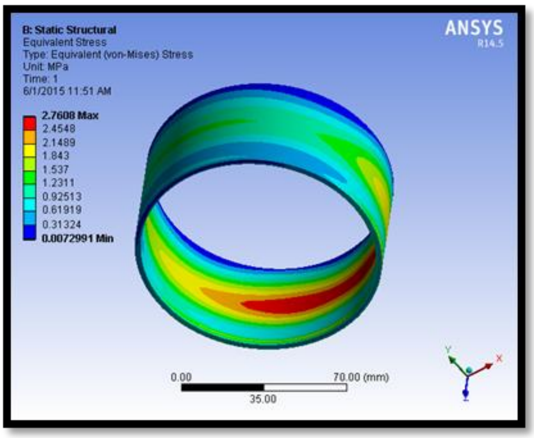
Imported Load From CFD And Applied The Pressure Area On The Component:



Total Deformation:



Equivalent Stress:



***Note*:**

Similarly all the procedure is same as above analysis to determine the pressure contours, total Deformation and Equivalent Stress.

RESULTS AND DISCUSSIONS:

variation of pressure with respect to eccentricity ratios at different l/d ratios:

L/D RATIO	Eccentricity ratio	Pressure(Pa)
0.5	0.3	1.490E+04
	0.5	2.066E+05
	0.7	2.812E+05
	0.9	3.634E+05
1.0	0.3	2.488E+05
	0.5	3.121E+05
	0.7	4.031E+05
	0.9	5.379E+05
1.5	0.3	3.523E+05
	0.5	4.215E+05
	0.7	5.151E+05
	0.9	6.449E+05

variation of displacements with respect to eccentricity ratios at different l/d ratios:

L/D RATIO	Eccentricity ratio	Displacement (mm)
0.5	0.3	0.0029644
	0.5	0.0053614
	0.7	0.0083703
	0.9	0.010352
1.0	0.3	0.0086261
	0.5	0.015092
	0.7	0.026131
	0.9	0.045613
1.5	0.3	0.019325
	0.5	0.041523
	0.7	0.07221
	0.9	0.10981

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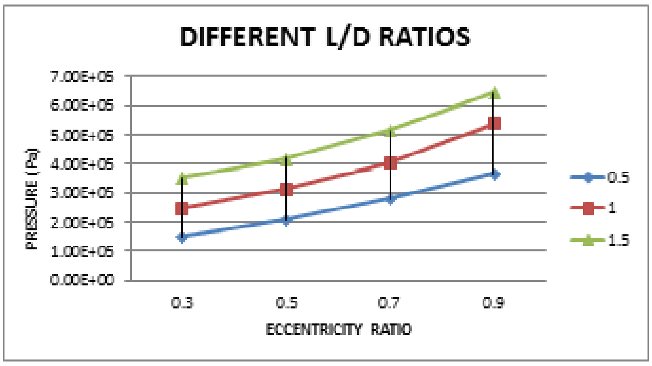
variation of stress with respect to eccentricity ratios at different l/d ratios

L/D RATIO	Eccentricity ratio	Stress (MPa)
0.5	0.3	2.7608
	0.5	3.8927
	0.7	6.1225
	0.9	7.5886
1.0	0.3	4.8936
	0.5	6.2448
	0.7	10.581
	0.9	16.994
1.5	0.3	7.0022
	0.5	10.341
	0.7	16.498
	0.9	23.94

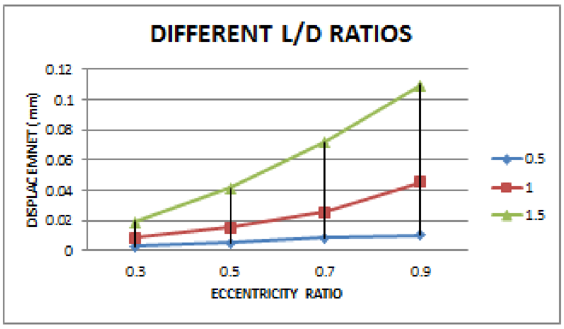
COMPARISON OF RESULTS FOR DIFFERENT L/D RATIOS:

Variation of maximum pressure for various eccentricity ratios and l/d ratios:



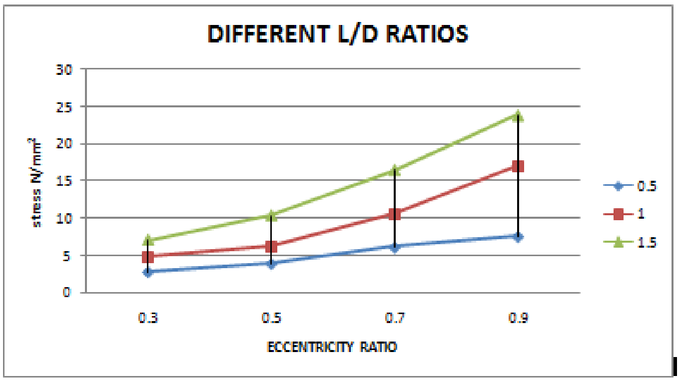
PRESSURE PLOT

Variation of maximum deformation for various eccentricity ratios and l/d ratios:



DISPLACEMENT PLOT

Variation of maximum stress for various eccentricity ratios and l/d ratios:



STRESS PLOT

CONCLUSION

In this thesis, Hydrodynamic journal bearings are analyzed by using Computational fluid dynamics (CFD) and fluid structure interaction (FSI) approach on different models by varying L/D ratios and eccentricity ratios using Ansys in order to evaluate the fluid pressures, Stress distribution and deformation in journal bearing. Journal bearings for different L/D ratios and eccentricity ratios are modeled in 3D modeling software Pro/Engineer. The L/D ratios considered are 0.5, 1.0, 1.5 and eccentricity ratios considered are 0.3, 0.5, 0.7 and 0.9.

By observing the CFD analysis results, the pressure is increasing by increasing the L/D ratios and eccentricity ratio thereby increasing the displacements and stress values.

By this thesis, deformation and stresses 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. It is observed that there is substantial amount of deformation of the bearing.

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Feature scope of the project:

In this thesis, the lubricants used are liquid lubricants. For further assessment, gas lubricants can be analyzed. Different L/D ratios and eccentricity ratios can also be considered for further work and for higher speeds.

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