COMPUTATIONAL FLUID FLOW ANALYSIS OF ELASTO HYDRO-DYNAMIC LUBRICATION JOURNAL BEARING

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ABSTRACT

In Elasto hydro dynamic lubrication occurs when a lubricant is introduce between the load carrying surfaces that are in rolling contact such as mating gears or bears. A lubricant presents metal to metal contact and the stability of surfaces can be determined by fluid dynamic laws. It is necessary to determination of bearing used under high loading condition in situation like engines which otherwise neglected therefore hydrodynamic lubrication analysis of journal bearing plays an important role in study of journal bearing, the relation between determination and oils film pressure on a journal bearing surface can be determined using structural analysis. A computational flow analysis gives a film pressure in this project the journal bearing are analyzed for Elasto hydro dynamic model using fluid structure interaction and computational fluid dynamic approaches, the analysis is carried out using SAE20W oil for different eccentricity values length to diameter ratio of 2.0, 2.1, 2.2, 2.3 and 2.4. The pressure field obtained from fluid dynamics is used in structural analysis to determine the displacement and stresses occurring in mating surfaces. Laminar steady flow is considering in fluid dynamics and aluminum, is considered as material in structural analysis. The CFD results are tested against analytical results before parametric study carried out. As length to diameter ratio increases from 2.0 to 2.4 the pressure values for lubricating using SAE20W oil increases from 3.3 bar to 3.6 bar respectively. It is observed that for increases in L/D ratio from 2.0 to 2.4 displacement values increases from 0.0098m to 0.014m and stresses increases 29.24 to 36.65 N/m2.

Keyword: *- journal bearing1, CFD2, CSD3, ANSYS4, SAE20W oil5, Aluminum6, L/D Ratio7and eccentricity.etc*

1. INTRODUCTION

At the point when there is a relative movement between two machine parts, one of the members which support the other, is called a bearing. Bearing is a mechanical segment that allows similar movement between two sections, such as the shaft and the housing, with a least friction. The function of the bearing is as follows:

- The bearing supports the shaft or the axle and holds it in the right position.
- The bearing ensures the free revolution of the axle or shaft with minimum friction.
- The bearing takes up the strengths that follow up on the pole or the pivot and transmits them to edge or the establishment.

1.1 Journal bearing:

If the relative motion between two machine parts is of rotation and the pressure on the bearing is perpendicular to the axis of the shaft, the bearing is known as a journal bearing. The part which is enclosed by and rubs against the other is called the journal and the part which encloses the journal is called the bearing. Mostly the journal rotates in the fixed bearing but in a few cases both the journal and bearing are in motion, for example a crack pin and it's bearing in the connecting rod. In some cases the journal is fixed and the bearing rotates as in a hoisting drum or a loose pulley.

2. METHODOLOGY

Elasto hydro dynamic lubrication is a typical fluid structure (FSI) problems and the analysis of Elasto hydro dynamic lubrication journal bearing is carried out by coupled field analysis method where fluid field is considered for lubrication oil, while structure field is considered for journal bearing. Hydrodynamic journal bearing rotate at high speed and carries heavy loads. So, analysis procedure involves the solution of pressure distribution in lubricating oil in sub sequent determination of deformation and stresses. In journal bearing taking into account the fluid structure interface i.e. bearing linear.

The brief methodology involves the fallowing important steps.

- Pressure field is obtained 8for full journal bearing with laminar flow conditions using computational fluid dynamics approach.
- Stress and deformation is evaluated by using the pressure field obtained from fluid dynamics approach stress distribution and oil film thickness are evaluated by using finite element method inner permitting appropriate boundary condition.

2.1 CFD for flow field analysis:

CFD is the investigation of the framework including fluid flow, heat transfer and related phenomena such as chemical reactions by means of computer based simulation. CFD is based on the fundamental governing equations of fluid dynamics - the continuity, momentum and energy equations. CFD studies are more significant to Engineering Sciences, spread fields, for example, climate gauging, land and topographical studies, and therapeutic applications et cetera. In the zone of Engineering Studies, CFD is essentially utilized as a configuration help for anticipating the execution qualities of hardware including Fluid/Gas stream and warmth exchange. The commercially available CFD software like FLUENT essentially consists of the following the basic steps.

2.2 Governing Equations in CFD:

(i) Continuity equation:

$$\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} + \frac{\partial w}{\partial z} = 0$$

(ii) Momentum equations

a. X-momentum equation

$$\rho \left(u \frac{\partial u}{\partial x} + v\frac{\partial v}{\partial y} + w\frac{\partial w}{\partial z}\right) = -\frac{\partial p}{\partial x} + \mu \left(\frac{\partial^2 u}{\partial x^2} + \frac{\partial^2 u}{\partial y^2} + \frac{\partial^2 u}{\partial z^2}\right)$$

(b) Y-momentum equation

$$\rho \left(u \frac{\partial u}{\partial x} + v\frac{\partial v}{\partial y} + w\frac{\partial w}{\partial z}\right) = -\frac{\partial p}{\partial y} + \mu \left(\frac{\partial^2 u}{\partial x^2} + \frac{\partial^2 u}{\partial y^2} + \frac{\partial^2 u}{\partial z^2}\right)$$

(c) Z-momentum equation

$$\rho \left(u \frac{\partial u}{\partial x} + v\frac{\partial v}{\partial y} + w\frac{\partial w}{\partial z}\right) = -\frac{\partial p}{\partial z} + \mu \left(\frac{\partial^2 u}{\partial x^2} + \frac{\partial^2 u}{\partial y^2} + \frac{\partial^2 u}{\partial z^2}\right)$$

(iii) Energy equation:

$$\left(u \frac{\partial T}{\partial x} + v\frac{\partial T}{\partial y} + w\frac{\partial T}{\partial z}\right) = \frac{1}{\alpha} \left(\frac{\partial^2 T}{\partial x^2} + \frac{\partial^2 T}{\partial y^2} + \frac{\partial^2 T}{\partial z^2}\right)$$

In the ELASTO hydro dynamic lubrication bearing, oil pressure is calculated by solving NAVIER-STROKE equation corresponding to fluid flow region subjected to boundary conditions. In order to get the numerical solution, journal bearings are modelled using Elasto hydro dynamic model and the solution are obtained by using finite volume method. For this the commercially available fluid flow solver ANSYS FLUENT is used.

Geometrical model is prepared using PRO/E CAD software and is then imported to fluent software. FLUENT solver gives numerical solution for given bearing loading subjected to boundary conditions.

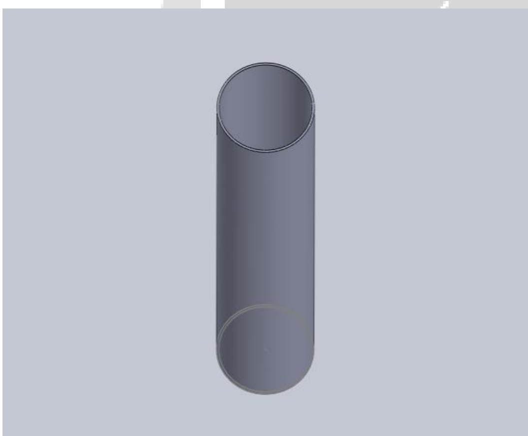
2.3 EHL journal bearings are modeled in PRO/E using geometrical data shown in below:

Table -1 DETAILS OF CIRCULAR JOURNAL BEARING

Journal radius	0.05 m
Radial clearance	50 µm
Bearing pad thickness	0.005 m
L/D ratio	2.0, 2.1, 2.2, 2.3,2.4
Eccentricity ratio	0.8

The geometrical models of EHL journal bearings are shown figures

1. L/D =2 AND ε =0.8



2. L/D =2.1 AND ε =0.8

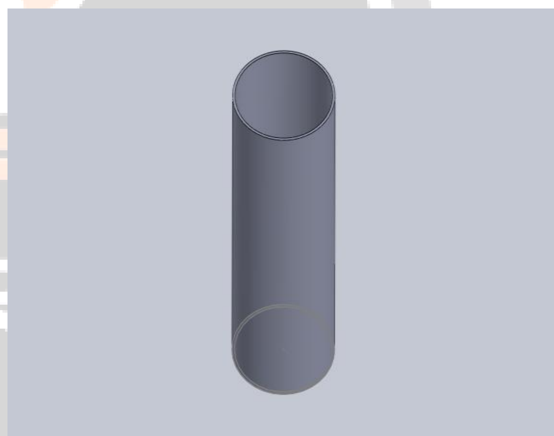
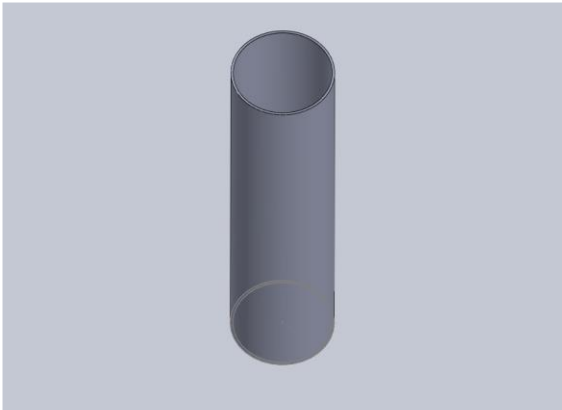


Fig -1: model of journal bearing with Length-Diameter = 2.1 and 2.2

3. L/D =2.2 AND ε =0.8



4. L/D =2.3 AND ε =0.8

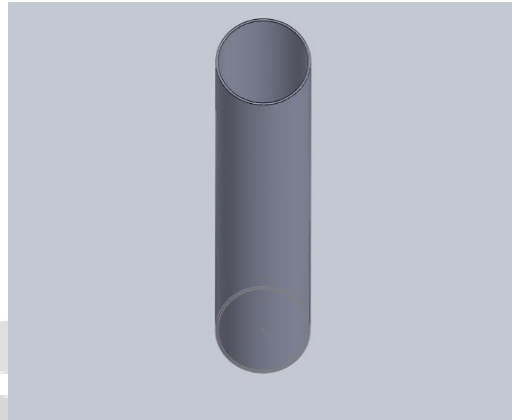


Fig -2: model of journal bearing with Length-Diameter = 2.3 and 2.4

5. L/D=2.4 AND ε =0.8

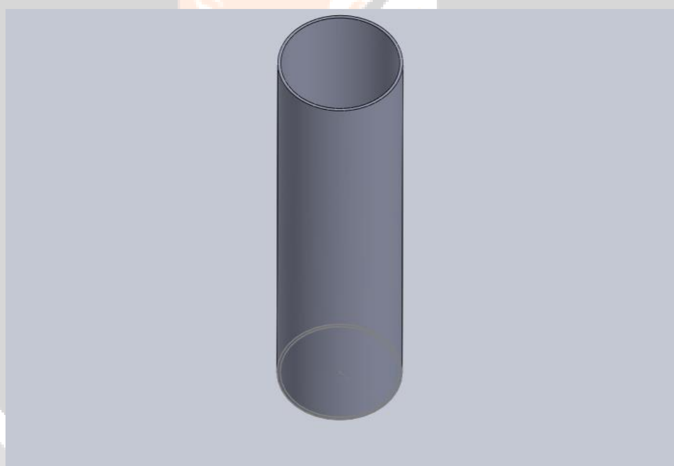


Fig -3: model of journal bearing with Length-Diameter = 2.5

Table -2: SAE20W OIL PROPERTIES:

Density	872 kg/m^3
Specific heat	19252.96 j/kg k
Thermal conductivity	0.136 w/m k
Viscosity	18.7 centistokes.

2.4 Problem solving steps in ANSYS 14.5 work bench.

The solution for the given fluid flow problem using ANSYS workbench is obtained by following the below mentioned 3 important steps.

1. Pre-processing.
2. Set up and solution.
3. Post processing.

2.5 Structural Analysis of journal bearing.

The pressure field obtained from fluid dynamics is used in structural analysis to determine the displacement and stresses occurring in mating surfaces. Laminar steady flow is considered in fluid dynamics and aluminium and bronze are considered as material in structural analysis.

Commercially available ANSYS software, which is based on FEM, is used for structural analysis. ANSYS is universally useful software to solve numerically the problems of mechanical/civil engineering involving static/changing, auxiliary investigation (both straight and nonlinear), warmth exchange, and liquid issues, and additionally acoustic and electromagnetic issues.

Table -3: Aluminum material properties:

Young’s modulus	68900 MPa
Poisson’s ratio	0.3
Density	0.269

3. RESULTS AND DISCUSSION:

In the present project work journal bearing is analysed using Elasto hydro dynamic model in order to find the pressure field and deformation of bearing mating surfaces analysis fluid dynamics and fluid structure interaction approaches. The commercial available ANSYS fluent software is used to predict oil film pressure deformation and stresses occurring in mating surfaces using SAE20W oil.

CFD model validation

The correctness of values obtained from coupled field analysis using fluid dynamics and fluid structural interaction approaches are verified against analytical calculation for simple case. Elasto hydro dynamic lubrication journal bearing modelled geometrically using commercial available Pro/E software. The geometry created is imported to FLUENT software and numerical simulation model is developed by imposing necessary boundary condition. Solution method is based on SIMPLE method.

Design data hand book is used to get the values of L/D ratio clearances, journal diameter, film thickness, journal speed and viscosity of oil for analytical calculation.

3.1Analytical Calculation:

Lubricating oil considered in calculation is SAE20W. General electric company's formula is

$$P_a = 6.2*10^5 \sqrt[3]{V_m}$$

We know that $V_m = \pi$ D N/60

Considering D = 100 mm, L/D = 2 and ε =0.8, we have

L = 2*100 = 200 mm =0.2 m

Therefore, $V_m = \pi$*100*3000/60

V_m =15.70 m/s

Then,

$P_a = 6.2*10^5 \sqrt[3]{V_m}$

$P_a = 6.2*10^5 \sqrt[3]{15.70}$

$P_a = 1.55273*10^6$ n/m^2 1.552 MPa. (Average pressure)

- Victor Tatarinoff's equation:

$P = 13.5 \frac{\eta m'}{\psi 2} \{\frac{L}{L+D}\}$

η= 18.7 centipoises,

$\eta = 18.7*10^{-3}*$

η= 0.01834470 N-M/S

ψ = C/D

$\psi = 50*10^{-4}$ /0.1

ψ = 0.05

$P = 13.5 *\frac{0.183447 *3000 /60}{0.05^2} * \{\frac{0.2}{0.2+0.1}\}$

P = 33020.04 n/m^2 (safe maximum pressure)

3.2CFD result

The result obtained from FLUENT for L/D = 2.0 and eccentricity = 0.8 with SAE20W in the form of pressure counter is as shown in figure.

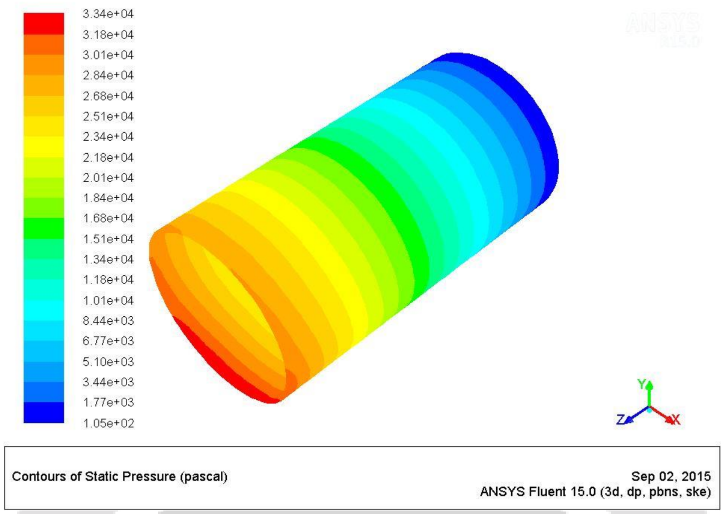


Fig -4: Pressure profile for L/D = 2.0 for SAE 20W oil.

CFD results are compared against the analytical calculation obtained for L/D ratio 2.0 with SAE 20W and Castor Oil and the comparison is shown the table 5.1it is accurate with 1.5 % Variation for both oil. Thus the CFD model chosen i.e. EHL model is validated and further numerical simulation are carried out with SAE20W and castor oil for different L/D ratio.

Oil	Analytical solution	CFD solution	Error
SAE20W	33020 N/m^2	33431.08 N/m^2	1.5 %

It is observed that CFD result are nearly matching with lower L/D ratio up to 2.2 and later CFD results are over predicting the analytical results and thus the numerical simulation model can be validated with reasonable accuracy within in the limits of five per cents.

1. L/D = 2.0 and ε = 0.8 **2. L/D = 2.1 and ε = 0.8**

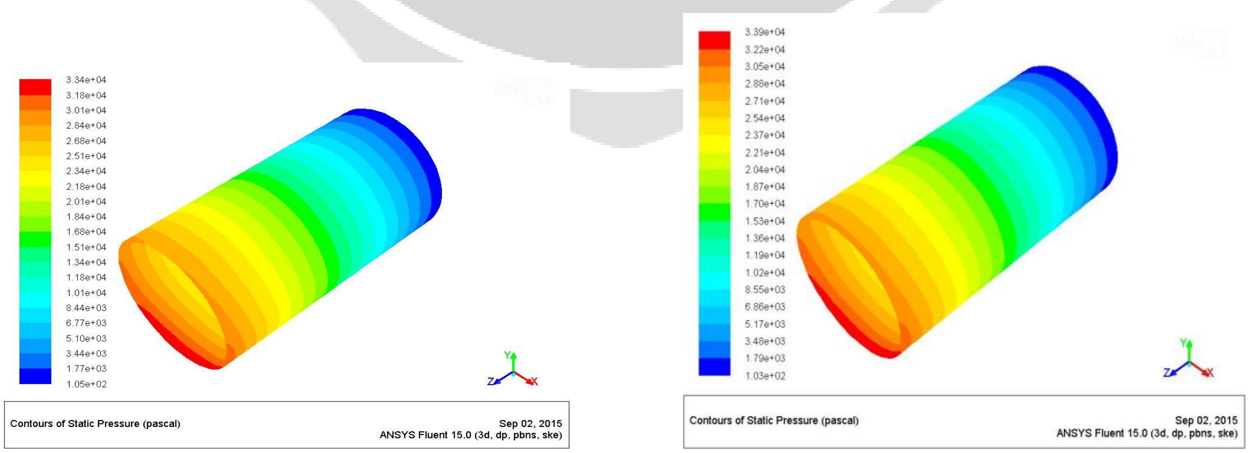


Fig -5: Pressure profile for L/D = 2.0 AND 2.1 for SAE 20W oil.

3. L/D = 2.3 and ε = 0.8 **4. L/D = 2.4 and ε = 0.8**

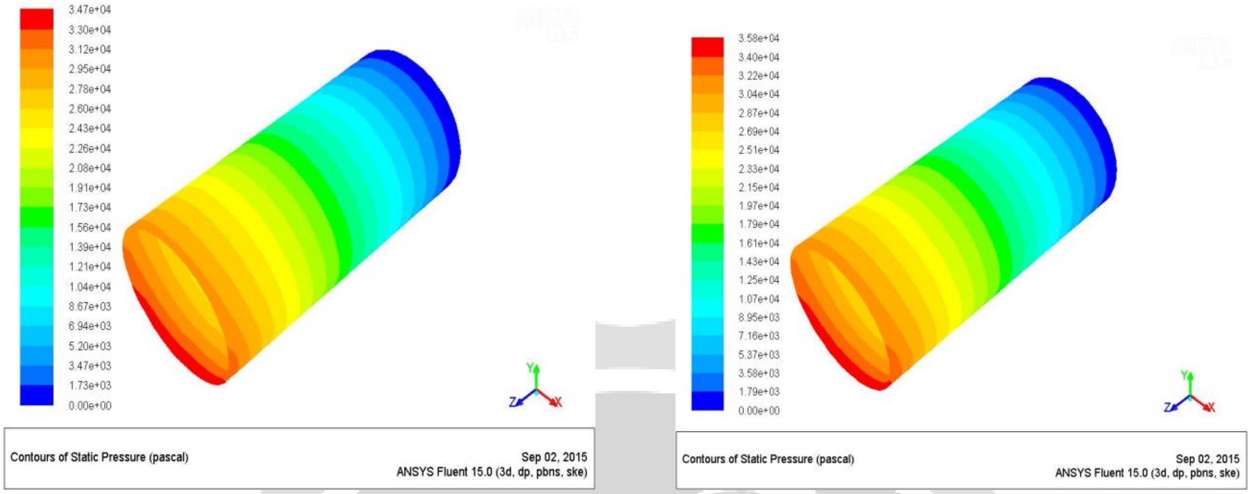


Fig -6: Pressure profile for L/D = 2.3 AND 2.4 for SAE 20W oil.

5. L/D = 2.5 and ε = 0.8

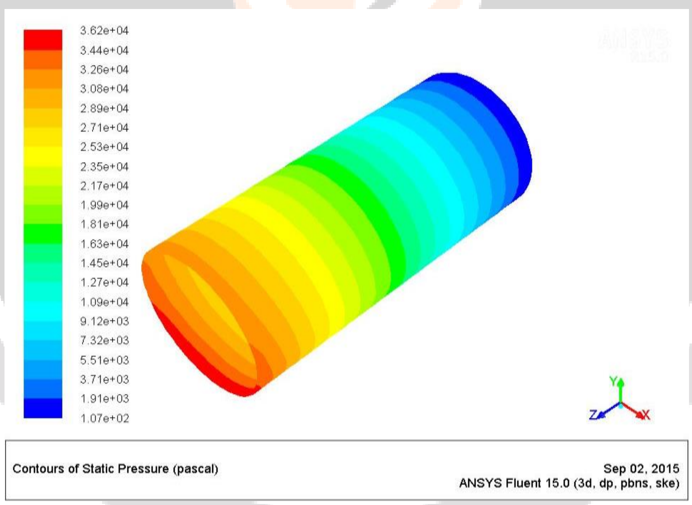


Fig -7: Pressure profile for L/D = 2.5for SAE 20W oil.

3.3FSI results:

The result is obtained from fluid flow analysis through CFD are gives as input to the structural analysis problem to solve fluid structure interaction problems. The pressure values obtained from by FLUENT is utilized in the coupled field analysis and is given in input to structural analysis that has been carried out using ANSYS to get displacement and stress values in journal bearings.

The material properties considering structural analysis are listed below. The displacement and stresses are shown for aluminium material.

1. L/D = 2.0 and ε =0.8

DISPLACEMENT

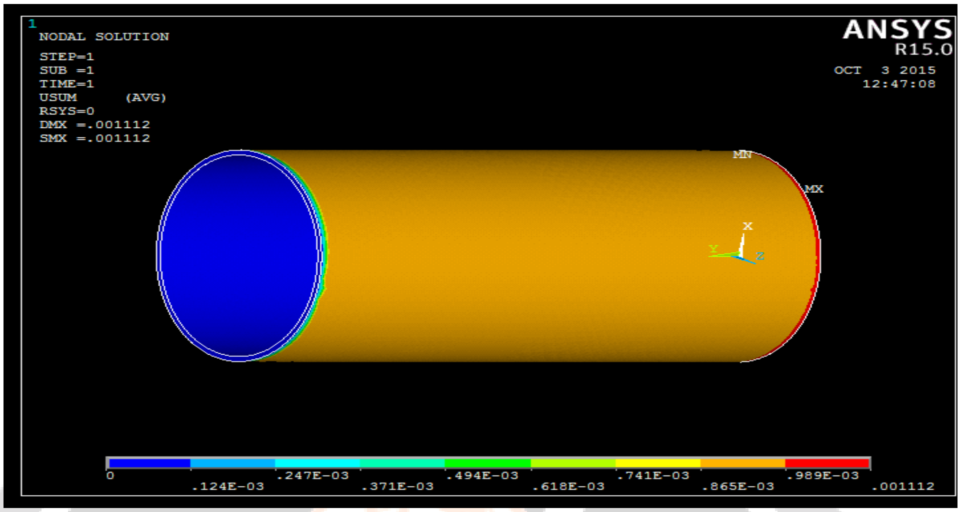


Fig -8: displacement for L/D = 2.0for aluminium material.

STRESS

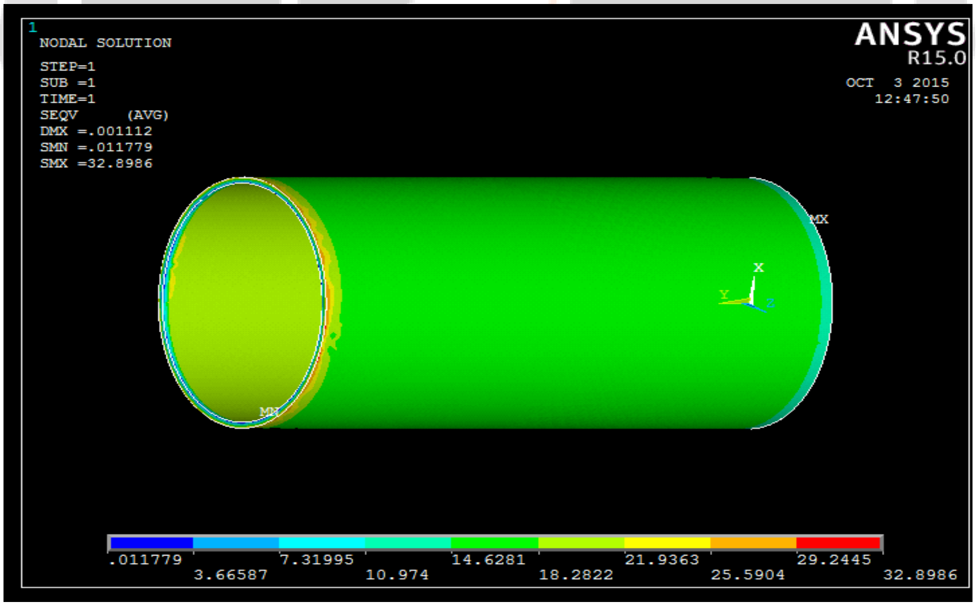


Fig -9: stress for L/D = 2.0for aluminium material.

2. L/D = 2.4 and ε = 0.8

DISPLACEMENT

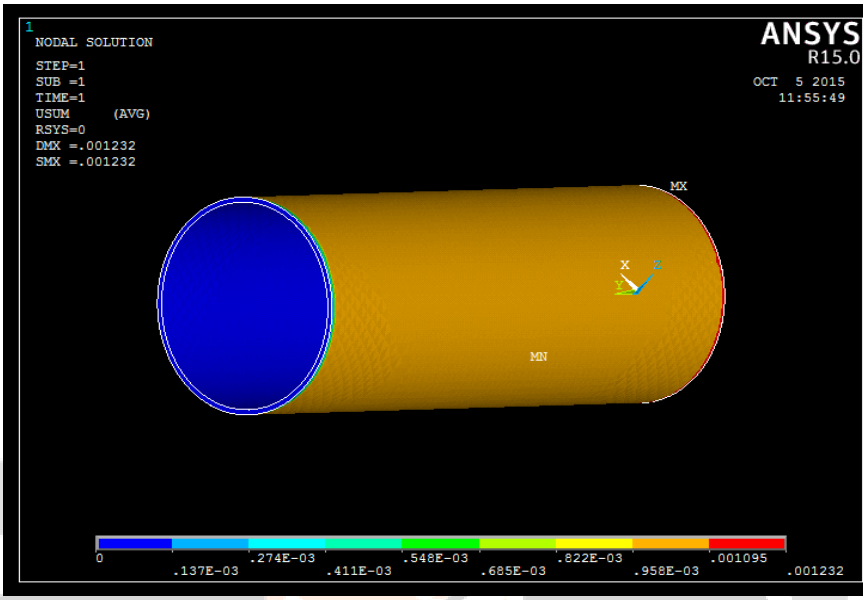


Fig -10: displacement for L/D = 2.4for aluminium material.

STRESS

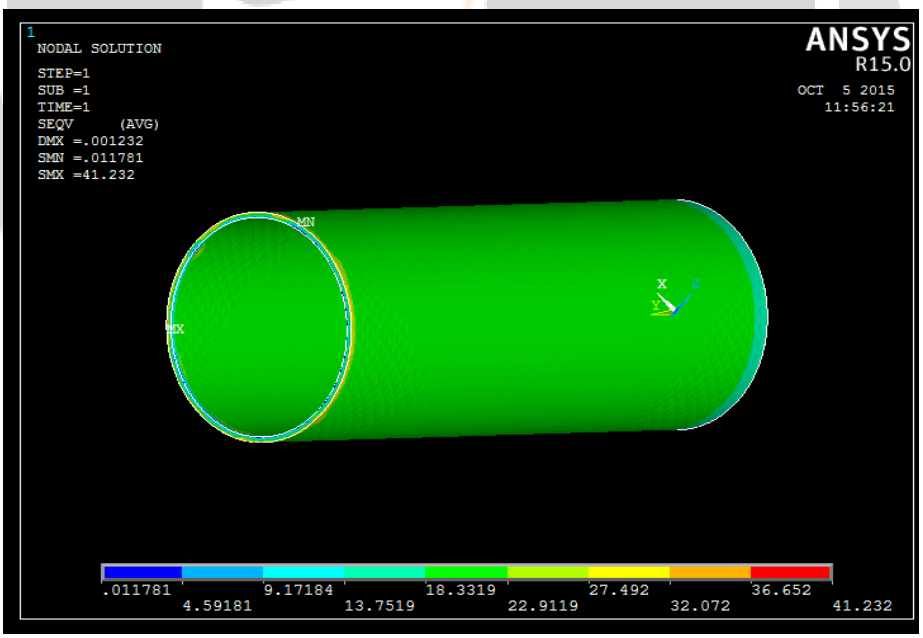
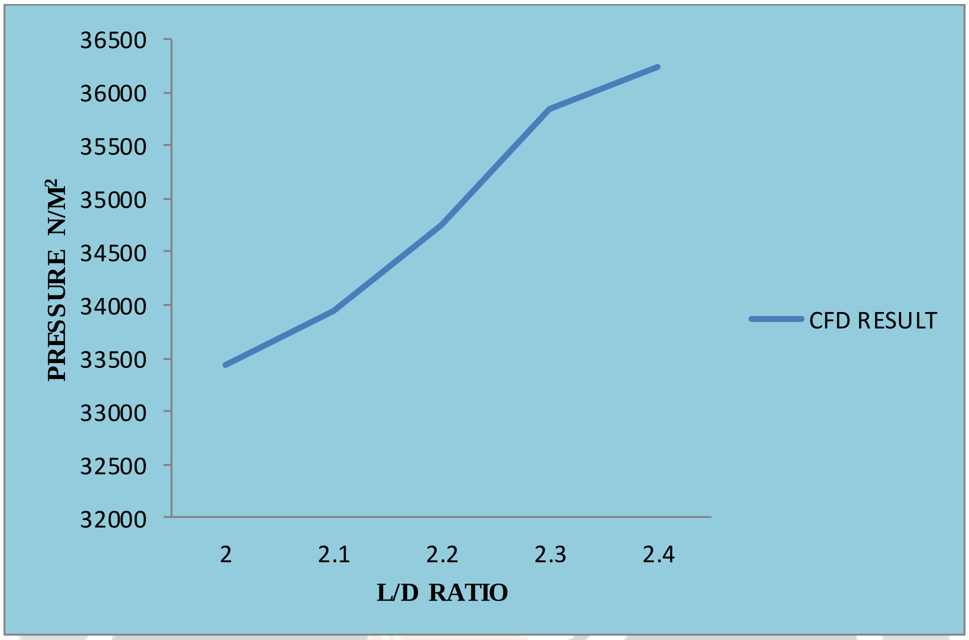
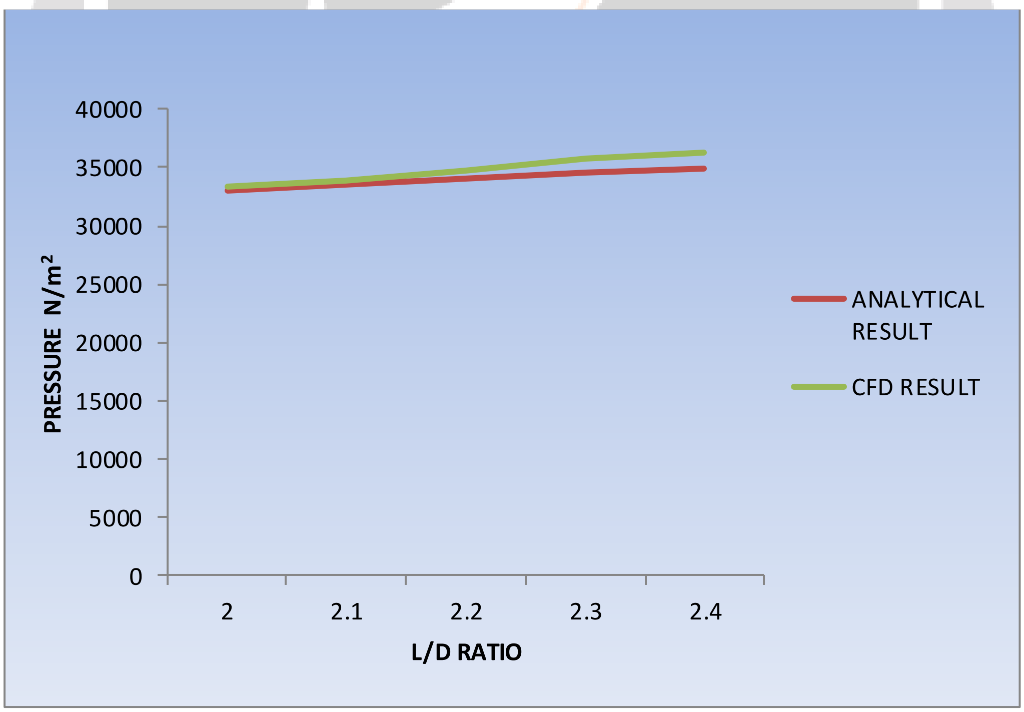


Fig -11: stress for L/D = 2.4for aluminium material.

3.4 Graphic representation for SAE20W for different L/D ratio



3.5COMPARISSION BETWEEN ANALYTICAL AND CFD RESULTS:



4. CONCLUSION:

The overall Elasto-hydro dynamic lubrication analysis of circular journal bearing has been conducted using computational fluid dynamics (CFD) and computational structural dynamics (CSD).

The CFD and structural analysis was carried out for different models using ANSYS in order to evaluate the fluid pressures, Stress distribution and displacement in journal bearing. Different models of journal bearing are designed by varying L/D ratios 2.0, 2.1, 2.2, 2.3, and 2.4 and eccentricity ratios 0.8. There geometrical is worked out in Pro/Engineer. CFD and structural analysis is carried out in ANSYS.

For same eccentricity values and different L/D ratio using SAE20W oil, L/D ratio of 2.0, 2.1, 2.2, 2.3 and 2.4 and same eccentricity value of 0.8, the pressure values are observed to be and film thickness pressure are to be 3.34, 3.39, 3.47, 3.58 and 3.62 N/m^2.The pressure field obtained from fluid dynamics is used in structural analysis to determine the displacement and stresses occurring in mating surfaces. Aluminum is considered as material in structural analysis. By considering aluminum material for different L/D ratio from 2.0, 2.1, 2.2, 2.3 and 2.4 and same eccentricity values of 0.8, the displacement are to be 0.0098, 0.01, 0.01, 0.01 and 0.014m and stresses are to be 29.24, 29.68, 30.36, 35.72 and 36.65 N/m^2 respectively.

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