|| Volume 5 || Issue 7 || July 2020 || ISSN (Online) 2456-0774
INTERNATIONAL JOURNAL OF ADVANCE SCIENTIFIC RESEARCH AND ENGINEERING TRENDS

DESIGN AND CFD ANALYSIS OF BEARING WITH DIFFERENT LUBRICANTS

[1] G.N.V.MADHUSUDHANARAO, [2] Dr.C.NAGABHASKAR

[1]M.Tech Student, Dept. of Mechanical Engineering, NRI Institute of Technology (Autonomous) Agiripalli (M), Vijayawada, Andhrapradesh

[2] Dr.C.NagaBhaskar, Professor, Dept. of Mechanical Engineering, NRI Institute of Technology (Autonomous), Agiripalli(M), Vijayawada, Andhrapradesh

[1]gnvmadhusudhan0906@gmail.com, [2]cnbhaskar@gmail.com

Abstract: A bearing is a machine element that constrains relative motion to only the desired motion, and reduces friction between moving parts. Development of manufacturing technology, rotating machinery becomes increasingly powerful with higher and higher rotation speed. Fluid lubricated journal bearings are widely used in large rotating machinery because of its low cost, long life, silent operation, and high radial precision and simple application. In this work journal bearings for L/D ratio and different eccentricity ratios are modelled in 3D modelling software CATIA. The L/D ratio considered is 0.5 and eccentricity ratios considered are 0.2, 0.4, 0.6 and 0.8. The liquid lubricants considered are SAE 20 oil, SAE 40 oil. Journal bearing models are developed for speed of 2000 rpm to study the interaction between the fluid and elastic behaviour 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.

I INTRODUCTION

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 axels. 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.

Figure 1 Roller bearings

Rolling bearings are made up of four elements and have an extremely simple basic structure they are,

1. Outer ring
2. Inner ring
3. Rolling element
4. Cage

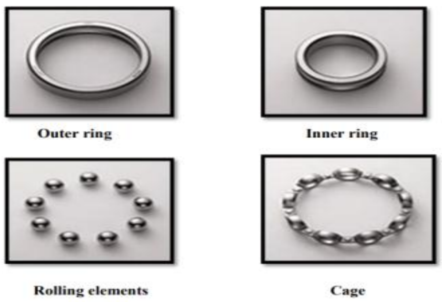


Figure 2 Parts of bearing

1.2 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.

1.2.1 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.

1.2.2BI-MATERIAL

Bi-material bearings consist of two materials, a metal shell and a plastic bearing surface. Common combinations include a steel-backed PTFE-coated bronze and aluminium-backed Freon. Steel-backed PTFE-coated bronze bearings are rated for more load than most other bi-metal bearings and are used for rotary and oscillating motions. 6 Aluminium-backed Freon are commonly used in corrosive environments because the Freon is chemically inert

1.2.3 BRONZE:

A common plain bearing design utilizes a hardened polished steel shaft And a softer bronze bushing. The bushing is replaced whenever it has worn too much. Common bronze alloys used for bearings include: SAE 841, SAE 660 (CDA 932), SAE 863, and CDA 954

1.2.4 LUBRICATION:

In 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 8 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. Lubrication can also describe the phenomenon where reduction of friction occurs unintentionally, which can be hazardous such as hydroplaning on a road. The science of friction, lubrication and wear is called tribology. Adequate lubrication allows smooth continuous operation of equipment, reduces the rate of wear, and prevents excessive stresses or seizures at bearings. When lubrication breaks down, components can rub destructively against each other, causing heat, local welding.

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. Most plain bearings have a plain inner surface, however some are grooved. The grooves help lubrication enter the bearing and cover the whole journal. Self-lubricating plain bearings have a lubricant contained within the bearing walls. There are many forms of self-lubricating bearings. The first, and most common, are sintered metal bearings, which have porous walls. The porous walls draw oil in via capillary action and release the oil when pressure or heat is applied. An example of a sintered metal bearing in action can be seen in self-lubricating chains, which require no additional lubrication during operation. Another form is a solid one-piece metal bushing with a figure eight groove channel on the inner diameter that is filled with graphite. A similar bearing replaces the figure eight groove with holes that are plugged with graphite; this allows the bearing to be lubricated inside and out. The last form is a plastic bearing, which has the lubricant molded into the bearing. The lubricant is released as the bearing is run in.

There are three main types of lubrication:

1. full-film condition,
2. Boundary condition,
3. Dry condition.

Full-film conditions are when the bearing's load is carried solely by a film of fluid lubricant and there is no contact between the two bearing surfaces. In mix or boundary conditions, load is carried partly by direct surface contact and partly by a film forming between the two. In a dry condition, the full load is carried by surface-to surface contact. Bearings that are made from bearing grade materials always run in the dry condition. The other two classes of plain bearings can run in all three conditions; the condition in which a bearing runs is dependent on the operating conditions, load, relative surface speed, clearance within the bearing, quality and quantity of lubricant, and temperature (affecting lubricant viscosity). If the plain bearing is not designed to run in the dry or boundary condition it will wear out and have a high coefficient of friction. Dry and boundary conditions may be experienced even in a fluid bearing when operating outside of its normal operating conditions; e.g., at start up and shutdown.

1.3 FLUID LUBRICATION:

Fluid lubrication results in a full-film or a boundary condition lubrication mode. A properly designed bearing system reduces friction by eliminating surface-to-surface contact between the journal and bearing through fluid dynamic effects. Fluid bearings can be hydrostatically or hydro dynamically lubricated. Hydrostatically lubricated bearings are lubricated by an external pump which always keeps a static amount of pressure. In a hydrodynamic bearing the pressure in the oil film is maintained by the rotation of the journal. Hydrostatic bearings enter a hydrodynamic state when the journal is rotating. Hydrostatic bearings usually use oil, while hydrodynamic bearings can use oil or grease, however bearings can be designed to use whatever fluid is available, and several pump designs use the pumped fluid as a lubricant. Hydrodynamic bearings require greater care in design and operation than hydrostatic bearings. They are also more prone to initial wear because lubrication does not occur until there is rotation of the shaft. At low rotational speeds the lubrication may not attain complete separation between shaft and bushing. As a result, hydrodynamic bearings may be aided by secondary bearings which support the shaft during start and stop periods, protecting the fine tolerance machined surfaces of the journal bearing. On the other hand, hydrodynamic bearings are simpler to install and are less expensive.

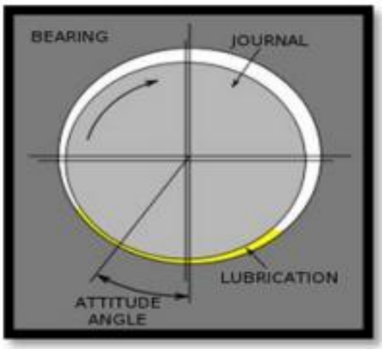


Figure 3A journal bearing under a hydrodynamic lubrication state showing how the journal centerline shifts from the bearing centerline

1.4 APPLICATIONS:

Bearings are not used only in cars, but in all kinds of machinery such as:

Trains
Aero planes
Washing Machines
Refrigerators

II LITERATURE REVIEW

[1]Mahender Janagamid,Prasuna Lilly Florence, P. H V Sesha Talpasa,Fluid structure interaction on journal bearing at different l/d and eccentricity ratios IJSETR Volume. 4, Issue 11, November 2015, Web page 3885-3894. 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.

[2[Hiromu Hashimoto and Sanae Wada, were derived the analytical solutions for three different pressure boundary conditions at inlet edge of turbulent thrust bearings.

[3].A.A.Lubrecht et. al., were carried out numerical analysis on EHL line contacts by using multigrid method. They found that computational time required for multigrid analysis is less compared to Newton-Raphson method .A detailed overview on the numerical analysis of hydrodynamic lubrication can be found in the Multilevel Methods in Lubrication by C.H. Venner and A.A. Lubrecht

[4]. Van Odyck D.E.A, was solved EHL problems numerically by using Stokes equation

[5] Petra Brajdic-Mitidieri, did the work on pocketed pad bearings using CFD. The results show that pockets can result in a major reduction in bearing friction coefficient

[6]. K. M. Panday et. al., were conducted 3D unsteady numerical analysis on journal bearing to find the performances

III DESIGN PARAMETERS AND DIMENSIONS

3.1 JOURNAL BEARING MODEL CALCULATION

L=Length of journal, mm

D=diameter of journal, mm

CASES	D(mm)	L/D	L(mm)
1	100	0.5	50

Details of JOURNAL:

Eccentricity calculations

Ɛ =eccentricity ratio

C= radial clearancemm

C=0.145mm

e = eccentricity (mm)

Ɛ=e/c

Cases	C	Ɛ	e= Ɛ×C
1	0.145	0.2	0.029
2	0.145	0.4	0.058
3	0.145	0.6	0.087
4	0.145	0.8	0.116

Eccentricity Calculation at different eccentricity ratio

3.2 FLUID: CASE 1: 0.2:

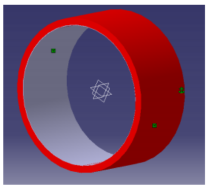


Figure 4Assembly of Solid & Fluid for case 1

3.3 FLUID: CASE 2: 0.4:

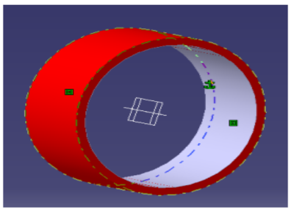


Figure 5Assembly of Solid & Fluid for case 2

3.4FLUID: CASE3: 0.6:

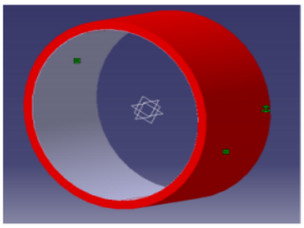


Figure 6Assembly for fluid case 3

3.5FLUID: CASE 4: 0.8:

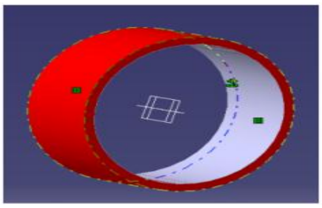


Figure 7 Assembly for fluid case 4

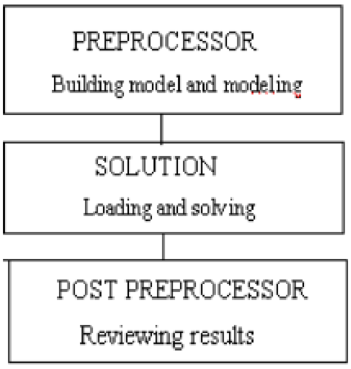
IV INTRODUCTION TO ANSYS SOFTWARE

ANSYS is an Engineering Simulation Software (computer aided Engineering). Its tools cover Thermal, Static, Dynamic, and Fatigue finite element analysis along with other tools all designed to help with the development of the product. The company was founded in 1970 by Dr. John A. Swanson as Swanson Analysis Systems, Inc. SASI. Its primary purpose was to develop and market finite element analysis software for structural physics that could simulate static (stationary), dynamic (moving) and heat transfer (thermal) problems. SASI developed its business in parallel with the growth in computer technology and engineering needs. The company grew by 10 percent to 20 percent each year, and in 1994 it was sold. The new owners took SASI's leading software, called ANSYS®, as their flagship product and designated ANSYS, Inc. as the new company name.

4.1STATIC ANALYSIS:

Static analysis calculates the effects of steady loading conditions on a structure, while ignoring inertia and damping effects, such as those caused by time varying loads. A static analysis can, however, include steady inertia loads (such as gravity and rotational velocity), and time-varying loads that can be approximated as static equivalent loads (such as the static equivalent wind arid seismic loads commonly defined in many building codes).

4.2 BASIC STEPS IN ANSYS:



4.3 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

4.4 METHODOLOGY FOR CFD:

- In all of these approaches the same basic procedure is followed.
- During pre-processing,
- The geometry (physical bounds) of the problem is defined.
- The volume occupied by the fluid is divided into discrete cells (the mesh).
- The mesh may be uniform or non-uniform.
- The physical modeling is defined. For example, the equation of motion+ enthalpy+ radiation+ species conservation.
- Boundary conditions are defined. This involves specifying the fluid behavior and properties at the boundaries of the problem. For transient problems, the initial conditions are also defined.
- The simulation is started and the equations are solved interactively as a study state or transient.
- Finally a post-processer is used for the analysis and visualization of the resulting solution.

4.5 ANALYSIS FOR SAE 20 OIL:

ANALYSIS OF JOURNAL BEARING
FSI: L/D Ratio=0.5

Eccentricity Ratio (Ɛ) =0.2, 0.4, 0.6 & 0.8
Fluid - SAE 20 Oil
Bearing Material - Babbitt
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.

CASE 1 WHEN L/D =0.5 & ECCENTRICITY=0.2

→→Ansys → workbench→ select analysis system → fluid flow fluent → double click →→Select geometry → right click → import geometry → select browse →open part → ok →→ Select mesh on work bench → right click →edit → select mesh on left side part tree → right click → generate mesh →

Model is constituted as one cylinder with a diameter D of 100 mm and another one with a diameter of 99.5 mm, with eccentricity ratio of 0.3. The model is designed with the help of pro-e and then import on ANSYS for Meshing and analysis. The analysis by CFDFSI approach is used in order to calculating pressure profile and temperature distribution. For meshing, the fluid ring is divided into two connected

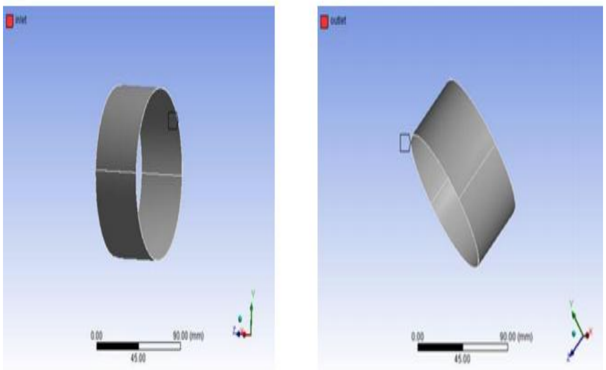


Figure 8lubricant inlet and outlet case 1

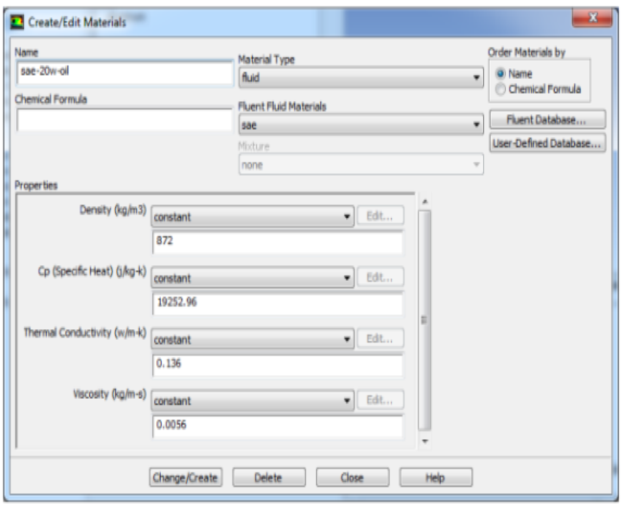


Figure 9Specifications of the fluid material for fluid at case 1

4.6 Boundary conditions>inlet>enter required inlet values

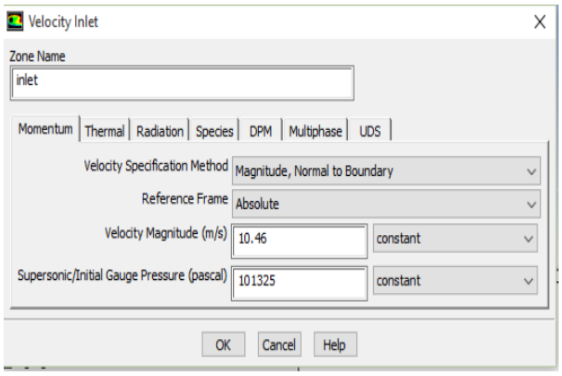
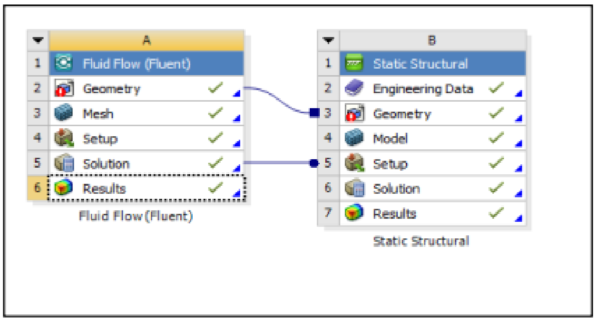


Figure 10Specifications of the inlet pressure for fluid at case 1

The plain journal bearing has only one high point pressure along the circumference of the journal bearing. This is due to geometry of bearing and how the fluid gap expands and contracts once around the circumference of the journal shaft. A typical pressure distribution along the circumference of the journal shaft of the journal bearing is shown in above fig, respectively for long and short journal bearing. Select static structural>now share the geometry of fluid flow (fluent) to geometry of static structural>and transfer the solution of fluid flow (fluent) to setup of static structural.



Interaction between cfd & structural analysis at case 1
Properties of solid materials:
Used material Babbitt
Density=0.000007272kg/mm3
Young's modulus=50000MPa
Poisson's ratio=0.35

The model is constituted as one cylinder with a diameter D of 100 mm and another one with a diameter of 110 mm. The model is designed with the help of pro-e and then import on ANSYS for Meshing and analysis. The analysis by CFD FSI approach is used in order to calculating pressure profile and temperature distribution. For meshing, the fluid ring is divided into two connected volumes. Then all thickness edges are meshed with 360 intervals. A tetrahedral structure mesh is used. .

Right click on the static structural>insert>select displacement>select fixing area in the model apply.

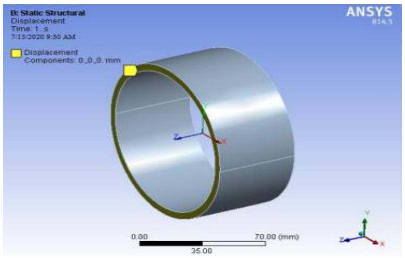


Figure 11Selecting the displacement and select fixing area in the model for solid at case

Right click on the static structural> insert> imported load from CFD> insert> pressure> select pressure area on the component>apply

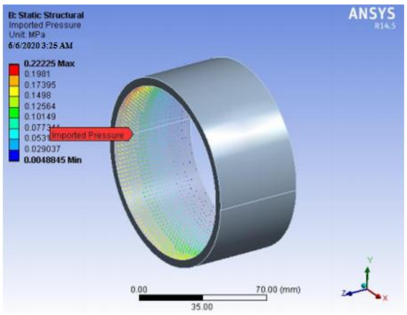


Figure 12Imported load from CFD and applied the pressure area on the component

Right click on solution>insert>deformation

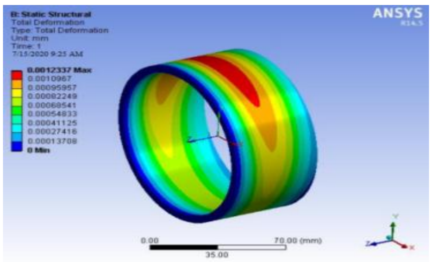


Figure 13Total deformation at case 1

4.7 CASE 2: WHEN L/D =0.5 & ECCENTRICITY=0.4:

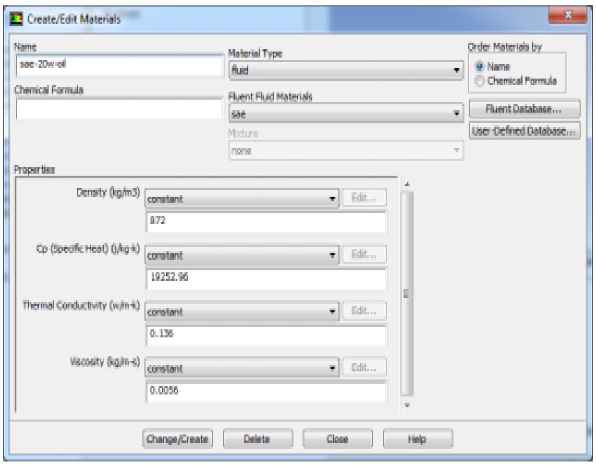


Figure 14 Specifying the fluid material for fluid at case 2

Boundary conditions>inlet>enter required inlet

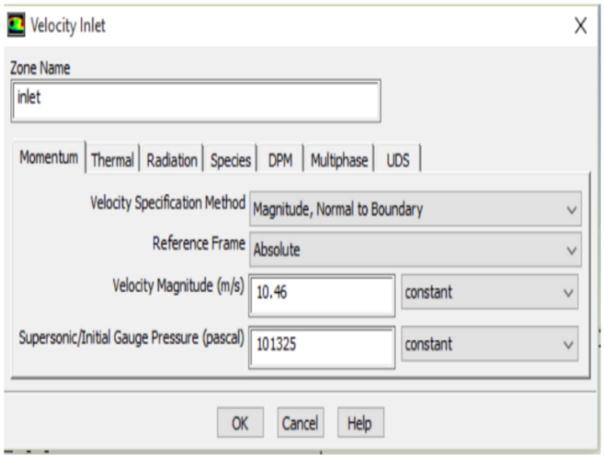


Figure 15Specifying the inlet pressure for fluid at case 2

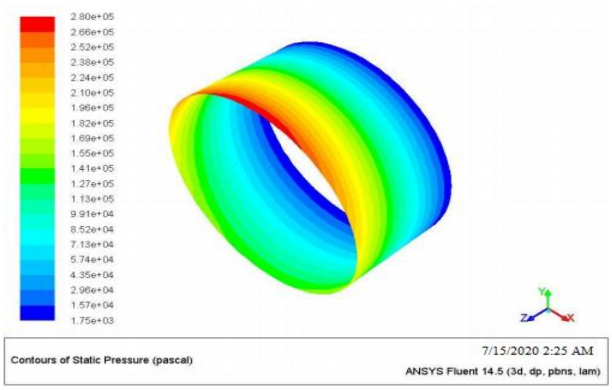


Figure 16Static pressure of case 1

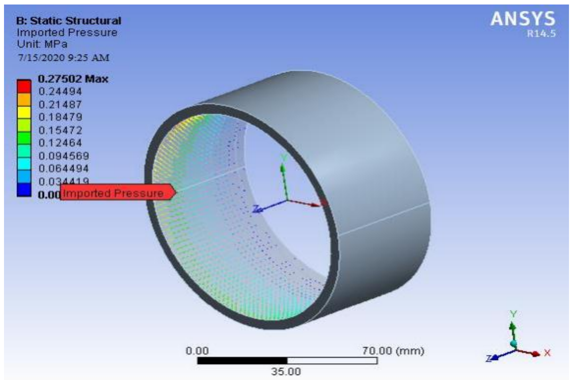


Figure 17CFD and applied the pressure area

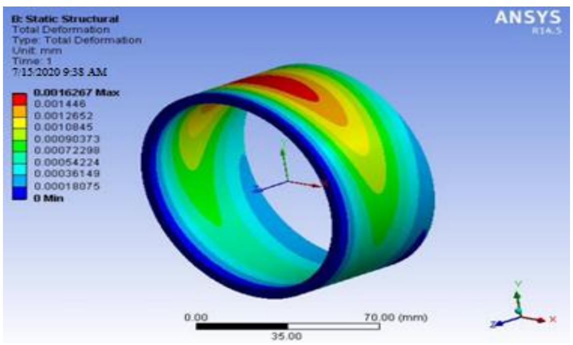


Figure 18Total deformation case2

CASE 3: WHEN L/D =0.5 & ECCENTRICITY=0.6:

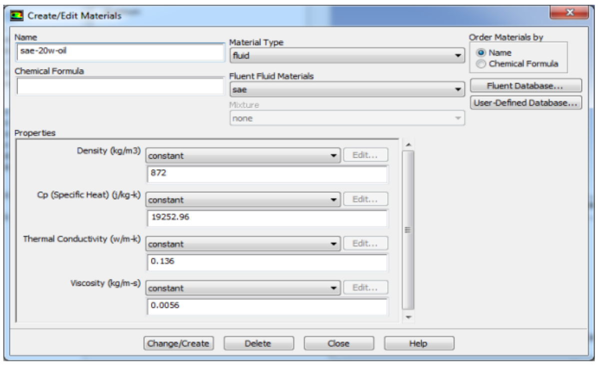


Figure 19Specifications of the fluid material case 3

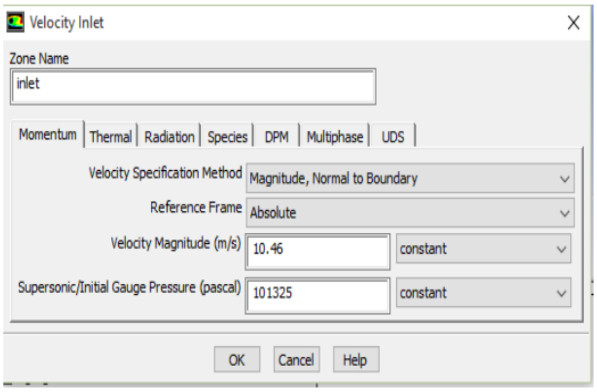


Figure 20Specifying the inlet pressure for fluid at case 3

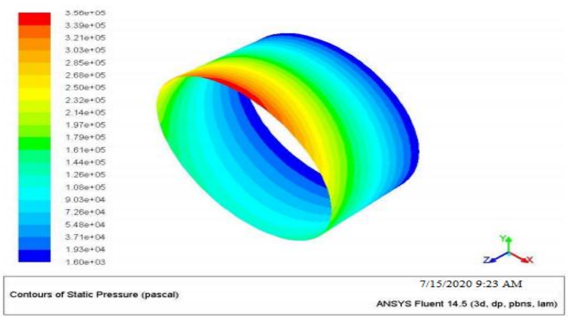


Figure 21Pressure con tours for fluid at case 3

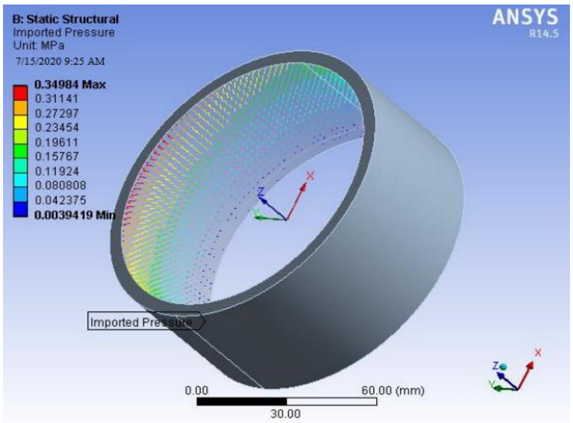


Figure 22CFD and applied the pressure

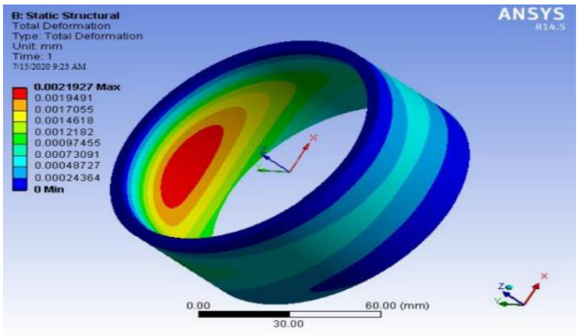


Figure 23CASE 4: WHEN L/D =0.5 & ECCENTRICITY=0.8

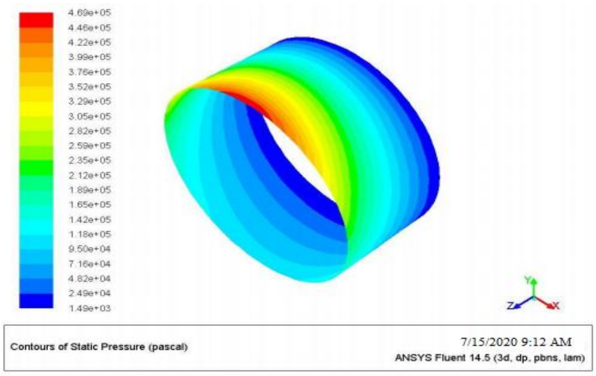


Figure 24Pressure contours for fluid at case 4

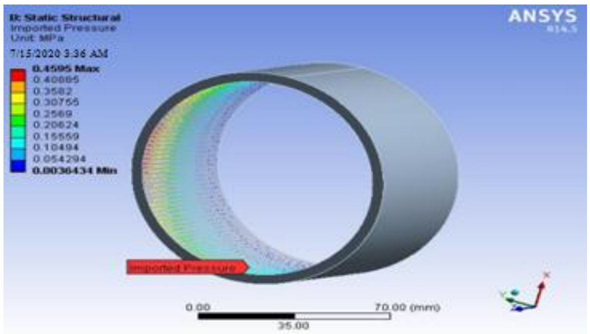


Figure 25CFD and applied the pressure area

Total deformation at case 4

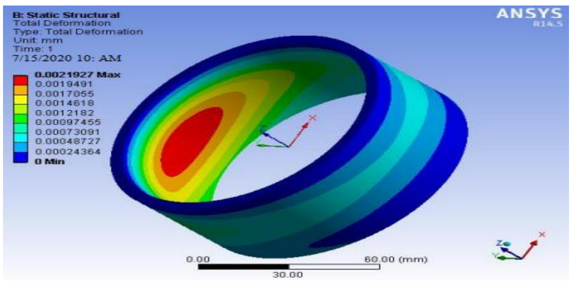


Figure 26Total deformation at case 4

V ANALYSIS FOR SAE 40 OIL;

ANALYSIS OF JOURNAL BEARING - FSI:
L/D Ratio=0.5
Eccentricity Ratio (Ɛ) =0.2, 0.4, 0.6 & 0.8
Fluid - SAE 40 Oil

CASE 1: WHEN L/D =0.5 & ECCENTRICITY=0.2:

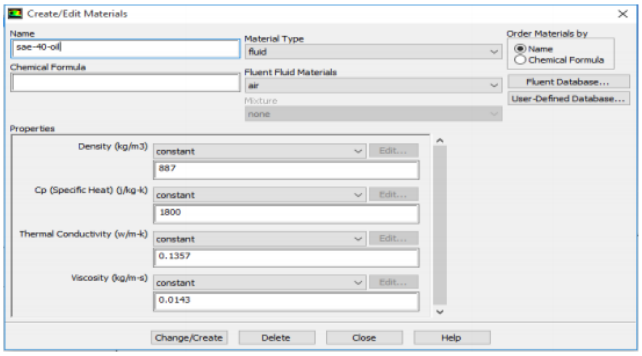


Figure 27Specifying the fluid material for fluid at case 1

Boundary conditions>inlet>enter required inlet values

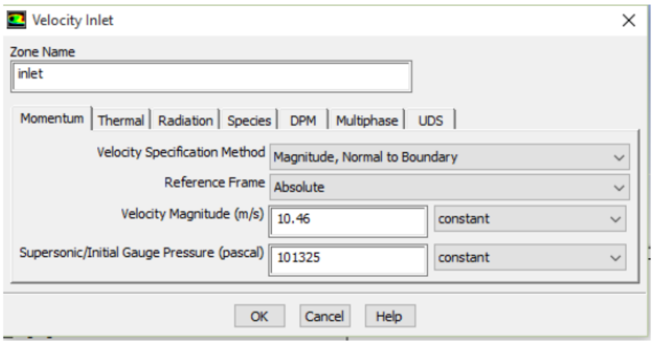


Figure 28Specifying the inlet pressure for fluid at case 1

VI RESULTS AND DISCUSSIONS

6.1 SAE-20OIL:

SAE-20-OIL:

Eccentricity ratios	Pressure MPa	Total deformation in mm
0.2	0.22225	0.0012337
0.4	0.27502	0.0016267
0.6	0.34984	0.0021927
0.8	0.4595	0.002988

Table 1 SAE-20-Oil Respect to Eccentricity Ratios at L/D 0.5

6.2 SAE-40-OIL:

Eccentricity ratios	Pressure MPa	Total deformation in mm
0.2	0.5648	0.0031421
0.4	0.66617	0.0043143
0.6	0.87597	0.0054917
0.8	1.1379	0.0073887

Table 2 SAE-40-Oil Respect to Eccentricity Ratios at L/D 0.5

VII GRAPHS:

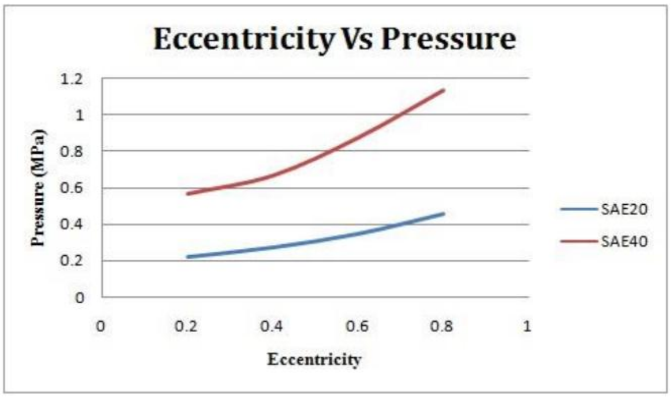


Figure 29 Graph between Eccentricity Vs Pressure

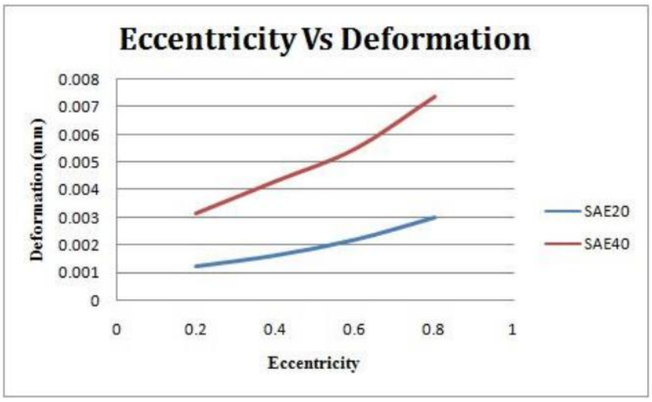


Figure 30 Graph between Eccentricity Vs Deformation

VIII CONCLUSION

Hydrodynamic journal bearings are analyzed by using Computational fluid dynamics (CFD) and fluid structure interaction (FSI) approach on L/D ratio 0.5 and eccentricity ratios using Ansys in order to evaluate the fluid pressures, Stress distribution and deformation in journal bearing. Journal bearings for L/D ratio and different eccentricity ratios are modeled in 3D modeling software CATIA. The L/D ratio considered is 0.5 and eccentricity ratios considered are 0.2, 0.4, 0.6 and 0.8. By observing the CFD analysis results, respect to the L/D ratio the pressure is increasing by increasing the eccentricity ratio there by increasing the displacements values. In this work we are using two fluids, they are SAE20 and SAE40 oils. In strain values for SAE 40 decreases suddenly and increases gradually when compared to SAE20 oil. In this work, 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. By comparing these results pressure, deformation, for SAE 20 oil are less as compared to SAE 40 oil. So SAE 20 oil and Eccentricity ratio 0.2 are best suited for journal bearing

IX FEATURE SCOPE OF THE PROJECT:

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

REFERENCES

[1] Mahender Janagam, D. Prasuna Lilly Florence and Dr. P. H V Sesha Talpa Sai, Fluid Structure Interaction On Journal Bearings At Different L/D And Eccentricity Ratios, International Journal of Science, Engineering and Technology Research (IJSETR), Volume 4, Issue 11, November 2015.

[2] B. S. Shenoy, R. S. Pai, D. S. Rao and R. Pai, Elasto-hydrodynamic lubrication analysis of full 360◦ journal bearing using CFD and FSI techniques, ISSN1746-7233, England, UK World Journal of Modelling and Simulation Vol. 5 (2009) No. 4, pp. 315-320.

[3] B. S. Shenoy, R. S. Pai, D. S. Rao, R. Pai,Elasto-hydrodynamic lubrication analysis of full 360 journal bearing using CFD and FSI techniques, World Journal of Modeling and Simulation, ISSN 1 746-7233, Vol. 5 (2009) No. 4, pp. 315-320.

[4]Priyanka Tiwari, Veerendra Kumar, Analysis of Hydrodynamic Journal Bearing Using CFD and FSI Technique, www.ijert.org, Volume/Issue: Vol. 3 - Issue 7 (July - 2014), eISSN: 2278-0181.

[5] Samuel A. McKee, Journal-Bearing Design As Related To Maximum Loads, Speeds, And Operating Temperatures, Part of Journal of Research of the National Bureau of Standards, Volume 19, October 1937.

[6] S. Sharma, D. Hargreaves, W. Scott, Journal bearing performance and metrology issues, Journal of Achievements in Materials and Manufacturing Engineering

[7] P.C. Mishra, Analysis of a Rough Elliptic Bore Journal Bearing using Expectancy Model of Roughness Characterization.

[8] Amit Chauhan, Amit Singla, Narender Panwar, Prashant Jindal. CFD Based Thermo-Hydrodynamic Analysis of Circular Journal Bearing. International Journal of Advanced Mechanical Engineering 2014;4:475-82.

[9] Bhushan B. Introduction to Tribology. Wiley publications 2002;ISBN: 9780471158936.

[10] Brajdic-Mitidieri, P., Gosman A. D., Ioannides, E., Spikes H. A. CFD Analysis of a Low Friction Pocketed Pad Bearing. Journal of Tribology, Trans ASME 2005;127:803-12.

[11] van Odyck, D. E. A. Stokes Flow in Thin Films. Ph.D thesis 2001; University of Twente Enschede, Netherlands.

[12] Versteeg H. K, W Malalasekera. An introduction to Computational Fluid Dynamics The Finite Volume Method. Longman 1995; 1st edition.