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DESIGN AND CFD ANALYSIS OF BEARING WITH DIFFERENT LUBRICANTS

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Abstract: With the 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

1. INTRODUCTION OF BEARING:

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.

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 bearings. They are also compact and lightweight, and they have a high load carrying capacity

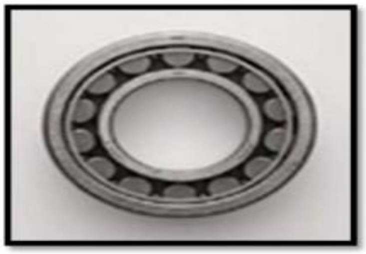


Fig 1: Roller bearings

1.2.TYPES OF BEARINGS:

1.2.1 D-EEP GROOVE BALL BEARING : Deep groove, or single row radial, ball bearings are the most widely used bearings. They utilize an uninterrupted raceway that makes them optimal for radial loads .This design permits precision tolerance, even at high-speed operation.

Fig 2: Deep groove ball bearing

1.2.2. CYLINDRICAL ROLLER BEARING: The rolling elements are the cylindrical roller type. Here too the rolling elements are the cylindrical roller type. However in this instance the shape of the cage differs.

Fig 3: Cylindrical roller bearing

1.2.3. TAPERED ROLLER BEARING: The rolling elements are of the tapered roller type. Because the rollers are tapered, this bearing is able to carry combined axial and radial loads.

Fig 4: Tapered roller bearing

1.2.4 SELF-ALIGNING ROLLER BEARING: This bearing has an automatic inner aligning function to compensate for minute misalignments between the and outer rings during operation.

Fig 5: Self aligning bearing

1.3. 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.

1.3.1. 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.

1.3.2. BI-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 aluminum-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 Aluminum-backed Freon are commonly used in corrosive environments because the Freon is chemically inert.

Fig 6: Split bi-material bushings

1.4. 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 MoS2) 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

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

- Trains
- Aero planes
- Washing Machines
- Refrigerators
- Air Conditioners
- Vacuum Cleaners
- Photocopy Machines
- Computers
- Satellites

II. DESIGN SOFTWARES

2.1. INTRODUCTION TO CAD: Throughout the history of our industrial society, many inventions have been patented and whole new technologies have evolved. Perhaps the single development that has impacted manufacturing more quickly and significantly than any previous technology is the digital computer. Computers are being used increasingly for both design and detailing of engineering components in the drawing office. Computer-aided design (CAD) is defined as the application of computers and graphics software to aid or enhance the product design from conceptualization to documentation. CAD is most commonly associated with the use of an interactive computer graphics system, referred to as a CAD system. Computer-aided design systems are powerful tools and in the mechanical design and geometric modeling of products and components. There are several good reasons for using a CAD system to support the engineering design function: To increase the productivity¬ To improve the quality of the design¬ To uniform design standards¬ To create a manufacturing data base¬ To eliminate inaccuracies caused by hand-copying of drawings and¬ inconsistency between Drawings

2.2. INTRODUCTION TO CATIA: CATIA is a one of the world's leading high-end CAD/CAM/CAE software packages. CATIA (Computer Aided Three dimensional Interactive Application) is a multi-platform PLM/CAD/CAM/CAE commercial software suite developed by Dassault Systems and marketed world-wide by IBM.CATIA is written in the C++ programming language. CATIA provides open development architecture through the use of interfaces, which can be used to customize or develop applications. The application programming interfaces supported Visual Basic and C++ programming languages. Commonly referred to as 3D Product Lifecycle Management (PLM) software suite, CATIA supports multiple stages of product development. The stages range from conceptualization, through design (CAD) and manufacturing (CAM), until 14 analysis (CAE). Each workbench of CATIA V5 refers an each stage of product development for different products. Catia V5 features a parametric solid/surface-based package which uses NURBS as the core surface representation and has several workbenches that provide KBE (Knowledge Based Engineering) support. Feature-based Modeling: In CATIA V5, solid models are created by integrating a number of building blocks called features. Parametric modeling: The parametric nature of a software package is defined as its ability to use the standard properties or parameters in defining the shape and size of a geometry. Associatively: Associatively ensures that if any modification is made in the model in any one of the workbenches of CATIA V5, it is automatically reflected in the other workbenches immediately. B-Rep modeling: Most of the components Designed using CATIA V5 are based on BRep modeling technique i.e. models are created by extruding the boundary of the model in a specified direction.

2.3. DESIGN OF SOLID:

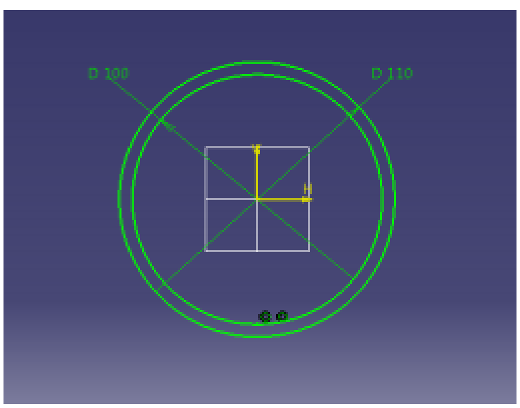


Fig:6 Sketcher

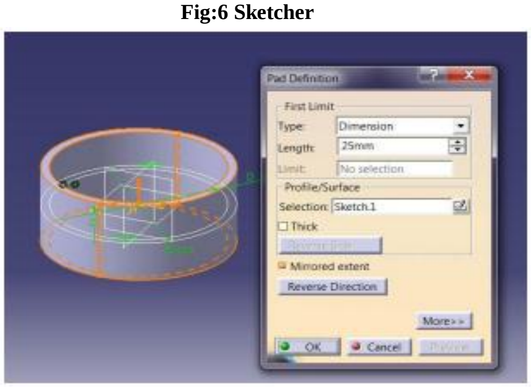


fig-7 Pad

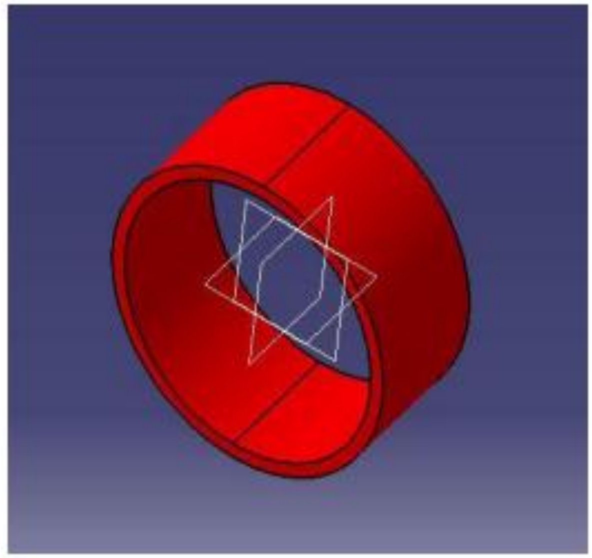


fig-8 Completed solid object

2.4.JOURNAL BEARING MODEL CALCULATIONS:

L=Length of journal, mm

D=diameter of journal, mm

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

Table-1. Details of JOURNAL:

Eccentricity calculations

ε =eccentricity ratio

C= radial clearance, mm

C=0.145mm

e = eccentricity (mm)

ε=e/c

Cases	C	ε	e= $\varepsilon \times$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

Table-2 Eccentricity Calculation at different eccentricity ratio

2.5. FLUID: CASE 1: 0.2

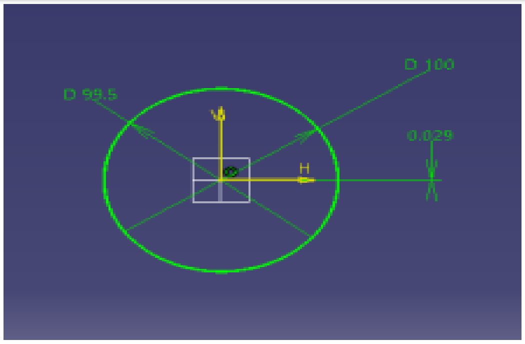


Fig-9 Sketcher for fluid case 1

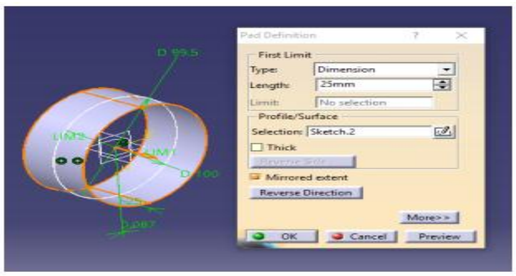


Fig-10 Pad for fluid case 1

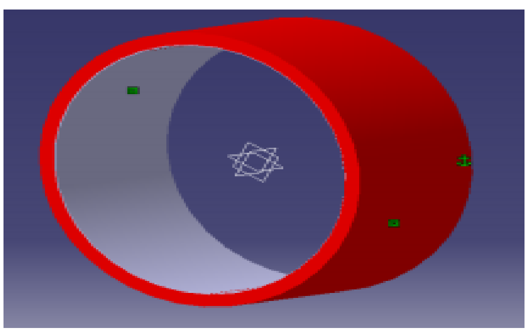


Fig-11 Assembly of Solid & Fluid for case 1

III. ANSYS

3.1. 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.

3.2. BENEFITS OF ANSYS:

The ANSYS advantage and benefits of using a modular simulation system in the design process are well documented. According to studies performed by the Aberdeen Group, best-in-class companies perform more simulations earlier. As a leader in virtual prototyping, ANSYS is unmatched in terms of functionality and power necessary to optimize components and systems.

- The ANSYS advantage is well-documented.
- ANSYS is a virtual prototyping and modular simulation system that is easy to use and extends to meet customers need, making it a low-risk investment that can expand as value is demonstrated within a company. It is scalable to all levels of the organization, degrees of analysis complexity, and stages of product development.

3.3. INTRODUCTION TO STRUCTURAL ANALYSIS: Structural analysis is probably the most common application of the finite element method. The term structural (or structure) implies not only civil engineering structures such as ship hulls, aircraft bodies, and machine housings, as well as mechanical components such as pistons, machine parts, and tools.

3.4. TYPES OF STRUCTURAL ANALYSIS: Different types of structural analysis are:

- Static analysis
- Modal analysis
- Harmonic analysis
- Transient dynamic analysis
- Spectrum analysis
- Bucking analysis
- Explicit dynamic analysis

3.4.1. STATIC 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).

Static analysis is used to determine the displacements, stresses, strains, and forces in structural components caused by loads that do not induce significant inertia and damping effects. Steady loading and response are assumed to vary slowly with respect to time. The kinds of loading that can be applied in a static analysis include: Externally applied forces and pressures

- Steady-state inertial forces (such as gravity or rotational velocity)
- Imposed (non-zero) displacements
- Temperatures (for thermal stain)
- A static analysis can be either linear or non-linear.

All types of non-linearity are allowed-large deformations, plasticity, creep, stress, stiffening, contact (gap) elements, hyper elastic elements, and so on. Over-view of steps in a static analysis: 23 The procedure for a modal analysis consists of three main steps: 1. Build the model.

2. Apply loads and obtain the solution. 3. Review the results.

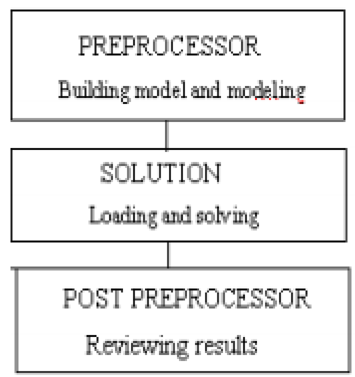
3.4.2. MODEL ANALYSIS: A Model analysis is typically used to determine the vibration characteristics (natural frequencies & mode shapes) of a structure or a machine component while it is being designed. It can also sever as a starting point for another, more detailed, dynamic analysis, such as a harmonic response or full transient dynamic analysis. Model analysis, while being one of the most basic dynamic analysis types available in ANSYS, can also be more computationally time consuming than a typical static analysis. A reduced solver, utilized automatically or manually selected master degrees of freedom is used t drastically reduce the problem size and solution time.

3.4.3. HARMONIC ANALYSIS: Used extensively by companies who produce rotating machinery, ANSYS Harmonic analysis is used to predict the sustained dynamic behavior of structures to consistent loading. Examples of rotating machines which produced or are subjected to harmonic loading are, Turbines

- Gas turbines for Aircraft
- & Power generation Steam Turbines
- Wind Turbines
- Water Turbine
- Turbo pumps
- Internal Combustion Engines
- Electric motors and generators
- Gas and fluid pumps
- Disc drives
- A harmonic analysis can be used to verify whether or not a machine design will successfully overcome resonance, fatigue & other harmful effects of forced vibrations.

3.4.4. TRANSIENT DYNAMIC ANALYSIS: Used to determine the response of a structure to arbitrarily time-varying loads. All nonlinearities mentioned under Static analysis above are allowed. **3.4.5. BUCKING ANALYSIS**: Used to calculate the buckling loads and determine the buckling mode shape. Both linear (Eigen value) buckling and nonlinear buckling analysis are possible

3.5. Basic Steps in ANSYS:

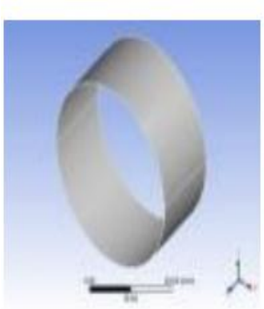


IV. ANALYSIS FOR SAE 20 OIL

4.1. 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.

4.2.CASE1WHENL/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 →



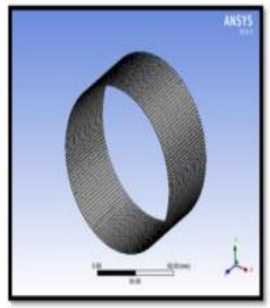


Fig- 12 Geometry model for fluid Fig-4.2 Meshed model for fluid at case 1

V. ANALYSIS FOR SAE 40 OIL

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

Eccentricity Ratio (Ɛ) =0.2, 0.4, 0.6 & 0.8Fluid - SAE 40 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.

5.2. 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

→→Expand Geometry & right click on part 1 & suppress the solid body

→→ Select mesh on work bench → right click →edit → select mesh on left side part tree → right click → generate mesh →

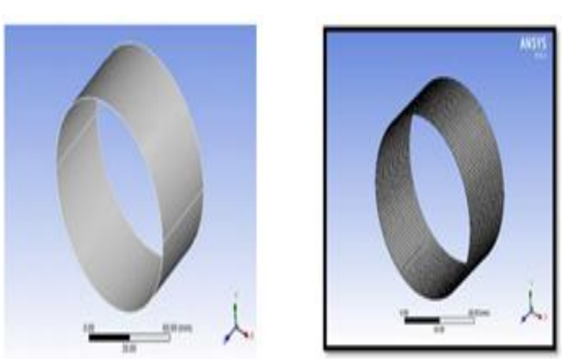


Fig12 geometry model & meshed model of fluid

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 volumes.

Select faces → right click → create named section → enter name → lubricant inlet

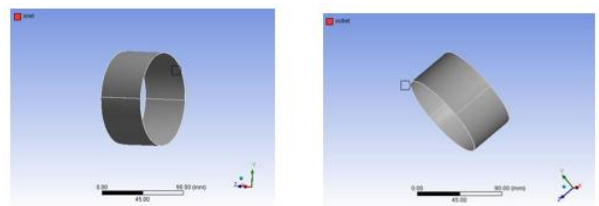


Fig-13 Naming the lubricant inlet & outlet sections for fluid at case 1

5.3.TOTAL DEDORMATION:

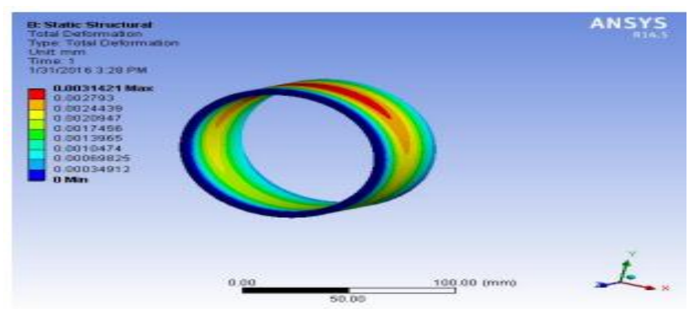
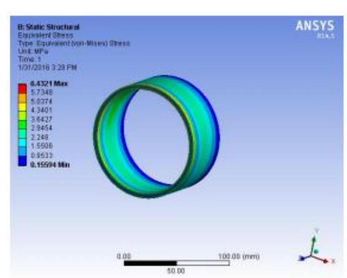


Fig-14 Total deformation at case 1



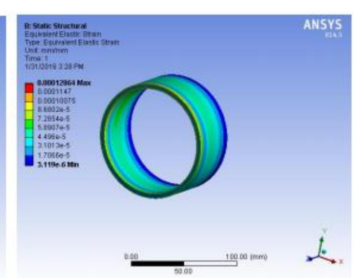


Fig-15 Equivalent stress at case 1 &Equivalent strain at case 1

5.4.CASE 3:

WHEN L/D =0.5 & ECCENTRICITY=0.6: →→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 →

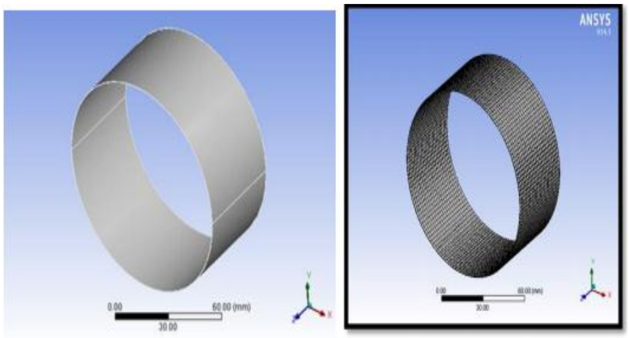


Fig-16 Geometry model for fluid at case 3 &Meshed model for fluid at case 3

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

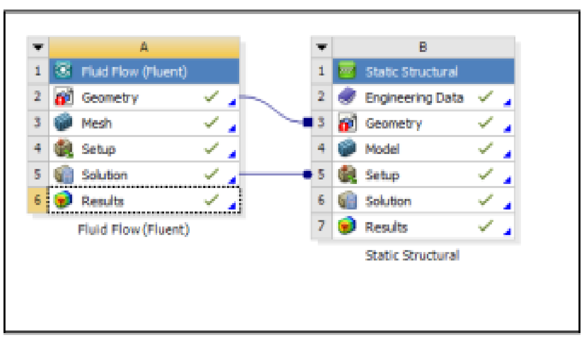


Fig-17 Interaction between CFD & STRUCTURAL analysis at case 4

VI. RESULTS

6.1. SAE-20-OIL:

Eccentricity ratios	Pressure MPa	Total deformation in mm	Stress MPa	Strain
0.2	0.22225	0.0012337	2.5257	5.0514e-5
0.4	0.27502	0.0016267	2.9943	5.98922e-5
0.6	0.34984	0.0021927	3.8717	7.7442e-5
0.8	0.4595	0.002988	5.0492	0.000101

Table-3 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	Stress MPa	Strain
0.2	0.5648	0.0031421	6.4321	0.00019426
0.4	0.66617	0.0043143	7.6096	0.0001286
0.6	0.87597	0.0054917	9.7121	0.00019426
0.8	1.1379	0.0073887	12.49	0.00024984

Table 4 SAE-40-Oil Respect to Eccentricity Ratios at L/D 0.5

6.3. GRAPHS:

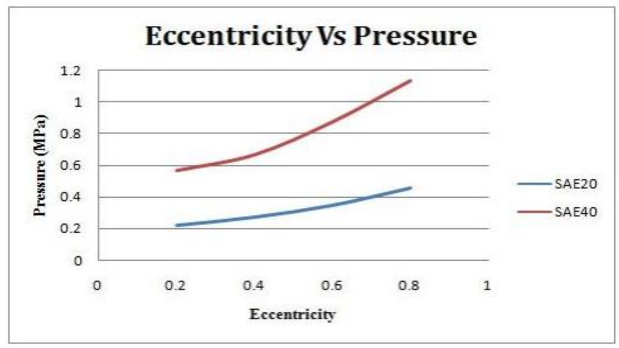
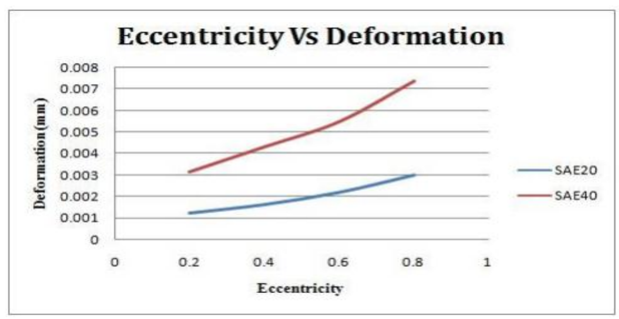


fig-18. Eccentricity Vs Pressure



Graph-6.2. Eccentricity Vs Deformation

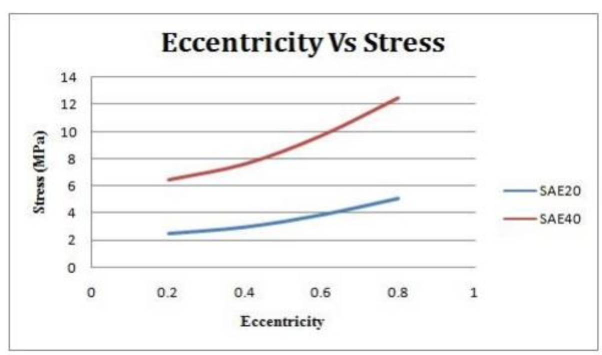


Fig:19 Eccentricity Vs Stress

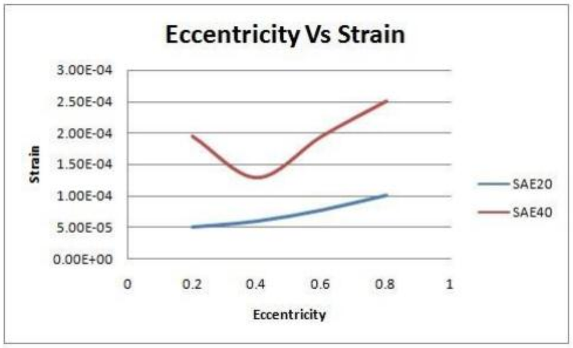


Fig:20.Eccentricity Vs Strain

VII. 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 and stress, strain 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, stress and strain 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.

7.1. 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.

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