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ANALYSIS OF COMPOSITE JOURNAL BEARING

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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 thesis, the finite element analysis will be done to compare gas lubricated cylindrical journal bearing with liquid lubricated journal bearings. Load-carrying capacity and dynamic force coefficients of gas cylindrical journal bearings will be analyzed for some geometric and operating parameters, such as journal eccentricity ratio and rotational speed.

In these thesis journal bearings for L/D ratio and different eccentricity ratios will be modeled in 3D modeling software CREO. The L/D ratio considered is 0.5 and eccentricity ratios considered are 0.2, 0.3 and 0.4 and 0.5. The gas lubricants considered are Air and Steam and they are compared with liquid lubricant SAE oil.

Journal bearing models are developed for speed of 20000 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 by composite material virgin poly-tetra-fluoro-ethylene (PTFE) together with a series of commercially available PTFE-based composites and a Babbitt material in boundary/mixed lubrication conditions.

Computational fluid dynamics (CFD) and fluid structure interaction (FSI) will be done in ANSYS.

1.INTRODUCTION

Bearings are machine elements which are used to support a rotating member They transmit the load from a rotating member to stationary member know as frame or housing .They permit relative motion of two members in one or two directions with minimum friction, and also prevent the motion in the direction of the applied load.

The sliding contact bearings radial bearings find wide applications in industries. The radial bearings are also called journal or sleeve bearings. The portion of the shaft inside the bearing is called the journal and this portion needs better finish and specific property. Depending on the extent to which the bearing envelops the journal, these bearings are classified as full partial and fitted bearings.

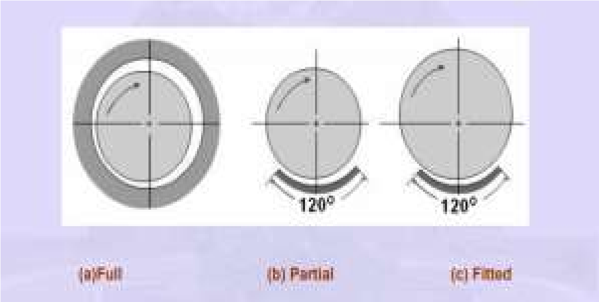


Fig 1.1 Variouse types of journal bearings

1.1 Hydrodynamic lubrication

a bearing is supplied with adequate oil, a pressure is developed in the clearance space when the journal rotates about an axis that is eccentric with the bearing axis. He exhibited that the load can be sustained by this fluid pressure without any contact between the two members

The load carrying ability of a hydrodynamic bearing arises simply because a viscous fluid resists being pushed around. Under proper conditions, this resistance to motion willdevelop a pressure distribution in the film that can support useful load. Two mechanisms responsible for this are wedge film and squeeze film action. The load supporting pressure in hydrodynamic bearings arises from either (1) the flow of a viscous fluid in a converging channel, the wedge film, or (2) the resistance of a viscous fluid to being squeezed out from the between approaching surface, the squeeze film

DESIGN

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

ISSN: 2320-1363

- 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 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.

INTEGRAL

Integral plain bearings are built into the object of use. A hole has been prepared into a bearing surface. Industrial integral bearings are usually made from cast iron or Babbitt and a hardened steel shaft is used in the bearing.

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.

PTFE

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

Table 1.2 Bearing properties of various PTFE alloys

	Temperature range	P(max.) [psi (MPa)]	V(max.) [sfm (m/s)]	PV(max.) [psi sfm(MPa m/s)]
SAE 841	10–220°F(−12104 °C)	2,000 psi (14 MPa)	1,200 (6.1 m/s)	50,000 (1.75 MPa m/s)
SAE 660	10–450°F(−12232 °C)	4,000 psi (28 MPa)	750 (3.8 m/s)	75,000 (2.63 MPa m/s)
SAE 863	10–220°F(−12104 °C)	4,000 psi (28 MPa)	225 (1.14 m/s)	35,000 (1.23 MPa m/s)
CDA 954	<500°F (260 °C)	4,500 psi (31 MPa)	225 (1.14 m/s)	125,000 (4.38 MPa m/s)

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

- Trains
- Airplanes
- Washing machines
- Refrigerators
- Air conditioners
- Vacuum cleaners
- Photocopy machines
- Computers
- Satellites

LUBRICATION

Lubrication is 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 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., PTFE, 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.

ISSN: 2320-1363

Examples of the second type of bearing are Oilites and plastic bearings made from polyacetal; examples of the third type are metalized graphite bearings and PTFE bearings.

Most plain bearings have a plain inner surface, however some are grooved. The grooves help lubrication enter the bearing and cover the whole journal.

LUBRICANT PROPERTIES

Properties of a good lubricant are:

1. It should give rise to low friction.

2. It should adhere to the surface and reduce the wear.

3. It should protect the system from corrosion.

4. It should have good cleaning effect on the surface.

5. It should carry away as much heat from the surface as possible.

6. It should have thermal and oxidative stability.

7. It should have good thermal durability.

8. It should have antifoaming ability.

9. It should be compatible with seal materials.

10.It should be cheap and available in plenty

1.6.2. FLUID LUBRICATION

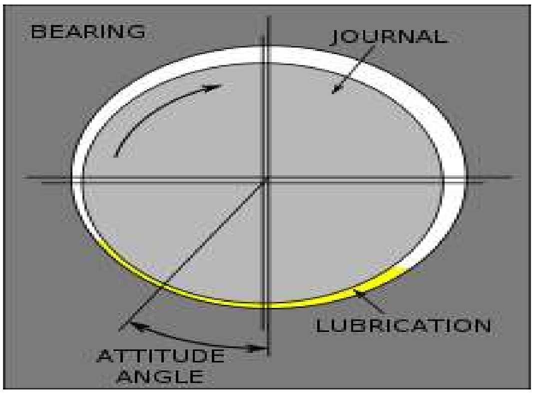


Fig 1.18Hydrodynamic Lubrication

A schematic of a journal bearing under a hydrodynamic lubrication state showing how the journal centerline shifts from the bearing centerline 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.

LUBRICANT FOR JOURNAL BEARING APPLICATION

Recommended Lubricants for the Bearing Application:

1. SAE 10 – spindle oil for light loaded bearings and high speeds.

2. SAE 20 – 40 – Machine oil for bearings of IC engines, machine tools, turbines etc.

3. SAE40-50 – Machine oil for diesel engines heavy load and medium speeds.

4. SAE 60-70 – machine oil for high temperature, heavy load and low speeds

1.6.4 Advantages:

1. Very low friction (hydrodynamic means that there is a full film of oil between the bearing and race components)
2. Lower wear and longer life than standard bearings (no metal-metal contact within the wearing portions of the bearing)
3. Should run cooler since there is less friction and mainly viscous loss to the oil

1.6.5 Disadvantages:

1. Hydrodynamic bearings require forced lubrication to maintain the full film
2. The correct viscosity of oil is required to avoid contact between metal pieces (temperature and load play into that)
3. More costly than standard bearings

2.LITERATURE REVIEW

[1]Mahender Janagamid,Prasuna LillyFlorence, 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.

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

IJMTARC – VOLUME – V – ISSUE – 23, JULY-SEP, 2018

ISSN: 2320-1363

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.

MODELLING

3.1INTRODUCTION TO CAD

Computer-aided design (CAD) is the use of computer systems (or workstations) to aid in the creation, modification, analysis, or optimization of a design. CAD software is used to increase the productivity of the designer, improve the quality of design, improve communications through documentation, and to create a database for manufacturing. CAD output is often in the form of electronic files for print, machining, or other manufacturing operations. The term CADD (for Computer Aided Design and Drafting) is also used.

INTRODUCTION TO CREO

PTC CREO, formerly known as Pro/ENGINEER, is 3D modeling software used in mechanical engineering, design, manufacturing, and in CAD drafting service firms. It was one of the first 3D CAD modeling applications that used a rule-based parametric system. Using parameters, dimensions and features to capture the behavior of the product, it can optimize the development product as well as the design itself.

4JOURNAL BEARING MODEL CALCULATIONS

L=length of journal, mm

D=diameter of journal, mm

Length of Journal

Table 3.1 Length of Journal

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

Eccentricity calculations

Ɛ=eccentricity ratio,

C=radial clearance, mm

C=0.145mm according journals

e =eccentricity mm

Ɛ=e/c

Eccentricity calculations at different eccentricity ratio:

Table 3.2 Eccentricity calculations at different eccentricity ratio

Cases	C	Ɛ	e =Ɛ×c
1	0.145	0.2	0.029
2	0.145	0.3	0.0435
3	0.145	0.4	0.058
4	0.145	0.5	0.0725

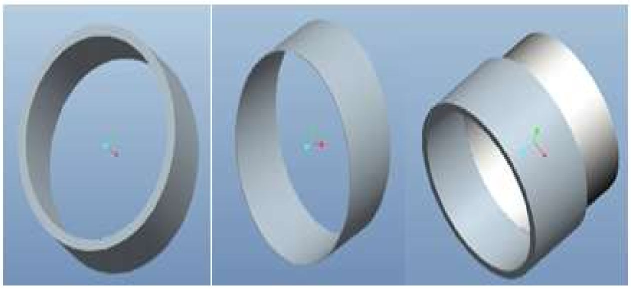
ANALYSIS

4.1MODELS AND 2D DRAWINGS OF JOURNAL BEARING IN PRO-ENGINEER

Table 4.1 L/D ratio- Eccentricity ratio

L/D ratio	Eccentricity ratio			
0.5	0.2	0.3	0.4	0.5

3D MODELS OFCYLINDRICAL JOURNAL BEARING



Solid Fluid Assembly

Fig4.1 3D models of cylindrical journalbearing

ISSN: 2320-1363

2D MODELSOF CYLINDRICAL JOURNAL BEARING

Case 1.1: when L/D=0.5;Ɛ=0.2

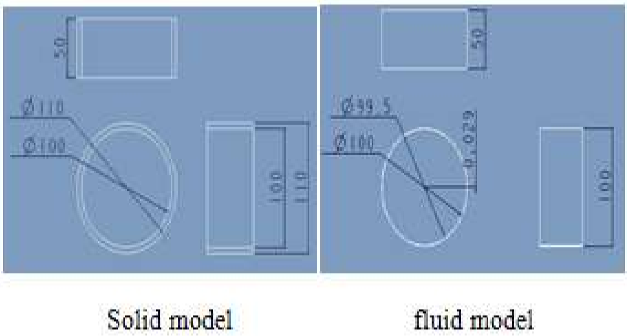


Fig 4.2 Case- 1.1 2D models of cylindrical journal bearing

INTRODUCTION TO FEA

Finite element analysis is a method of solving, usually approximately, certain problems in engineering and science. It is used mainly for problems for which no exact solution, expressible in some mathematical form, is available. As such, it is a numerical rather than an analytical method. Methods of this type are needed because analytical methods cannot cope with the real, complicated problems that are met with in engineering. For example, engineering strength of materials or the mathematical theory of elasticity can be used to calculate analytically the stresses and strains in a bent beam, but neither will be very successful in finding out what is happening in part of a car suspension system during cornering.

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.

4.4.1.METHODOLOGY

In all of these approaches the same basic procedure is followed.

- During preprocessing
  - 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 equations of motion + enthalpy + radiation + species conservation

STATIC ANALYSIS OF CYLINDRICAL JOURNAL BEARING

- FSI (FLUD STRUCTURE INTERFACE)

L/D RATIO=0.5

ECCENTRICITY RATIO (Ɛ) =0.2, 0.3, 0.4 &0.5

SPEED OF JOURNAL BEARING= 20,000rpm

FLUID - SAE 40W OIL and AIR

BEARING MATERIAL –BABBIT &PTFE

CYLINDRICAL JOURNAL BEARING

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.

4.5 Case 1.1:when L/D=0.5; Ɛ=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 →

4.5.1.IMPORTEDMODELFROMGEOMETRY

IJMTARC – VOLUME – V – ISSUE – 23, JULY-SEP, 2018

ISSN: 2320-1363

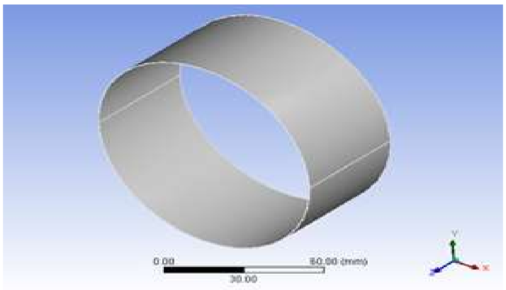


Fig 4.6 Geometrymodel

Analysis of cylindrical journal bearing Meshed model

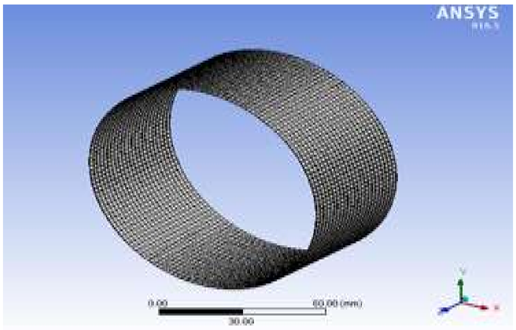
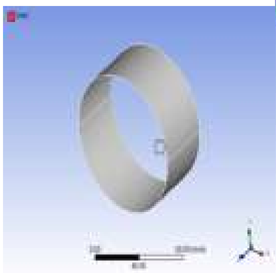


Fig 4.7Meshed Model

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 0.2. 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. Then all thickness edges are meshed with 360 intervals. A tetrahedral structure mesh is used. So the total number of nodes and elements is 6576 and 3344. Select faces → right click → create named section → enter name → air inlet



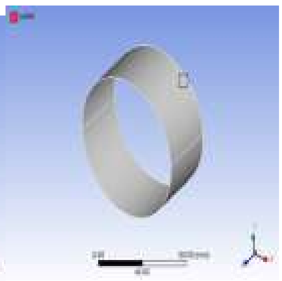


Fig 4.8 Cylindrical journal bearing with air inlet

Fig 4.9 Cylindrical journal bearing with air outlet

Contours of static pressure by using SAE 40 oil:

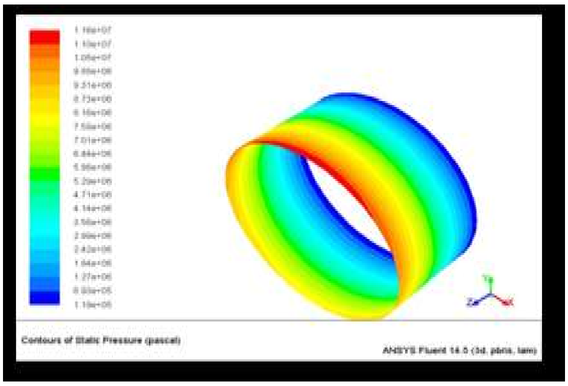


Fig 4.12 Contours of static pressure

According to pressure counters the maximum pressure is 5.739e+005Pa at middle portion of the journal bearing and minimum pressure 5.006e+003Pa at ends of the journal bearing with eccentricity 0.2.

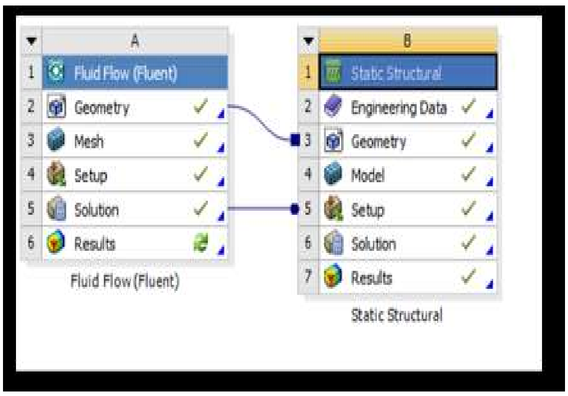
The plain journal bearing has only one high point pressure along the circumference of the journal bearing. This is due to geometry of bearing and how the fluid gap expands and contracts once around the circumference of the journal shaft. A typical pressure distribution along the circumference of the 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 used material Babbitt

Density=0.000007272kg/mm^3

Young’s modulus=50000MPa

Poisson’s ratio=0.35



IJMTARC – VOLUME – V – ISSUE – 23, JULY-SEP, 2018

ISSN: 2320-1363

Fig 4.13 Static structural

Now right click on the model in static structural>geometry

4.5.4 GEOMETRY MODEL:

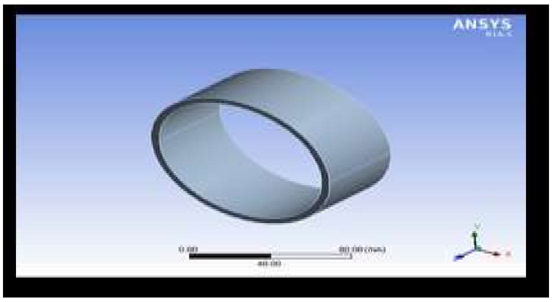


Fig 4.14Geometrymodel

4.5.5 MESHED MODEL:

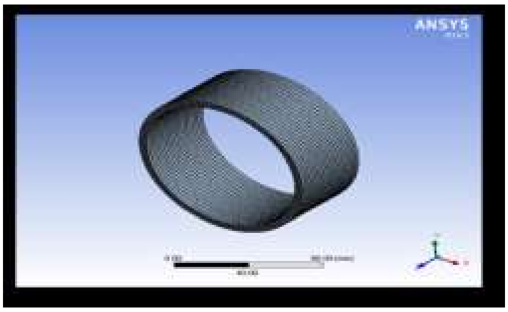


Fig 4.15Meshed model

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 CFDFSI 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. So the total number of nodes and elements is 8975 and 5583.
Right click on the static structural>insert>select displacement>select fixing area in the model apply

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

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

Right click on static structural>solve

Right click on solution>insert>deformation>total deformation

MATERIAL – Babbitt

4.5.6 TOTAL DEFORMATION:

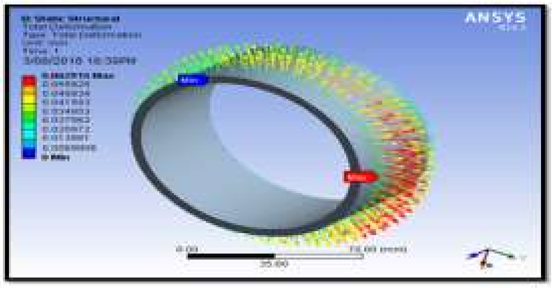


Fig4.16Static analysis of cylindrical journal bearing with deformation

we get to know this technique gives the deformation of the bearing due to action of hydrodynamic forces developed which is important for accurate performance of the bearings operation under severe conditions It is observed that there is substantial amount of deformation of the bearing. When the loads applied i.e. velocity and pressure are imported and applied on journal bearing of Babbitt material, the maximum deformation value is 0.062915mm.
Right click on solution>insert>stress>equivalent stress

4.5.7 EQUIVALENT STRESS:

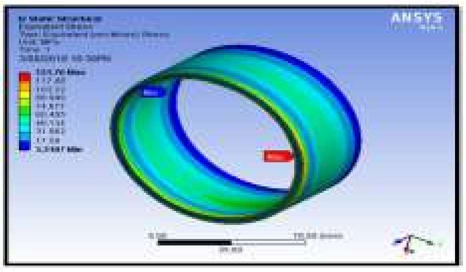


Fig4.17 static analysis of cylindrical journal bearing with stress

When the loads i.e. pressure and velocity applied on journal bearing of Babbitt material, the maximum stress value is 131.76MPa at middle portion of the journal bearing and minimum stress is 3.3187MPa.

MATERIAL – PTFE

4.5.8 DEFORMATION:

IJMTARC – VOLUME – V – ISSUE – 23, JULY-SEP, 2018

ISSN: 2320-1363

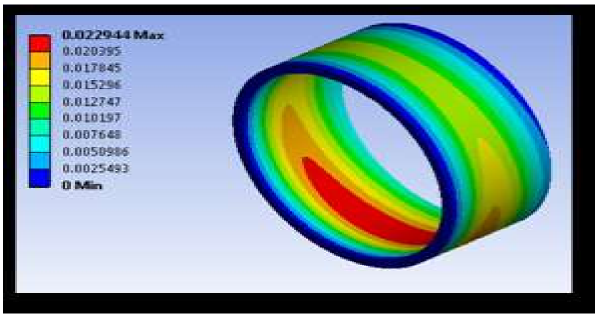


Fig4.18 static analysis of cylindrical journal bearing with deformation

4.5.9 STRESS:

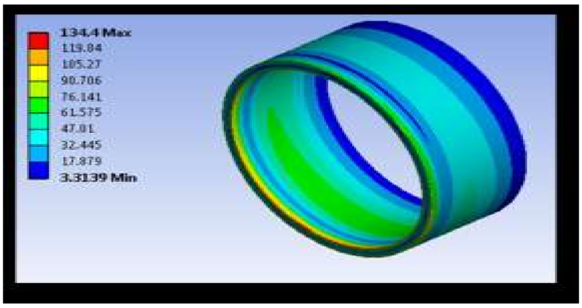


Fig4.19 static analysis of cylindrical journal bearing with stress

CYLINDRICAL JOURNAL BEARING

RESULT TABLE

Variationof maximum pressure with respect to eccentricity ratio at sae 40 oil

table 5.1	
Eccentricity ratio	PRESSURE
0.2	1.16E+07
0.3	1.29E+07
0.4	1.44E+07
0.5	1.63E+07

Variation of maximum pressure with respect to eccentricity ratio at air

table 5.2	
Eccentricity ratio	PRESSURE
0.2	1.45E+04
0.3	1.61E+04
0.4	1.81E+04
0.5	2.04E+04

Variation of maximum displacement with respect to eccentricity ratio at sae 40 oil

table 5.2	
Eccentricity ratio	PRESSURE
0.2	1.45E+04
0.3	1.61E+04
0.4	1.81E+04
0.5	2.04E+04

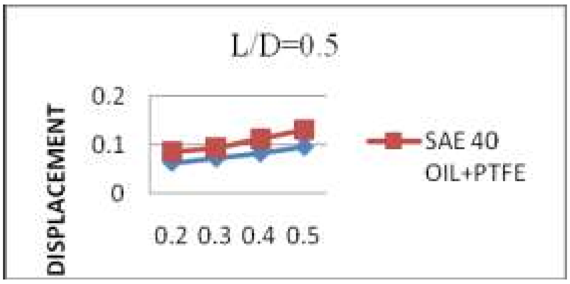


Fig 5.3graphical representation for maximum displacement vs eccentricity ratio at sae 40 oil

Variation of maximum displacement with respect to eccentricity ratio at sae 40 oil

table 5.3		
Eccentricity ratio	SAE 40 OIL+BABBITTE	SAE 40OIL+PTFE
0.2	0.062915	0.022944
0.3	0.071855	0.022948
0.4	0.082413	0.030093
0.5	0.095379	0.034834

Variation of maximum displacement with respect to eccentricity ratio at air

table 5.6		
Eccentricity ratio	AIR+BABBITTE	AIR+PTFE
0.2	0.16493	0.16819
0.3	0.18203	0.18501
0.4	0.20449	0.20919
0.5	0.2329	0.24028

Variation of maximum stress with respect to eccentricity ratio at sae 40 oil

table 5.5		
Eccentricity ratio	SAE 40 OIL+BABBITTE	SAE 40 OIL+PTFE
0.2	131.76	134.4
0.3	145.48	132.77
0.4	163.28	167.18
0.5	186.01	192.01

Variation of maximum stress with respect to eccentricity ratio at sae air

table 5.4		
Eccentricity ratio	AIR+BABBITTE	AIR+PTFE
0.2	7.88E-05	2.87E-05
0.3	8.99E-05	3.28E-05
0.4	0.0001032	3.76E-05
0.5	0.00011938	4.36E-05

Graphs:

IJMTARC – VOLUME – V – ISSUE – 23, JULY-SEP, 2018

ISSN: 2320-1363

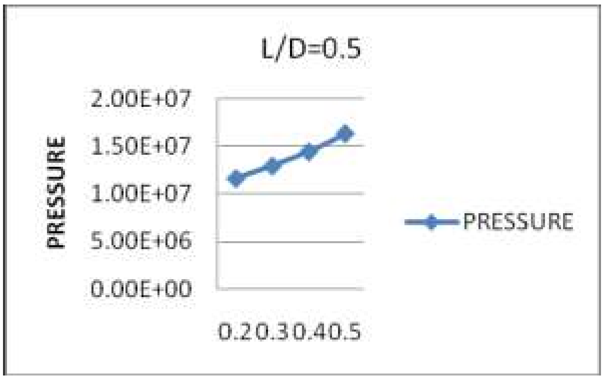


Fig 5.1graphical representation for maximum pressure vs eccentricity ratio at sae 40oil

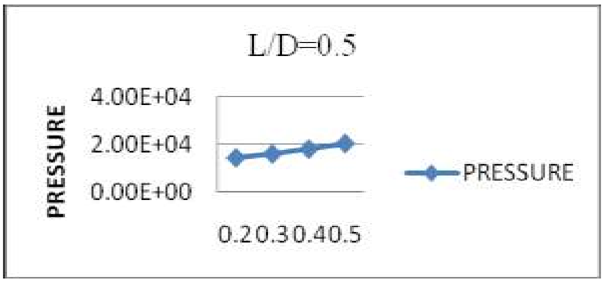


Fig 5.2graphical representation for maximum pressure vs eccentricity ratio at air

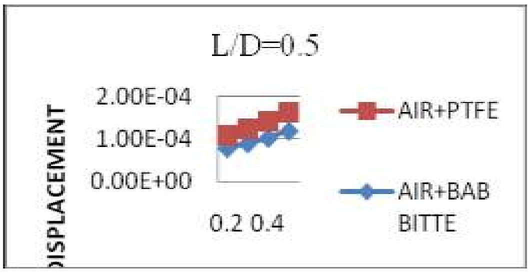


Fig 5.4graphical representation for maximum displacement vs eccentricity ratio at air

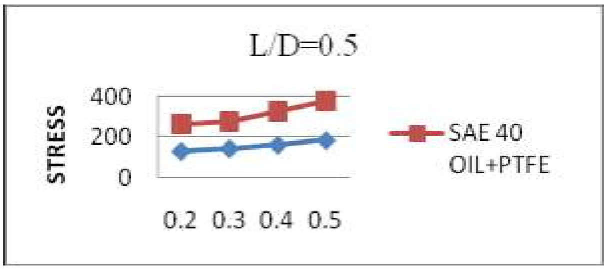


Fig 5.5graphical representation for maximum stress vs eccentricity ratio at sae oil

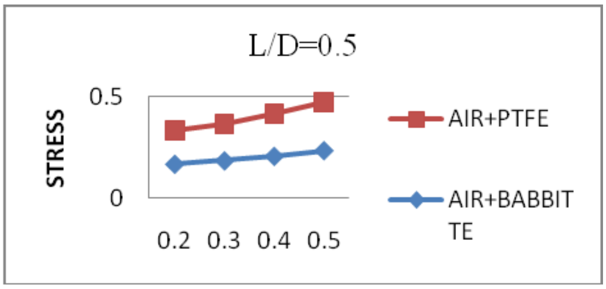


Fig 5.6graphical representation for maximum stress vs eccentricity ratio at air

6. CONCLUSION& FUTURE SCOPE

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 and eccentricity ratios considered are 0.2, 0.3, 0.4 and 0.5. By observing the CFD analysis results, the pressure is increasing by 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. The cylindrical journal bearing due to action of hydrodynamic forces the deformation and stress values are less for cylindrical journal bearing. The cylindrical journal bearing with different fluids deformation and stress values are very less for air lubricant. And stresses are more for PTFE material. Materials with low Young's modulus leads to low rigidity and high strength materials produces good impact behavior because the yield stress is always higher than the maximum stress occurred in the journal bearing. So we conclude that the air lubricant is a better fluid and PTFE is a better material for journal bearing. So that the journal bearing manufacturing with PTFE material.

FUTURE SCOPE: There is scope for further study of vibration monitoring of journal bearings for the smooth operation of critical machinery and equipment. Several parameters have been identified, whose effectiveness, both technically and economically has to be proved

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with further investigations. The advanced approach of the current research work can be extended for future work by considering the following:

- This research has discussed new techniques for detecting failure in the journal bearings. Further, there is possibility of undertaking various tests with different materials of shafts and bearing.

- Further, the tests can focus on shaft diagnosis with different shaft specimens, with faults at different locations and depths, to find the significance of vibration signals from journal bearings.

- To measure the natural frequencies of different components in the journal bearing test rig such as AC electronic motor, ball bearing, belts, coupling and gear box.

- To evaluate metal to metal contact, during fault simulation, an oil wear debris analysis needs to be carried out on the oil taken out of the journal bearing at different time intervals.

- Further an investigation can be under taken to determine the vibration properties of the lubrication grease in the grease film formed and the damping properties of the grease on the vibration of journal and the bearing.

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