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Fluid Structure Interaction of Gas Lubricated Cylindrical and Elliptical 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 is done to compare gas lubricated cylindrical and elliptical 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 are modeled in 3D modeling software Pro/Engineer. The L/D ratios considered is 0.8 and eccentricity ratiosconsidered are 0.2, 0.4, 0.6 and 0.8. The gas lubricants considered are Air and they are compared with liquid lubricant SAE30&40 oil.Journal bearing models are developed for speed of 5000 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.

INTRODUCTION TO BEARINGS:
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 (in railroading sometimes called a solid bearing) is the simplest type of bearing, comprising just a surface and no rolling elements. Therefore the journal (i.e., the part of the shaft in contact with the bearing) slides over the bearing surface. The simplest example of a plain bearing is a shaft rotating in a hole. A simple linear bearing can be a pair of flat surfaces designed to allow motion; e.g., a drawer and the slides it rests on or the ways on the bed of a lathe. Plain bearings, in general, are the least expensive type of bearing. They are also compact and lightweight, and they have a high load-carrying capacity.

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

- Journal (friction, radial or rotary) bearing: This is the most common type of plain bearing; it is simply a shaft rotating in a bearing. In locomotive and railroad car applications a journal bearing specifically referred to the plain bearing once used at the ends of 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. It is a hole that has been prepared into a bearing surface. Industrial integral bearings are usually made from cast iron orbabbitt and a hardened steel shaft is used in the bearing. Integral bearings are not as common because bushings are easy to accommodate and can be replaced if necessary. Depending on the material, an integral bearing may be less expensive but it cannot be replaced. If an integral bearing wears out then the item may be replaced or reworked to accept a bushing. Integral bearings were very common in 19th-century machinery, but became progressively less common as interchangeable manufacture permeated the industry. An example of a common integral plain bearing is the hinge, which is both a thrust bearing and a journal bearing.

Bushing:

A bushing, also known as a bush, is an independent plain bearing that is inserted into a housing to provide a bearing surface for rotary applications; this is the most common form of a plain bearing. Common designs include solid (sleeve and flanged), split, and clenched bushings. A sleeve, split, or clenched bushing is only a "sleeve" of material with an inner diameter (ID), outer diameter (OD), and length. The difference between the three types is that a solid sleeved bushing is solid all the way around, a split bushing has a cut along its length, and a clenched bearing is similar to a split bushing but with a clench (or clinch) across the cut. A flanged bushing is a sleeve bushing with a flange at one end extending radially outward from the OD. The flange is used to positively locate the bushing when it is installed or to provide a thrust bearing surface.[9] Sleeve bearings of inch dimensions are almost exclusively dimensioned using the SAE numbering system.

The numbering system uses the format -XXYY-ZZ, where XX is the ID in sixteenths of an inch, YY is the OD in sixteenths of an inch, and ZZ is the length in eights of an inch. Metric sizes also exist. A linear bushing is not usually pressed into a housing, but rather secured with a radial feature. Two such examples include two retaining rings, or a ring that is molded onto the OD of the bushing that matches with a groove in the housing. This is usually a more durable way to retain the bushing, because the forces acting on the bushing could press it out. The thrust form of a bushing is conventionally called a thrust washer.

Two-piece:

Two-piece plain bearings, known as full bearings in industrial machinery, are commonly used for larger diameters, such as crankshaft bearings. The two halves are calledshells. There are various systems used to keep the shells located. The most common method is a tab on the parting line edge that correlates with a notch in the housing to prevent axial movement after installation. For large, thick shells a button stop or dowel pin is used. The button stop is screwed to the housing, while the dowel pin keys the two shells together. Another less common method uses a dowel pin that keys the shell to the housing through a hole or slot in the shell.

The distance from one parting edge to the other is slightly larger than the corresponding distance in the housing so that a light amount of pressure is required to install the bearing. This keeps the bearing in place as the two halves of the housing are installed. Finally, the shell's circumference is also slightly larger than the housing circumference so that when the two halves are bolted together the bearing crushes slightly. This creates a large amount of radial force around the entire bearing which keeps it from spinning. It also forms a good interface for heat to travel out of the bearings into the housing.

Bronze:

A common plain bearing design utilizes a hardened and polished steel shaft and a softer bronze bushing.

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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.

Cast iron:

A cast iron bearing can be used with a hardened steel shaft because the coefficient of friction is relatively low. The cast iron glazes over therefore wear becomes negligible.[6]

Graphite:

In harsh environments, such as ovens and dryers, a copper and graphite alloy, commonly known by the trademarked name graphalloy, is used. The graphite is a dry lubricant, therefore it is low friction and low maintenance. The copper adds strength, durability, and provides heat dissipation characteristics. **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 ashydroplaning on a road. The science of friction, lubrication and wear is called tribology.

Bearing properties of various bi-material bearings

	Temperature range	(Max.) P [psi (MPa)]	(Max.) V [sfm (m/s)]	(Max. PV) [psi sfm (MPa m/s)]
Steel-backed PTFE-coated bronze	−328 –536 °F −200 –280 °C	36,000 psi or 248 MPa	390 (2.0 m/s)	51,(1.00079 MPa m/s)
Aluminum-backed frelon	−400 –400 °F −240 –204 °C	3,000 psi or 21 MPa	300 (1.52 m/s)	20,(0.00070 MPa m/s)

ANALYSIS OF CYLINDRICAL JOURNAL BEARING - FSI
(FLUD STRUCTURE INTERFACE)
L/D RATIO=0.8
ECCENTRICITY RATIO (Ɛ) =0.2, 0.4, 0.6&0.8
FLUID – AIR, SAE 30, SAE40 OIL
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.

ECCENTRICITY=0.2
FLUID-AIR

→→Ansys → workbench→ select analysis system → fluid flow fluent → double click

→→Select geometry → right click → import geometry → select browse →open part → ok

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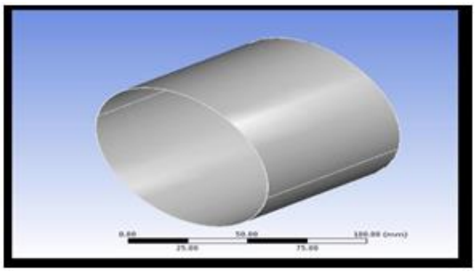
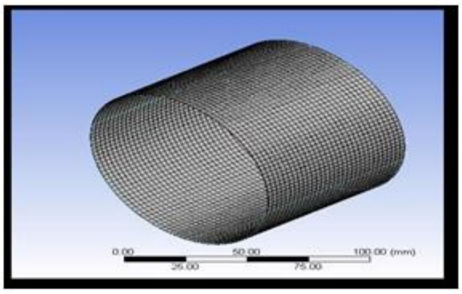
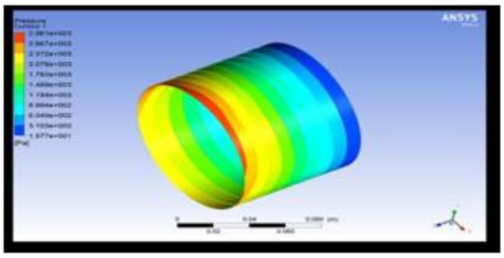


→→ Select mesh on work bench → right click →edit → select mesh on left side part tree → right click → generate mesh →



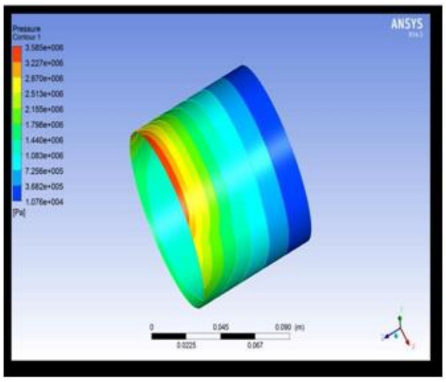
Pressure contour:



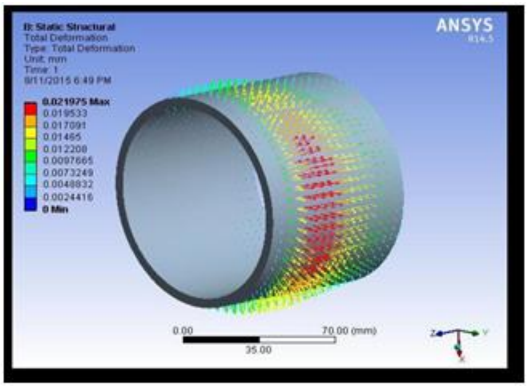
Select static structural>now share the geometry of fluid flow (fluent) to geometry of static structural>and transfer the solution of fluid flow (fluent) to setup of static structural

FLUID - SAE 40 OIL

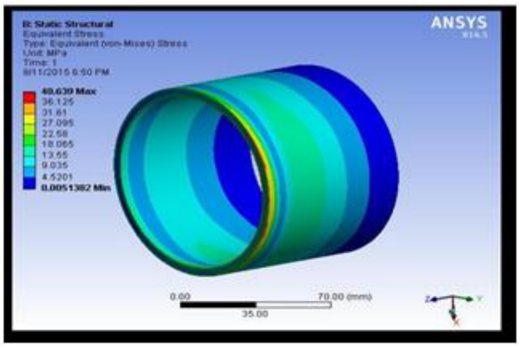
Pressure contour



Total deformation



Equivalent stress



Shear stress

ANALYSIS OF ELLIPTICAL JOURNAL BEARING - FSI (FLUD STRUCTURE INTERFACE)

L/D RATIO=0.8

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.

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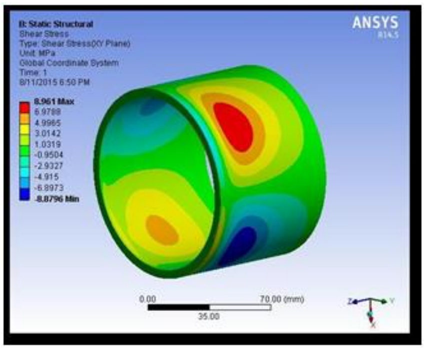
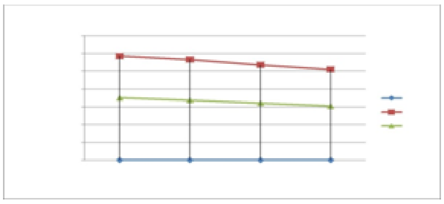


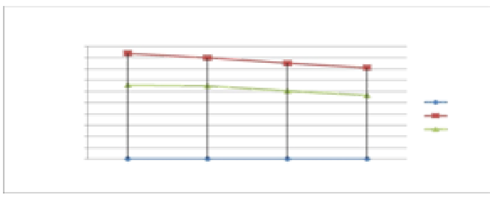
ELLIPTICAL JOURNAL BEARING ECCENTRICITY RATIO 0.2

RESULTS	FLUIDS		
	AIR	SAE 30 oil	SAE 40 oil
PRESSURE(MPa)	2.986e+002	4.693e+005	2.371e+005
DISPLACEMENT(mm)	1.1397e-6	0.00094411	0.00083257
STRESS(MPa)	0.0022423	2.9287	1.754
SHEAR STRESS(MPa)	0.00017581	0.18767	0.13129

As eccentricity increases shear stress decreases.



As eccentricity increases displacment and stress decreases.



CONCLUSION:

In this thesis, Hydrodynamic journal bearings are analyzed by using Computational fluid dynamics (CFD) and fluid structure interaction (FSI) approach on cylindrical and elliptical journal bearing for 0.8 L/D ratio and 0.2, 0.4, 0.6 and 0.8 eccentricity ratios using Ansys in order to evaluate the fluid pressures, Stress distribution and deformation in journal bearing. Journal bearings for different eccentricity ratios are modeled in 3D modeling software Pro/Engineer.By observing the CFD analysis results, the pressure is increasing by increasing the L/D ratios and eccentricity ratio thereby increasing the displacements and stress values for both cylindrical and elliptical journal bearing.By comparing the results between cylindrical and elliptical journal bearing, the pressure thereby stress and deformation values are less for cylindrical journal bearing than elliptical bearing.

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