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Design and Analysis of Thermo Hydro Dynamic Plain Journal Bearing by Using FSI Tool

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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 thermo 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 thermo hydrodynamic journal bearings. Thermo 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 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.

Keywords: **Journal Bearing; CFD; ANSYS;**

I. INTRODUCTION

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.Bearings enhance the functionality of machinery and help to saveenergy. 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 axles.

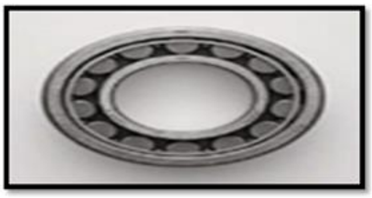


Fig.1 Roller Bearing

II. LITERATURE REVIEW

In the paper by PriyankaTiwari [1], Thermo hydrodynamic journal bearings are analyzed by using Computational fluid dynamics (CFD) and fluid structure interaction (FSI) approach in order to find Pressure profile and temperature distribution in the bearing structure, satisfying the boundary conditions. The Journal bearing is designed in ANSYS software, the journal is modeled as a „„moving wall““ With an absolute rotational speed of 3000rpm and bearing is modeled as a “stationary wall”. Design parameters like pressure distribution and temperature distribution are considered for the analysis. It is assumed that the flow of lubricant is laminar and steady. Also cavitations effects in the bearing are neglected by setting all negative pressures to ambient pressures. Design data like journal diameter, clearance, L/D ratio, minimum film thickness, journal speed and oil viscosity are taking by machine design data book for making analytical calculation. The CFD results were compared in order to validate the model with the analytical results and good agreements were found.

INTRODUCTION TO CAD

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.

INTRODUCTION TO PRO/ENGINEER

Pro/ENGINEER, PTC's parametric,integrated3D CAD/CAM/CAE solution, is used by discrete manufacturers for mechanical engineering, design and manufacturing. This powerful and rich design approach is used by companies whose product strategy is family-based or platform-driven, where a prescriptive design strategy is critical to the success of the design process by embedding engineering constraints and relationships to quickly optimize the design, or where the resulting geometry may be complex or based upon equations. Pro/ENGINEER provides a complete set of design, analysis and manufacturing capabilities on one, integral, scalable platform.

INTRODUCTION TO FEA

FEA consists of a computer model of a material or design that is stressed and analyzed for specific results. It is used in new product design, and existing product refinement. A company is able to verify a proposed design will be able to perform to the client's specifications prior to manufacturing or construction. Modifying an existing product or structure is utilized to qualify the product or structure for a new service condition.In case of structural failure, FEA may be used to help determine the design modifications to meet the new condition.

INTRODUCTION TO ANSYS

ANSYS is general-purpose finite element analysis (FEA) software package. Finite Element Analysis is a numerical method of deconstructing a complex system into very small pieces (of user-designated size) called elements. The software implements equations that govern the behaviour of these elements and solves them all; creating a comprehensive explanation of how the system acts as a whole. These results then can be presented in tabulated, or graphical forms. This type of analysis is typically used for the design and optimization of a system far too complex to analyze by hand. Systems that may fit into this category are too complex due to their geometry, scale, or governing equations. ANSYS provides a cost-effective way to explore the performance of products or processes in a virtual environment. This type of product development is termed virtual prototyping.

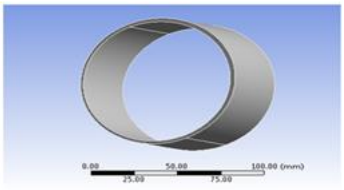
INTRODUCTION TO CFD

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.

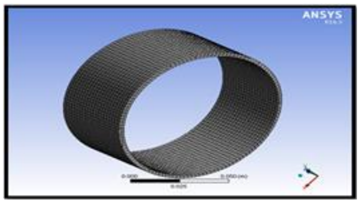
III. RESULTS & DISCUSSIONS

ANALYSIS OF JOURNAL BEARING -FSI (FLUD SOLID INTERFACE)

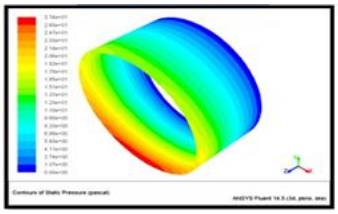
L/D RATIO=0.5
ECCENTRICITY (e) =0.8
FLUID-HELIUM
BEARING MATERIAL - BABBIT
GEOMETRY MODEL



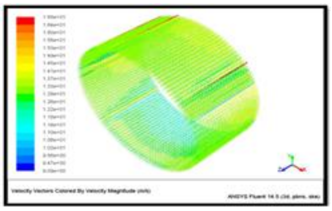
MESHED MODEL



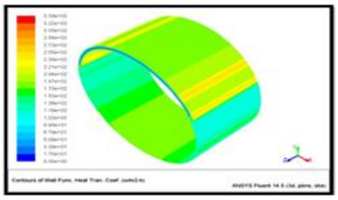
BOUNDARY CONDITIONS
SPEED AT 2500 rpm
PRESSURE CONTOURS



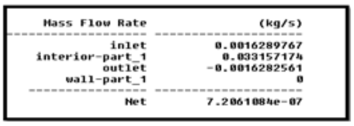
VELOCITY MAGNITUDE



HEAT TRANSFER COEFFICIENT

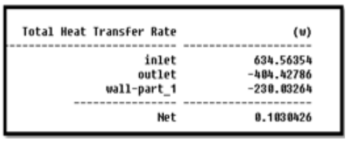


MASS FLOW RATE



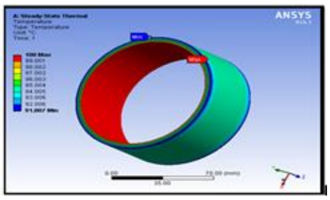
```
        Mass Flow Rate                 (kg/s)
-------------------- --------------------
                 inlet           0.0016289767
      interior-part_1            0.033157174
                outlet          -0.0016282561
           wall-part_1                      0
     ---------------- --------------------
                   Net          7.2061084e-07
```

HEAT TRANSFER RATE

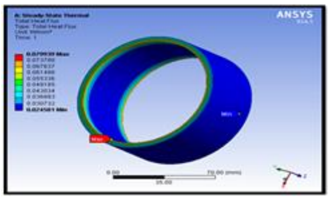


```
   Total Heat Transfer Rate                   (w)
-------------------------- --------------------
                      inlet             634.56354
                     outlet            -404.42786
                wall-part_1            -230.03264
           ---------------- --------------------
                        Net             0.1030426
```

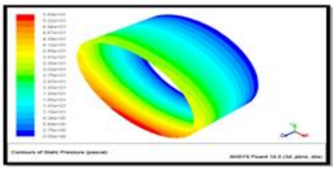
TEMPERATURE



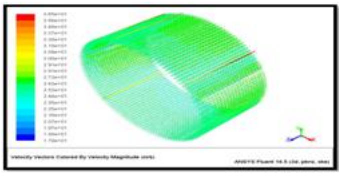
HEAT FLUX



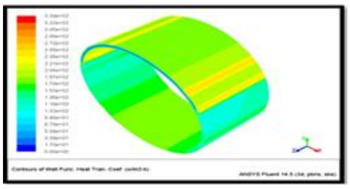
SPEED AT 5000 rpm
FLUID-HELIUM
PRESSURE CONTOURS



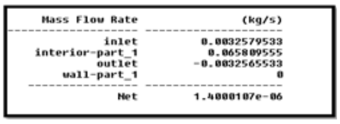
VELOCITY MAGNITUDE



HEAT TRANSFER COEFFICIENT

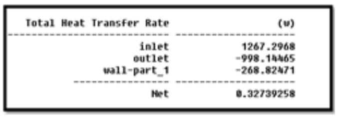


MASS FLOW RATE



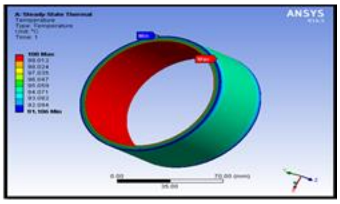
```
        Mass Flow Rate                 (kg/s)
-------------------- --------------------
                 inlet           0.0032579533
      interior-part_1            0.065809555
                outlet          -0.0032565533
           wall-part_1                      0
     ---------------- --------------------
                   Net          1.4000107e-06
```

HEAT TRANSFER RATE

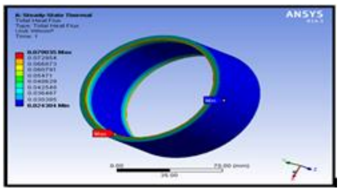


```
   Total Heat Transfer Rate                   (w)
-------------------------- --------------------
                      inlet             1267.2968
                     outlet            -998.14465
                wall-part_1            -268.82471
           ---------------- --------------------
                        Net            0.32739258
```

TEMPERATURE

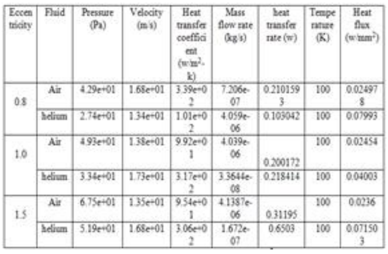


HEAT FLUX



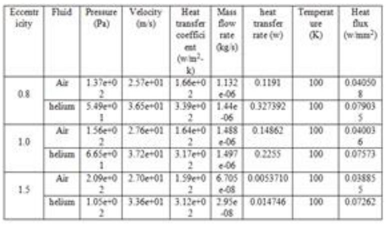
RESULTS TABLES

SPEED- 2500RPM



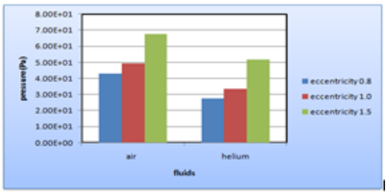
Eccentricity	Fluid	Pressure (Pa)	Velocity (m/s)	Heat transfer coefficient (w/m^2-k)	Mass flow rate (kg/s)	heat transfer rate (w)	Temperature (K)	Heat flux (w/mm^2)
0.8	Air	4.29e+01	1.68e+01	3.39e+02	7.206e-07	0.2101593	100	0.024978
	helium	2.74e+01	1.34e+01	1.01e+02	4.059e-06	0.103042	100	0.07993
1.0	Air	4.93e+01	1.38e+01	9.92e+01	4.039e-06	0.200172	100	0.02454
	helium	3.34e+01	1.73e+01	3.17e+02	3.3644e-08	0.218414	100	0.04003
1.5	Air	6.75e+01	1.35e+01	9.54e+01	4.1387e-06	0.31195	100	0.0236
	helium	5.19e+01	1.68e+01	3.06e+02	1.672e-07	0.6503	100	0.071503

SPEED- 5000RPM

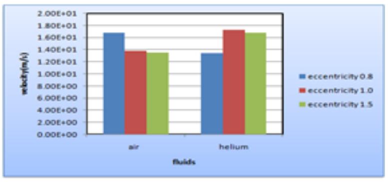


Eccentricity	Fluid	Pressure (Pa)	Velocity (m/s)	Heat transfer coefficient (w/m^2-k)	Mass flow rate (kg/s)	heat transfer rate (w)	Temperature (K)	Heat flux (w/mm^2)
0.8	Air	1.37e+02	2.57e+01	1.66e+02	1.132 e-06	0.1191	100	0.040508
	helium	5.49e+01	3.65e+01	3.39e+02	1.44e -06	0.327392	100	0.079035
1.0	Air	1.56e+02	2.76e+01	1.64e+02	1.488 e-06	0.14862	100	0.040036
	helium	6.65e+01	3.72e+01	3.17e+02	1.497 e-06	0.2255	100	0.07573
1.5	Air	2.09e+02	2.70e+01	1.59e+02	6.705 e-08	0.0053710	100	0.038855
	helium	1.05e+02	3.36e+01	3.12e+02	2.95e -08	0.014746	100	0.07262

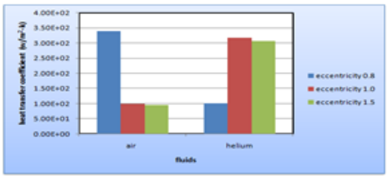
AT 2500 RPM
PRESSURE PLOT



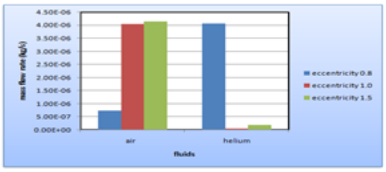
VELOCITY PLOT



HEAT TRANSFER COEFFICIENT PLOT



MASS FLOW RATE PLOT



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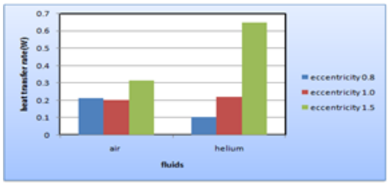

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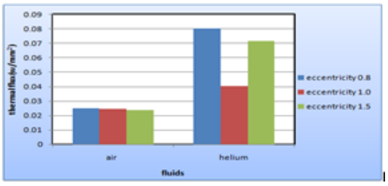
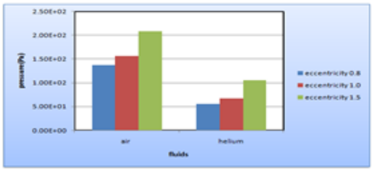
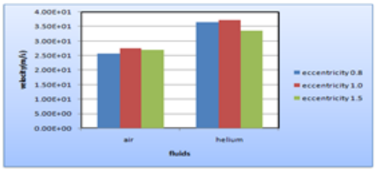


SPEED AT 5000rpm

PRESSURE PLOT



VELOCITYPLOT



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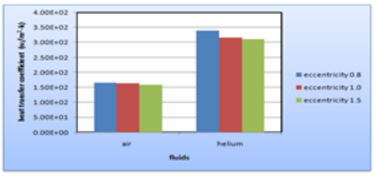
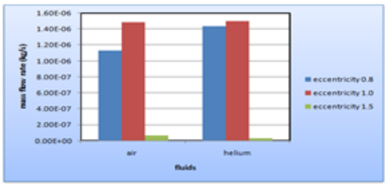


MASS FLOW RATE PLOT



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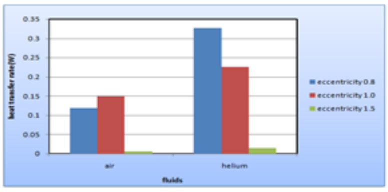

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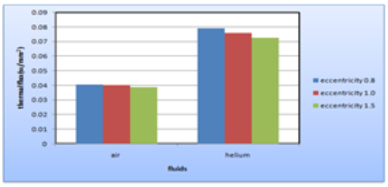

IV. CONCLUSION

In this thesis, Thermo hydrodynamic journal bearings are analyzed by using Computational fluid dynamics (CFD) and fluid solid interaction (FSI) approach on different models by varying L/D ratios and eccentricity ratios using ANSYS in order to evaluate the fluid pressures, velocity, heat transfer coefficient, mass flow rate, heat transfer rate, temperature distribution and heat flux. Journal bearings for different eccentricities are modeled in 3D modeling software Pro/Engineer. The eccentricities considered are 0.8, 1.0 and 1.5 at different fluids (air and helium).

By observing the CFD analysis results, the pressure is increasing by increasing eccentricities thereby increasing the thermal flux values. Heat transfer rate values are increasing by increasing the speed by the fluid air. Mass flow rate more value at eccentricity 1.0 by the fluid air at 5000rpm. Heat transfer coefficient values are more for eccentricity 0.8 and fluid helium and thermal flux values are more for eccentricity 0.8 and fluid helium.

So we concluded the thermo hydrodynamic journal bearing, the suitable eccentricity is eccentricity 0.8 and increases the efficiency by using helium when compare the air.

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