NUMERICAL AND FLUID SOLID INTERACTION (FSI) ANALYSIS OF FLUID FILM JOURNAL BEARING AT DIFFERENT ECCENTRICITY RATIOS

SHAIK MOHAMMAD NASEER AHMED[1] GADDE ANILKUMAR[2]

[1]M. Tech scholar, Department of mechanical engineering, G V R & S College of Engineering & Technology, Budampadu, Guntur, Andhra Pradesh 522013

[2]Associate professor & HOD, Department of mechanical engineering, G V R & S College of Engineering & Technology, Budampadu, Guntur, Andhra Pradesh 522013

Abstract *Journal bearings have the longest records of medical look at of any elegance of fluid film bearings. In a fluid film bearing, the stress in the oil film satisfies the Reynolds equation which intern is a feature of film thickness. Structural distortion of the housing and the improvement of hydrodynamic pressure in a complete journal bearing are strongly coupled as a consequence require a blended solution.*

Oil film pressure is 1 of the key working parameters describing the operating conditions in hydrodynamic journal bearings. Hydrodynamic journal bearings are analyzed by the use of Computational fluid dynamics (CFD) and fluid structure interplay (FSI) method to be able to locate deformation of the bearing.

In this thesis journal bearings for different L/D ratios and eccentricity ratios are modeled in 3D modeling software program CATIA. The L/D ratios considered are 0.5, 1.0, 1.5 and eccentricity ratios taken into consideration are 0.3, 0.5, 0.7 and 0.9.

Journal bearing models are developed for pace of 2000 rpm to look at the interplay between the fluid and elastic behavior of the bearing. The speed is the input for CFD evaluation and the strain acquired from the CFD analysis is taken as enter for structural evaluation.

Computational fluid dynamics (CFD) and fluid shape interplay (FSI) is accomplished in Ansys.

I. INTRODUCTION

Almost all industry transforms energy from one form to another by involving machinery in some way. Modern industry could not exist without the ubiquitous electric motor, turbine, generator, pump or the whole host of rotating machinery. All these rotating machines involve a shaft supported on some form of bearing. New machine designs for these applications require high operating speeds, flexible rotors and higher power densities as part of the quest for higher performance and lower unit cost. These changes, which make machines more sensitive to small changes in system parameters, as well as the need to reduce time-to-market and prototype costs have created a need for ever more accurate mathematical models for use in the design stage. Important machine elements are the bearings. Not only must the rotor weight and operating loads be supported, but the bearings also have a very strong influence on the dynamic behavior of the rotor. These needs for accurate bearing models have led industry to move from approximate solutions to the governing equations and design charts, to more sophisticated models.

The design of journal bearings is considered to be important to the development of rotating machinery. Journal bearings are essential machine components for compressors, pumps, turbines, internal combustion engines, motor, generators, etc (Keith, 1986, Keith, 1990). In a journal bearing (Keith, 1986, Keith, 1990, Shingley, 1986) a shaft or journal rotates or oscillates within a close fitting cylindrical sleeve and the relative motion is sliding. The journal and bearing surfaces are separated by a film lubricant (liquid or gas) that is supplied to the clearance space between the surfaces. The clearance space permits assembly of the journal and bearings, provides space for the lubricant, accommodates unavoidable thermal expansions and tolerates any shaft misalignment or deflection. The finite element method (FEM) applied to hydrodynamic lubrication has gained popularity since its early uses in the late 1960's by Reddi (Reddi, 1969) and others. The finite element method continues to be attractive because it offers conceptual ease in coupling together hydrodynamic and elastic properties and also flexibility in

2handling complex geometry and complex boundary conditions. For example, simple iterative techniques used in conjunction with finite element methods can give solutions to some problems with complex geometry and boundary conditions. Oh and Huebner (Oh and Huebner, 1973) provide a finite element formulation where journal bearing elastic distortions are computed by an iterative technique for steady state cases. The finite element approach can be used to solve difficult problems (such as in turbulent conditions). Therefore there are many proprietary software packages available to compute these fluid problems. FLUENT is one of the softwares packages available and was used in this project.

Journal Bearings

Journal bearings are used in a variety of engineering applications, so proper study of tribology has a major impact on their performance. A journal bearing consists of a cylindrical body around a rotating shaft, used either for supporting a radial load or simply as a guide for smooth transmission of torque. It involves a stationary sleeve (or bushing) with a complete 360 arc or various arrangements of a partial arc or arcs in a housing structure. The inner surface is commonly lined with a soft bearing material such as lead, tin, white metal and babbitt metal or even plastic. Plain journal bearings are susceptible to a form of instability known as selfexcited oil whirl. Over the years, a series of bearing designs have been developed for suppressing such vibration problems, such as bearings with tilting pad, elliptical, pressure dam, and offset split bearings.

Once the shaft is in steady state, it assumes a position within the bearing bush whose coordinates are eccentricity e and attitude angle φ, as shown in Figure 1. Eccentricity is simply the displacement of the journal center Oj from the bushing center Ob. Attitude angle is the angle between the load line and the line between these centers. Eccentricity decreases and attitude angle commonly increases with more vigorous oil-film pumping action by the journal at higher speeds and with increased lubricant viscosity.

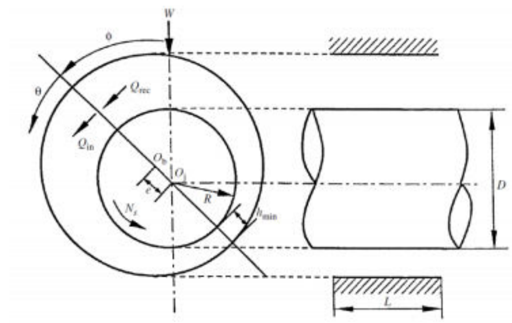


Fig 1: Cross section of a journal bearing and its characteristic geometric parameters

II. LITERATURE REVIEW

Huixia jin et al have carried out numerical simulation of central circumferential groove of hydrodynamic journal bearing with the help of CFD software. From result it is found out that groove depth affect the load zssone, bearing carrying capacity, cavitations zone and vapour fraction.

Samuel Cupillard et al have performed CFD analysis of journal bearing with smooth and textured surface. The focus of this study is to determine the influence surface texture on eccentricity ratio and frictional force. During the analysis considered the flow is laminar and isothermal at unsteady condition. From this study it is found out that for light loading condition increased the minimum film thickness and reduced frictional force and for high loading conditions increasing pressure zone decreases the frictional force.

Amit Solanki et al have optimized the design parameter such as load carrying capacity of hydrodynamic journal bearing using Genetic Algorithm. From results it concluded that the load carrying capacity is proportional to rotational speed of journal, L/D ratio, length and radial clearance of journal.

III. METHODOLOGY

In this thesis journal bearings for distinctive L/D ratios and eccentricity ratios are modeled in 3D modeling software Pro/Engineer. The L/D ratios taken into consideration are 0.5, 1.0, 1.5 and eccentricity ratios considered are 0.3, 0.5, 0.7 and 0.9.

Journal bearing fashions are evolved for speed of 2000 rpm to look at the interplay among the fluid and stress of the bearing. The velocity is the enter for CFD analysis and the pressure acquired from the CFD evaluation is taken as input for structural analysis.

Computational fluid dynamics (CFD) and fluid structure interaction (FSI) is finished in Ansys.

Journal bearing Nomenclature

L-----Length of the journal bearing mm

D-----Diameter of the journal bearing, mm

C-----Radial clearance, mm

Ɛ-----Eccentricity ratio

e-----Eccentricity, mm

Journal bearing model calculations

L/d ratios 0.5, 1.0&1.5

Eccentricity ratio=0.3, 0.5, 0.7&0.9

Length calculations

L=length of journal, mm

D=diameter of journal, mm

L/d=0.5

D=100mm

L=0.5×100

L= 50mm

L/d = 1

D=100mm

L =1X100 = 100

L/d = 1.5

D=100mm

L =1.5X100 = 150mm

Eccentricity calculations

Ɛ=e/c

E=eccentricity mm

C=radial clearance, mm

C=0.145mm according journals

Ɛ=e/c

Ɛ=0.3

0.3=e/0.145

e = 0.3X0.145 = 0.0435mm

Ɛ=0.5

0.5=e/0.145

e = 0.5X0.145 = 0.0725mm

Ɛ=0.7

0.7=e/0.145

e = 0.7X0.145 = 0.1015mm

Ɛ=0.9

0.9=e/0.145

e = 0.9X0.145 = 0.1305mm

Models and 2d drawings of journal bearing in pro-engineer

L/D ratio	Eccentricity ratio			
0.5	0.3	0.5	0.7	0.9
1.0	0.3	0.5	0.7	0.9
1.5	0.3	0.5	0.7	0.9

Models of journal bearing using pro-E wildfire 5.0

The journal bearing is modeled using the given specifications and design formula from data book. The isometric view and exploded view of journal bearing are shown in below figure. The profile is sketched in sketcher and then it is extruded up to 50mm, 100mm and 150mm (face width) using extrudes option.

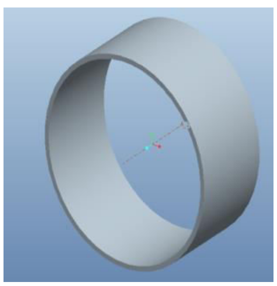


Fig 2: Solid model

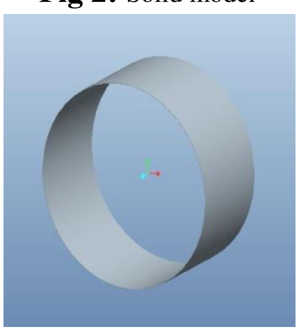


Fig 3: Fluid model

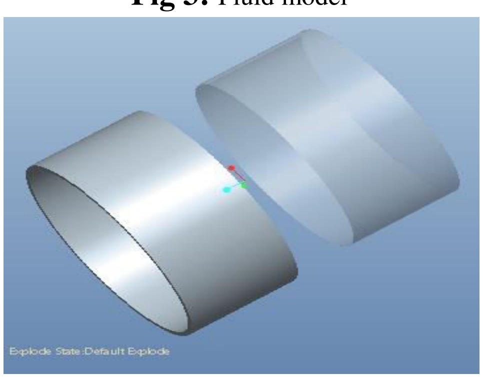


Fig 4: Assembly model

IV RESULTS AND ANALYSIS

4.1 L/D =0.5 & ECCENTRICITY=0.3

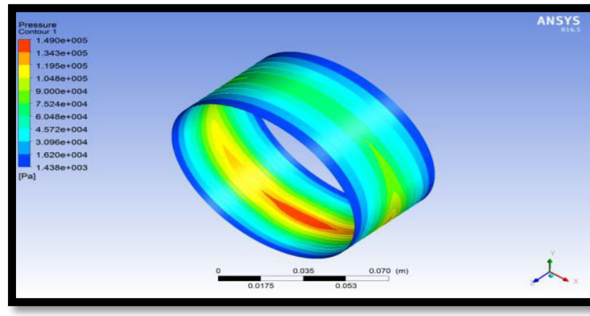


Fig 5: Pressure contour for L/D =0.5 and eccentricity =0.3

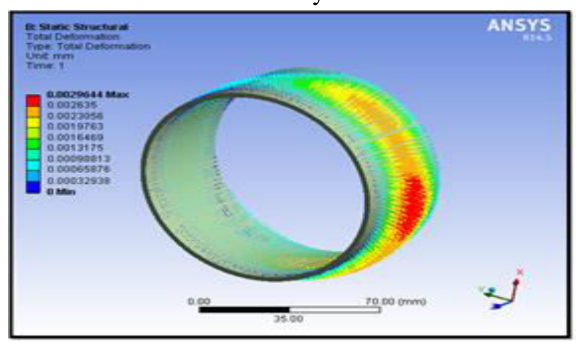


Fig 6: Total deformation for L/D =0.5 and eccentricity =0.3

This technique gives the deformation of the bearing due to action of hydrodynamic forces Developed that's essential for accurate overall performance of the bearings operation beneath extreme conditions It is located that there may be tremendous quantity of deformation of the bearing.

When the loads applied on magazine bearing the use of Polyetheretherket1 (PEEK), the most deformation value is 0.0029644mm

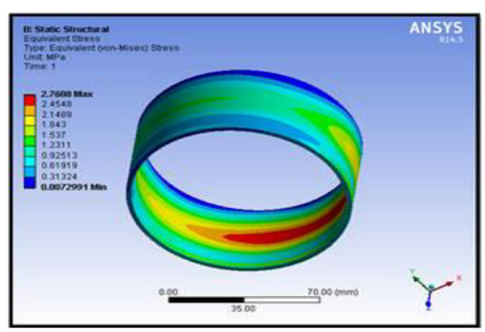


Fig 7: Equivalent stress for L/D =0.5 and eccentricity =0.3

When the loads applied on journal bearing using Polyetheretherket1 (PEEK), the maximum stress value is 2.7608MPa at middle portion of the journal bearing and minimum stress is 0.0072991MPa.

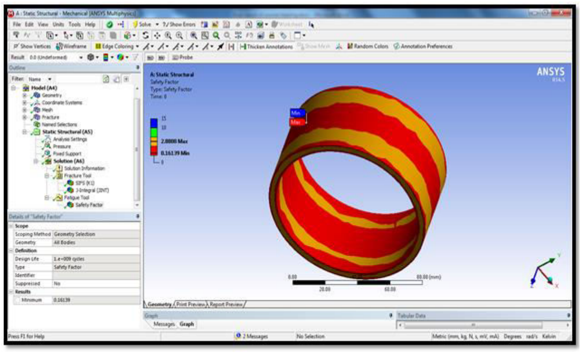


Fig 8: Safety factor for L/D=0.5 and eccentricity =0.3

4.2 L/D =0.5 & ECCENTRICITY=0.5

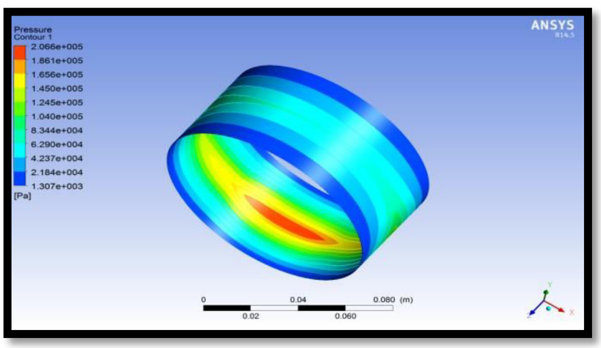


Fig 9: Pressure contour for L/D=0.5 and eccentricity =0.5

According to stress counters the maximum stress is 2.0066e+005Pa at center part of the journal bearing and minimal pressure 1.307e+003Pa at ends of the magazine bearing.

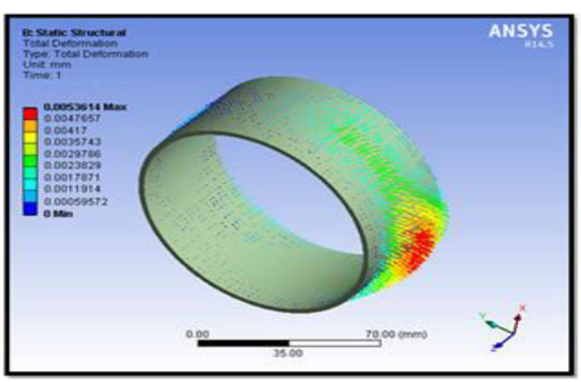


Fig 10: Total deformation for L/D=0.5 and eccentricity =0.5

When the masses applied on journal bearing the use of Polyetheretherket1 (PEEK), the maximum deformation price is 0.0053614mm.

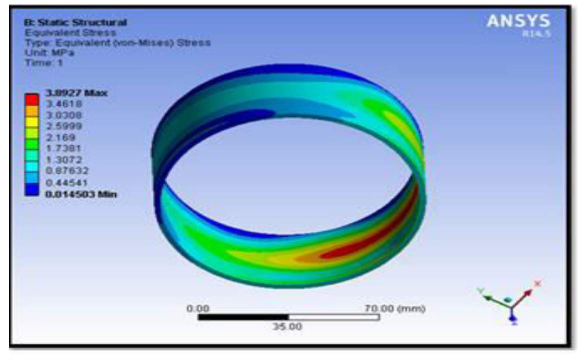


Fig 11: Equivalent stress for L/D=0.5 and eccentricity =0.5

When the masses applied on magazine bearing the usage of Polyetheretherket1 (PEEK), the most stress value is 3.8927MPa and minimal pressure is zero.014503MPa.

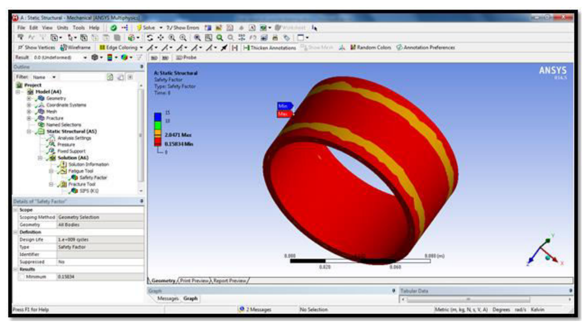


Fig 12: Safety factor for L/D=0.5 and eccentricity =0.5

4.3 L/D =0.5 & ECCENTRICITY=0.7

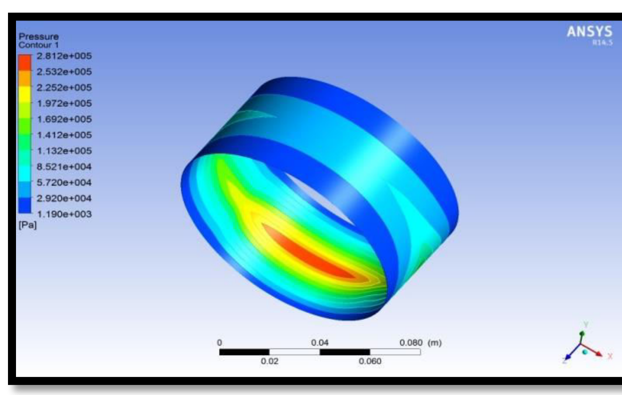


Fig 13: Pressure contour for L/D=0.5 and eccentricity =0.7

According to pressure counters the maximum pressure is 2.812e+005Pa at middle portion of the journal bearing and minimum pressure 1.190e+003Pa at ends of the journal bearing.

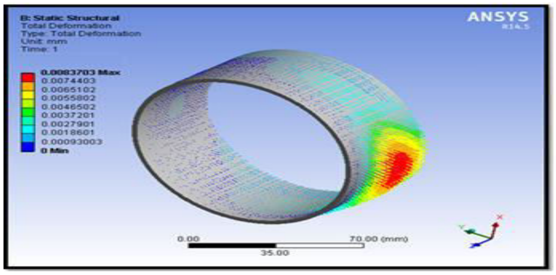


Fig 14: Total deformation for L/D=0.5 and eccentricity =0.7

When the loads applied on journal bearing using Polyetheretherket1 (PEEK), the maximum deformation value is 0.0083703mm

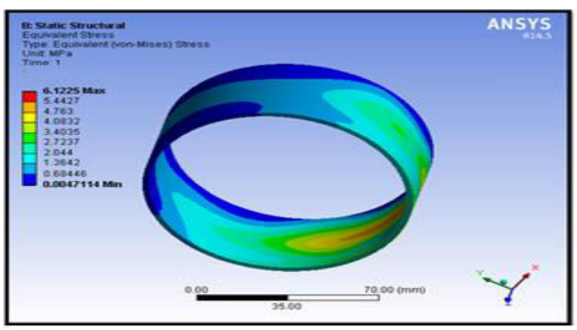


Fig 15: Equivalent stress for L/D=0.5 and eccentricity =0.7

When the loads applied on journal bearing using Polyetheretherket1 (PEEK), the maximum stress value is 6.1225MPa and minimum stress is 0.0047114MPa.

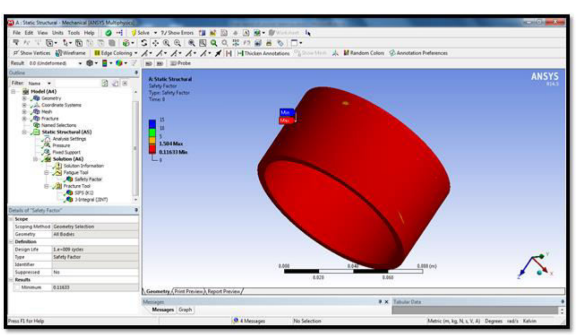


Fig 16: Safety factor for L/D=0.5 and eccentricity =0.7

4.4 L/D =0.5 & ECCENTRICITY=0.9

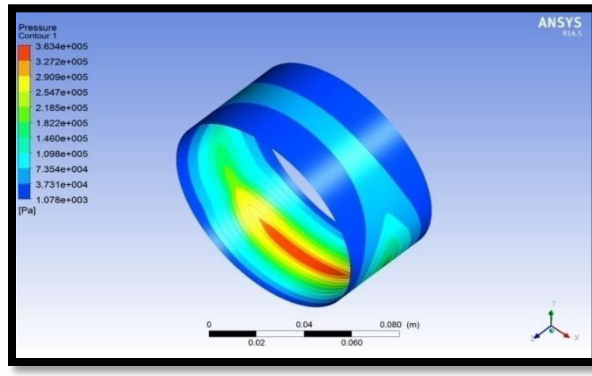


Fig 17: Pressure contour for L/D=0.5 and eccentricity =0.9

According to pressure counters the maximum pressure is 3.634e+005Pa at middle portion of the journal bearing and minimum pressure 1.078e+003Pa at ends of the journal bearing.

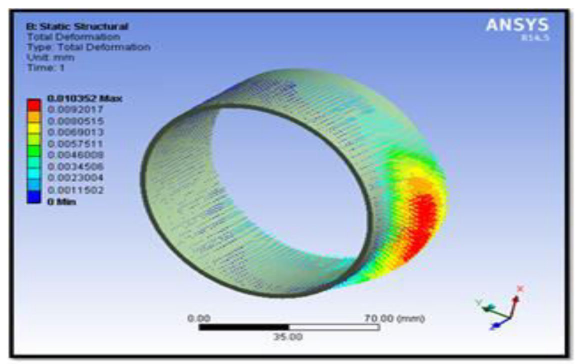


Fig 18: Total deformation for L/D=0.5 and eccentricity =0.9

When the loads applied on journal bearing using Polyetheretherket1 (PEEK), the maximum deformation value is 0.010352mm.

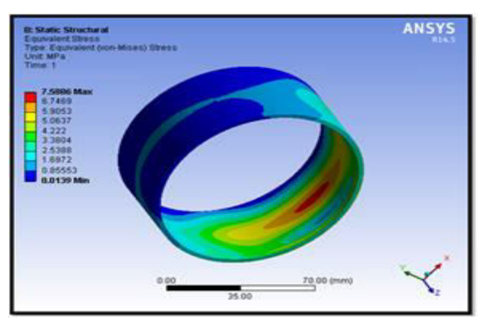


Fig 19: Equivalent stress for L/D=0.5 and eccentricity =0.9

When the loads applied on journal bearing using Polyetheretherket1 (PEEK), the maximum stress value is 7.5886MPa and minimum stress is 0.0139MPa.

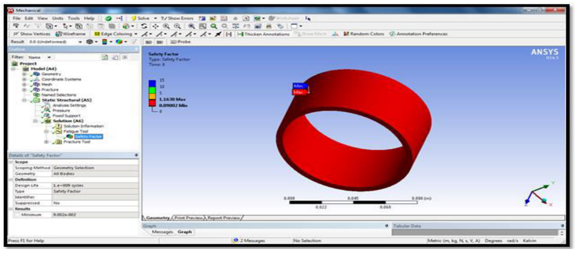


Fig 20: Safety factor for L/D=0.5 and eccentricity =0.9

4.5 L/D =1.0 & ECCENTRICITY=0.3

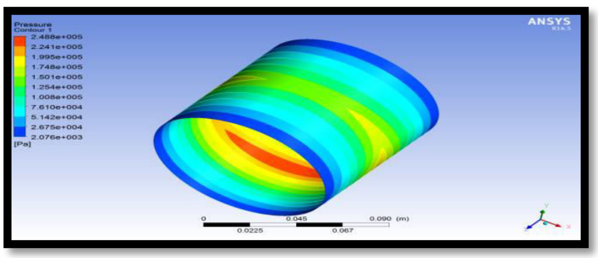


Fig 21: Pressure contour for L/D=1 and eccentricity =0.3

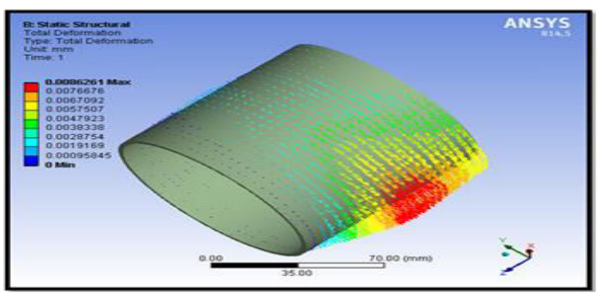


Fig 22: Total deformation for L/D=1 and eccentricity =0.3

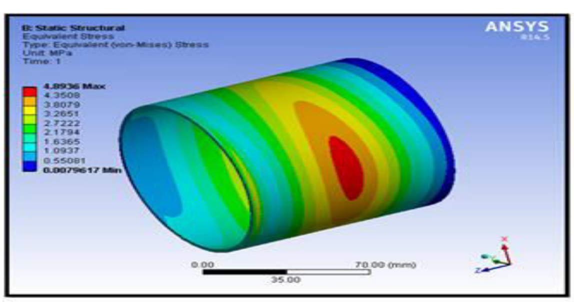


Fig 23: Equivalent stress for L/D=1 and eccentricity =0.3

When the loads applied on journal bearing using Polyetheretherket1 (PEEK), the maximum stress value is 4.8936MPa and minimum stress is 0.0079617MPa.

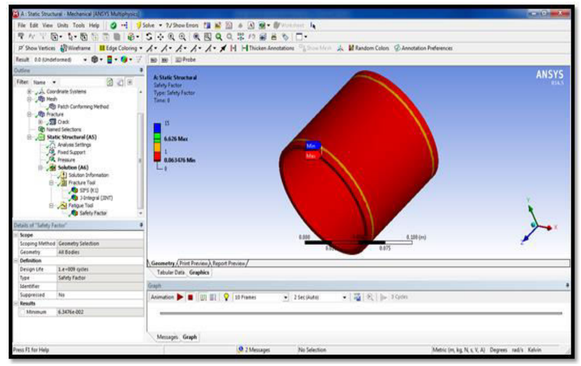


Fig 24: Safety factor for L/D=1.0 and eccentricity =0.3

4.6 L/D =1.0 & ECCENTRICITY=0.5

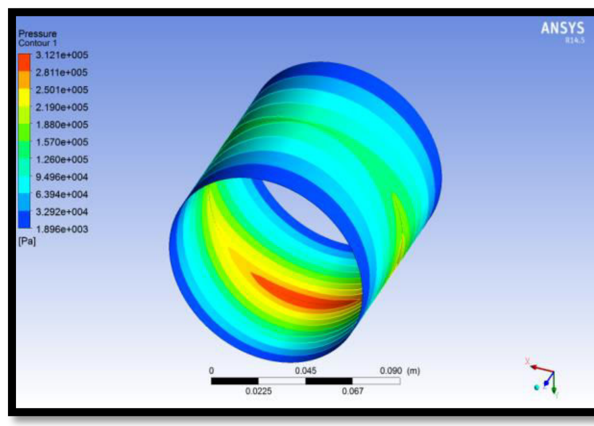


Fig 25: Pressure contour for L/D=1.0 and eccentricity =0.5

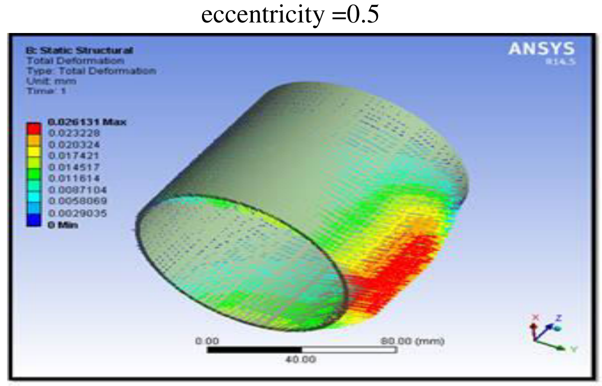


Fig 26: Total deformation for L/D=1.0 and eccentricity =0.5

When the loads applied on journal bearing using Polyetheretherket1 (PEEK), the maximum deformation value is 0.0026131mm.

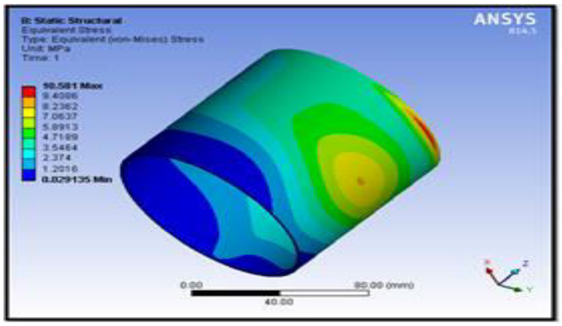


Fig 27: Equivalent stress for L/D=1.0 and eccentricity =0.5

When the loads applied on journal bearing using Polyetheretherket1 (PEEK), the maximum stress value is 10.501MPa and minimum stress is 0.029135MPa.

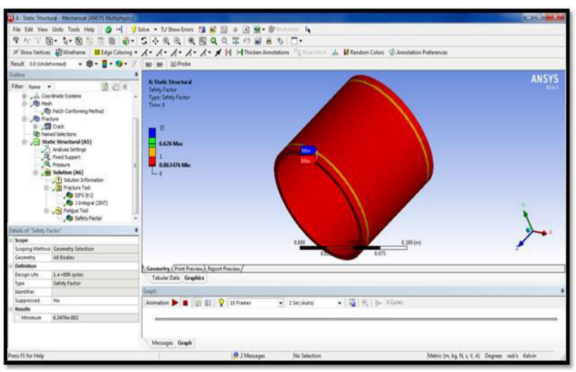


Fig 28: Safety factor for L/D=1.0 and eccentricity =0.5

4.7 L/D =1.0 & ECCENTRICITY=0.7

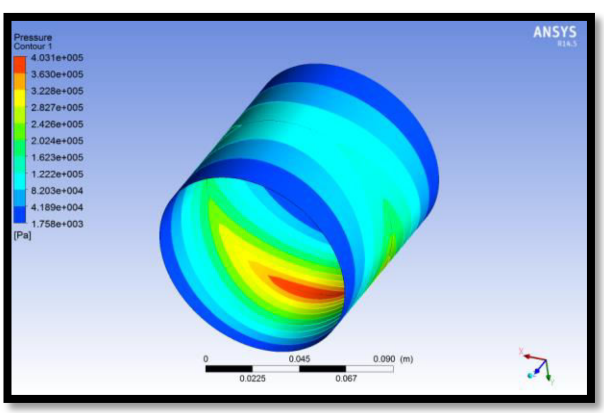


Fig 29: Pressure contour for L/D=1.0 and eccentricity =0.7

According to pressure counters the maximum pressure is 4.031e+005Pa at middle portion of the journal bearing and minimum pressure 1.758e+003Pa at ends of the journal bearing.

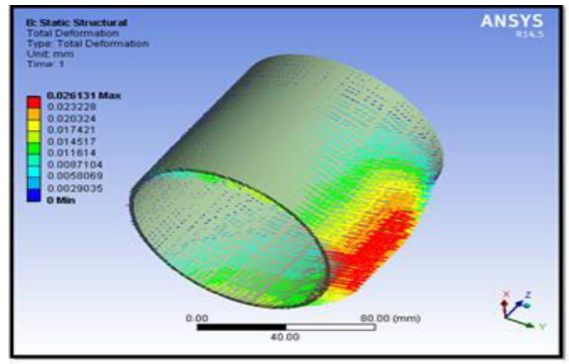


Fig 30: Total deformation for L/D=1.0 and eccentricity =0.7

When the loads applied on journal bearing using Polyetheretherket1 (PEEK), the maximum deformation value is 0.0026131mm

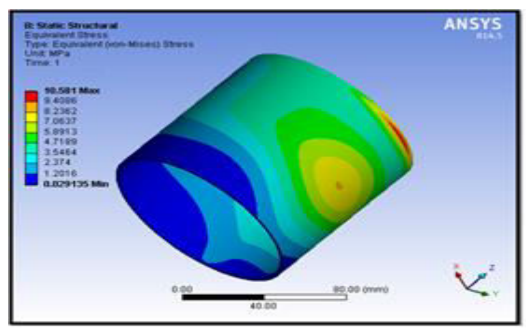


Fig 31: Equivalent stress for L/D=1.0 and eccentricity =0.7

When the loads applied on journal bearing using Polyetheretherket1 (PEEK), the maximum stress value is 10.501MPa and minimum stress is 0.029135MPa.

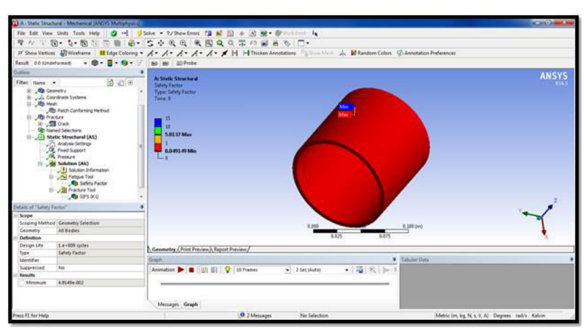


Fig 32: Safety factor for L/D=1.0 and eccentricity =0.7

4.8 L/D =1.0 & ECCENTRICITY=0.9

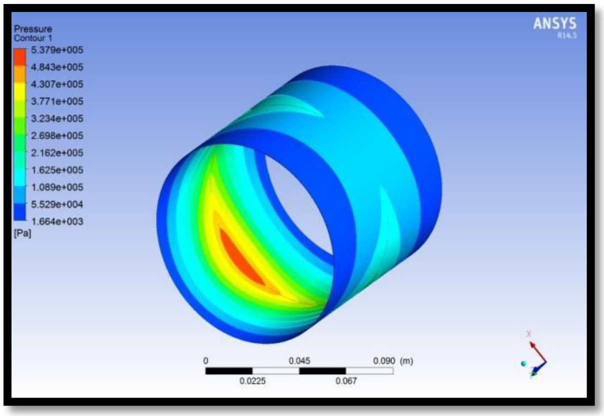


Fig 33: Pressure contour for L/D=1.0 and eccentricity =0.9

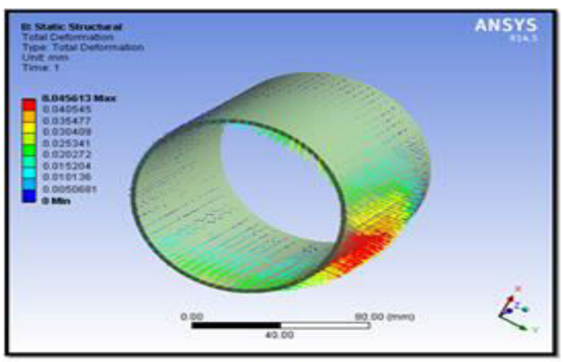


Fig 34: Total deformation for L/D=1.0 and eccentricity =0.9

When the loads applied on journal bearing using Polyetheretherket1 (PEEK), the maximum deformation value is 0.045613mm

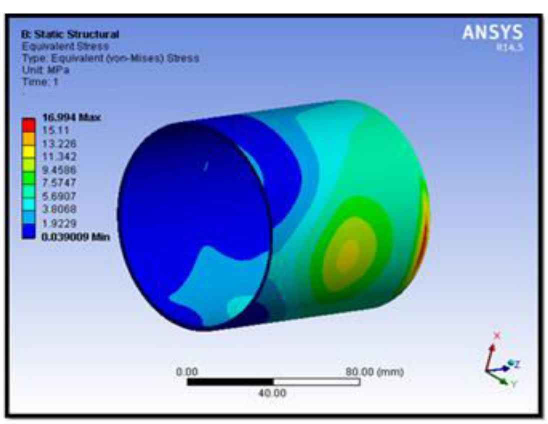


Fig 35: Equivalent stress for L/D=1.0 and eccentricity =0.9

When the loads applied on journal bearing using Polyetheretherket1 (PEEK), the maximum stress value is 16.994MPa and minimum stress is 0.039009MPa.

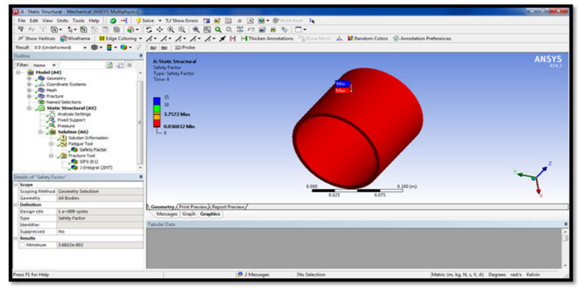


Fig 36: Safety factor for L/D=1.0 and eccentricity =0.9

4.9 L/D =1.5 & ECCENTRICITY=0.3

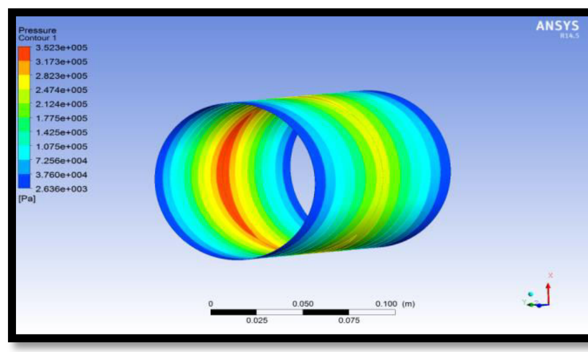


Fig 37: Pressure contour for L/D=1.5 and eccentricity =0.3

According to pressure counters the maximum pressure is 3.523e+005Pa at middle portion of the journal bearing and minimum pressure 2.636e+003Pa at ends of the journal bearing.

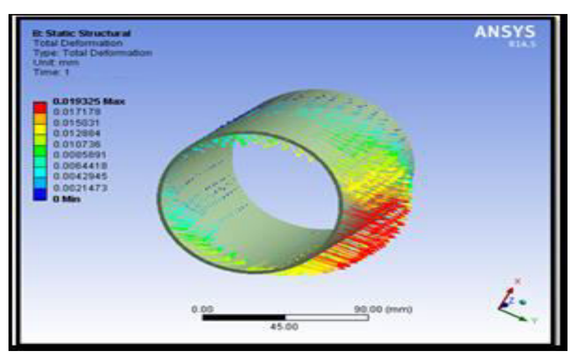


Fig 38: Total deformation for L/D=1.5 and eccentricity =0.3

When the loads applied on journal bearing using Polyetheretherket1 (PEEK), the maximum deformation value is 0.019325mm

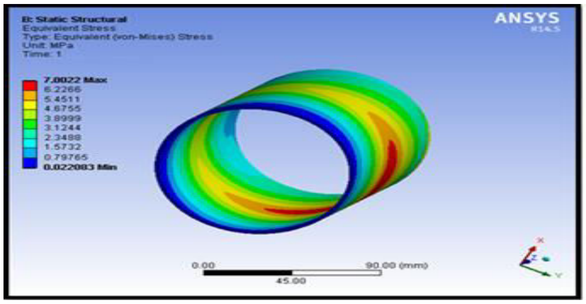


Fig 39: Equivalent stress for L/D=1.5 and eccentricity =0.3

When the loads applied on journal bearing using Polyetheretherket1 (PEEK), the maximum stress value is 7.0022MPa and minimum stress is 0.022083MPa.

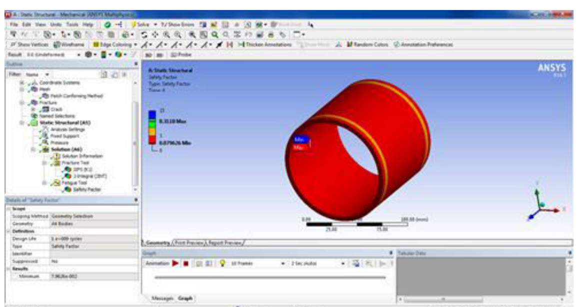


Fig 40: Safety factor for L/D=1.5 and eccentricity =0.3

4.10 L/D =1.5 & ECCENTRICITY=0.5

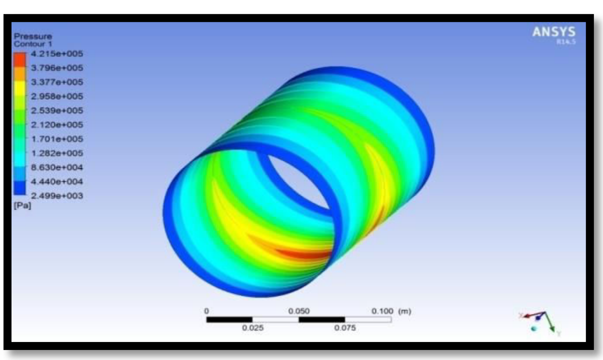


Fig 41: Pressure contour for L/D=1.5 and eccentricity =0.5

According to pressure counters the maximum pressure is 4.215e+005Pa at middle portion of the journal bearing and minimum pressure 2.499e+003Pa at ends of the journal bearing.

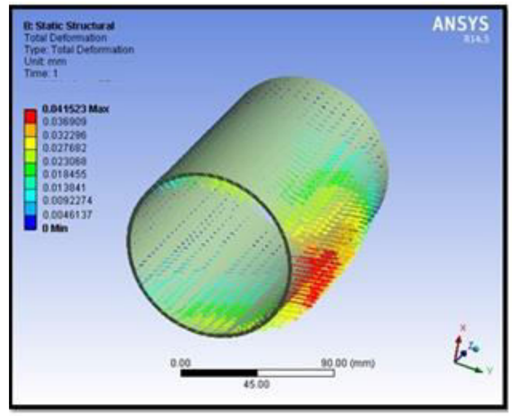


Fig 42: Total deformation for L/D=1.5 and eccentricity =0.5

When the loads applied on journal bearing using Polyetheretherket1 (PEEK), the maximum deformation value is 0.041523mm

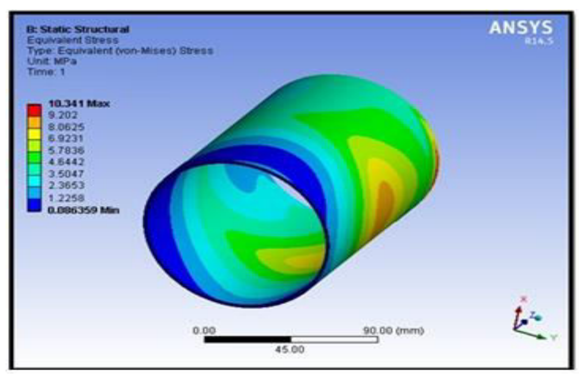


Fig 43: Equivalent stress for L/D=1.5 and eccentricity =0.5

When the loads applied on journal bearing using Polyetheretherket1 (PEEK), the maximum stress value is 10.241MPa and minimum stress is 0.086359MPa.

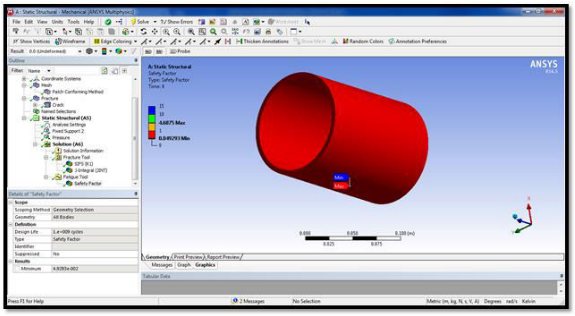


Fig 44: Safety factor for L/D=1.5 and eccentricity =0.5

4.11 L/D =1.5 & ECCENTRICITY=0.7

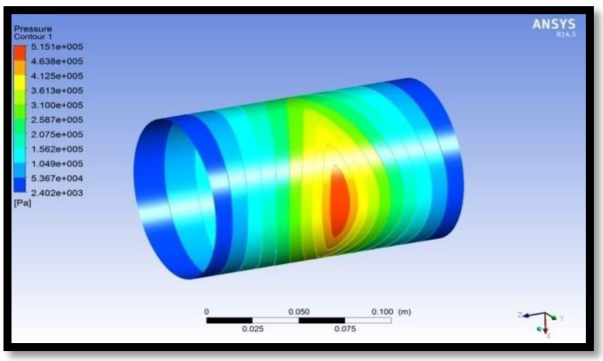


Fig 45: Pressure contour for L/D=1.5 and eccentricity =0.7

According to pressure counters the maximum pressure is 5.151e+005Pa at middle portion of the journal bearing and minimum pressure 2.402e+003Pa at ends of the journal bearing.

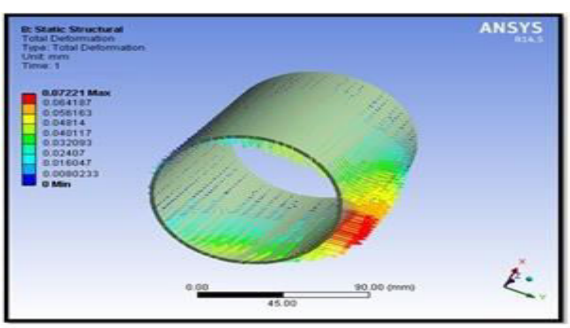


Fig 46: Total deformation for L/D=1.5 and eccentricity =0.7

When the loads applied on journal bearing using Polyetheretherket1 (PEEK), the maximum deformation value is 0.07221mm

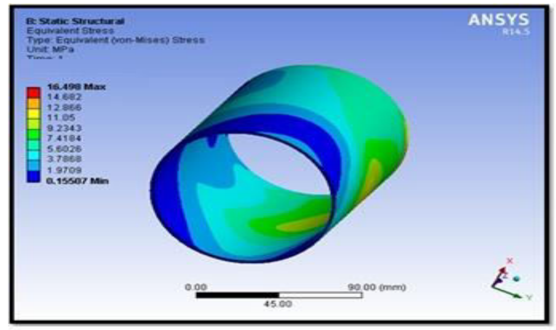


Fig 47: Equivalent stress for L/D=1.5 and eccentricity =0.7

When the loads applied on journal bearing using Polyetheretherket1 (PEEK), the maximum stress value is 16.498MPa and minimum stress is 0.15507MPa.

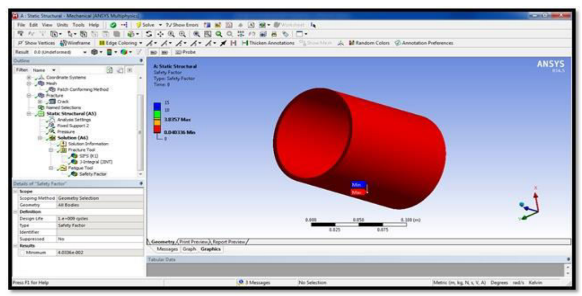


Fig 48: Safety factor for L/D=1.5 and eccentricity =0.7

4.12 L/D =1.5 & ECCENTRICITY=0.9

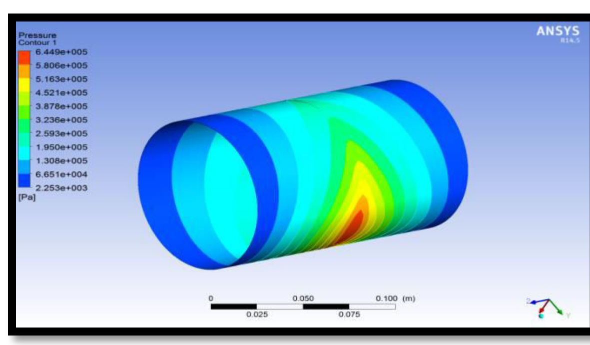


Fig 49: Pressure contour for L/D=1.5 and eccentricity =0.9

According to pressure counters the maximum pressure is 6.449e+005Pa at middle portion of the journal bearing and minimum pressure 2.253e+003Pa at ends of the journal bearing.

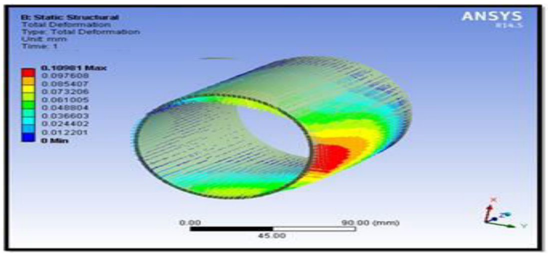


Fig 50: Total deformation for L/D=1.5 and eccentricity =0.9

When the loads applied on journal bearing using Polyetheretherket1 (PEEK), the maximum deformation value is 0.010981mm

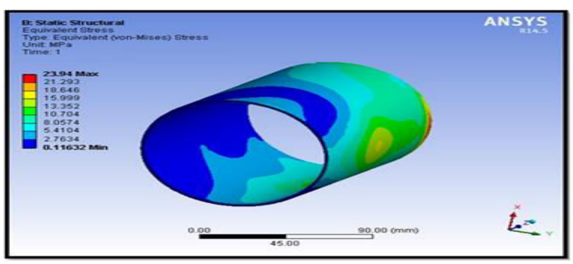


Fig 51: Stress contour for L/D=1.5 and eccentricity =0.9

When the loads applied on journal bearing using Polyetheretherket1 (PEEK), the maximum stress value is 23.94MPa and minimum stress is 0.11632MPa.

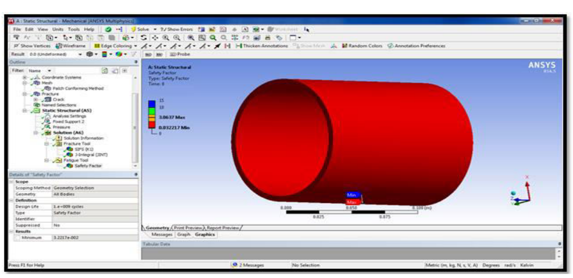


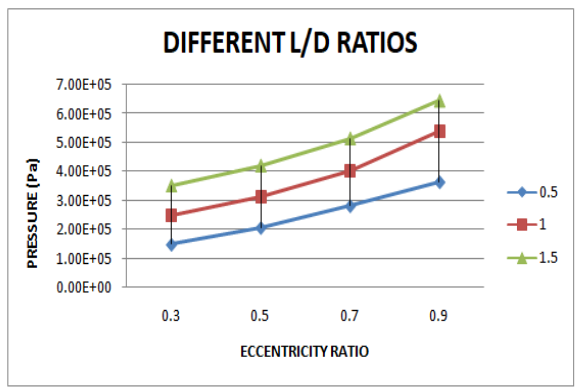
Fig 52: Safety factor for L/D=1.5 and eccentricity =0.9

4.13 RESULTS TABLE

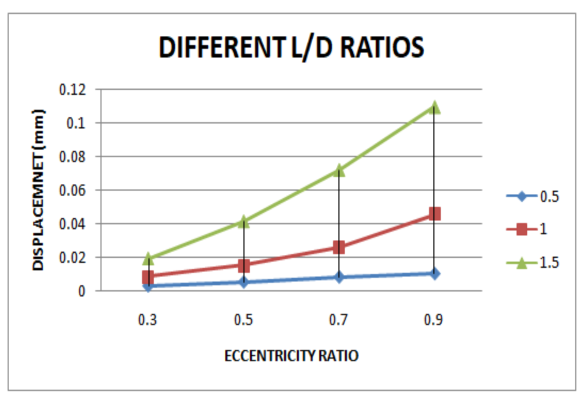
Table 1: Results

L/D ratio	Eccentricity ratio	Pressure (Pa)	Displacement (mm)	Stress (MPa)	Safety factor	SIFS (MPa.mm$^{0.5}$)	J-integral (j/m^2)
0.5	0.3	1.49E+05	0.0029644	2.7608	2.8808	0.69192	0.002165
	0.5	2.066E+05	0.0053614	3.8927	2.0471	0.9594	0.0041632
	0.7	2.812E+05	0.0083703	6.1225	1.504	0.3058	0.0077125
	0.9	3.634E+05	0.010352	7.5886	1.1638	1.6875	0.012881
1.0	0.3	2.488E+05	0.0086261	4.8936	8.3118	2.7765	0.035012
	0.5	3.121E+05	0.015092	6.2448	6.626	3.4829	0.055095
	0.7	4.031E+05	0.026131	10.581	5.0137	4.4946	0.091745
	0.9	5.379E+05	0.045613	16.994	3.7572	5.9976	0.16337
1.5	0.3	3.523E+05	0.019325	7.0022	5.6082	3.7526	0.063953
	0.5	4.215E+05	0.041523	10.241	4.6875	4.4897	0.091545
	0.7	5.151E+05	0.07221	16.498	3.8357	5.4867	0.13672
	0.9	6.449E+05	0.10981	23.94	3.0637	6.8693	0.2143

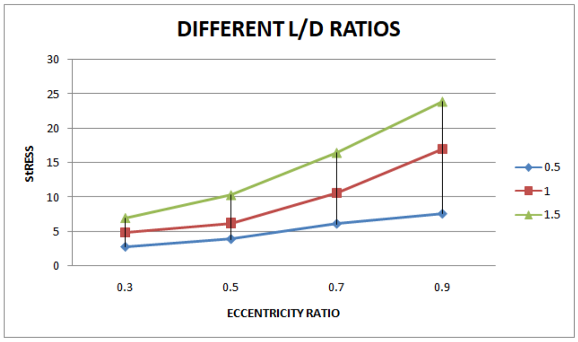
4.14 Comparison of results for different l/d ratios



Graph 1: Pressure for various L/D ratios



Graph 2: Displacements for different L/D ratios



Graph 3: Stress for different L/D ratios

5. CONCLUSIONS

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 E . 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.

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.

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.

By observing the static analysis the stress values are increases by increasing the L/D ratio of journal bearing. The minimum stress value at 0.3 eccentricity ratio, L/D ratio 0.5.

In particular, they are phenomena in which a crack propagates deeply into the depth direction, such as through fracture of an inner ring under fitting stress. Contact stress is compressive in 3 axes, but the values are different; then strain can be tensile in the direction at a right angle to the maximum-compression stress direction. We consider that the crack propagates by this tensile strain. When contact stress is small, a crack, produced by some cause, can propagate by this elastic tensile strain. When contact stress is large, residual tensile strain is produced by plastic deformation and this residual tensile strain can also influence the crack propagation.

REFERENCES

[1] A. Ouadoud, A. Mouchtachi, N. Boutammacht, "Hydrodynamic Journal Bearing," Journal Of Advanced Research In Mechanical Engineering ,Vol.2-2011/Iss.1, Pp. 33-38.

[2] Dinesh Dhande, Dr D W Pande, Vikas Chatarkar, "Analysis Of Hydrodynamic Journal Bearing Using Fluid Structure Interaction Approach," International Journal Of Engineering Trends And Technology (IJETT) - Volume4 Issue8- August 2013

[3] B. S. Shenoy, R. S. Pai, D. S. Rao, R. Pai, "ElastoHydrodynamic Lubrication Analysis Of Full 360 Journal Bearing Using CFD And FSI Techniques," ISSN 1 746-7233, England, UK World Journal Of Modelling And Simulation Vol. 5 (2009) No. 4, Pp. 315-320

[4] K.P. Gertzos, P.G. Nikolakopoulos, C.A. Papadopoulos, Lubrication By Bingham Lubricant", Tribology International 41 (2008) 1190– 1204 · December 2008

[5] S. Chaitanya Kumar, R. Ganapathi, "CFD Analysis on Hydrodynamic Plain Journal Bearing using Fluid Structure Interaction Technique", International Journal of Engineering Research & Technology (IJERT) ISSN: 2278-0181, Vol. 4 Issue 07, July-2015

[6] B. Manshoora, M. Jaata, Zaman Izzuddina, Khalid Amira, "CFD Analysis Of Thin Film Lubricated Journal Bearing," The Malaysian International Tribology Conference 2013.

[7] Jamaluddin Md Sheriff, Kahar Osman, Asral, "Effect Of Circumferential Groove Sinusoidal Waviness On The Load Carrying Capacity Of Journal

Bearing With BioBased Lubricant" , 2010 International Conference On Science And Social Research (CSSR 2010), December 5 - 7, 2010, Kuala Lumpur, Malaysia [22] Marco Tulio C. Faria, " On The Hydrodynamic Long Journal Bearing Theory", Proceedings Of The World Congress On Engineering 2014 Vol II, WCE 2014, July 2 - 4, 2014, London, U.K.

[8] Huixia Jin, Weiming Zuo, "Simulation And Heat Transfer Calculation On A Journal Bearing With A Center Circumferential Groove In Load Zone", International Journal Of Advancements In Computing Technology(IJACT) Volume5, Number1,January 2013

[9] Samuel Cupillard, Michel J. Cervantes And Sergei Glavatskih, "A CFD STUDY OF A FINITE TEXTURED JOURNAL BEARING" , 24th Symposium On Hydraulic Machinery And Systems OCTOBER 27-31.

[10] Amit Solanki, Prakash Patel, Bhagirath Parmar, "Design Formulation And Optimum Load Carrying Capacity Of Hydrodynamic Journal Bearing By Using Genetic Algorithm", International Journal For Res Earch In Ap Pl I Ed Sc I Enc E And Engineering Technolo Gy (I Jras Et) Vol. 2 Issue II, February 2014 ISSN: 2321-9653