# CFD Analysis of Conical Journal Bearing

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***Abstract***- *Conical journal bearings have significant advantage of carrying radial and axial load simultaneously. And hence eliminates the need of employing separate thrust and journal bearing. In recent times many researchers began to employ the commercial computational fluid dynamics programs in their investigation.*

*An attempt is made to utilise CFD technique to investigate the performance of conical hydrodynamic journal bearing in terms of pressure distribution and load carrying capacity. ANSYS Fluent 6.3 analysis tool has been used to solve the Navier - Stoke equation governing the flow of lubricant in clearance space of journal and bearing. Study of the hole-entry hybrid conical journal bearing with uniform distribution of holes at an angle of 30 deg in circumferential direction is done. Results are presented for bearing with various semicone angles viz. 5, 10, 15, 20, 25 deg with hole size of 1mm and 2mm in terms of pressure distribution and load carrying capacity. The results show that maximum pressure developed increases with increase in semicone angle Identify the constructs of a Journal – Essentially a journal consists of five major sections. The number of pages may vary depending upon the topic of research work but generally comprises up to 5 to 7 pages. These are:multi-label learning, more than one class can be assigned to an instance. With the increase in the number of data and eccentricity ratio is increases as maximum pressure developed. And it decreases when hole diameter is increased.*

***Keywords***- Conical journal bearing, CFD analysis, ANSYS Fluent 6.3

## I. INTRODUCTION

Conical journal bearings are bearings which have significant advantage of carrying radial and axial load simultaneously thereby eliminating the need of employing separate thrust and journal bearing. Conical journal bearings are used in precision machine tool applications such as lathes and in grinding machines[1][2].These are also used in medical science for axial blood pump[3]. Performance of the conical journal bearing could be improved by externally pressurised fluid making it a radial-thrust hybrid journal bearing.

Hybrid journal bearings are broadly classified as recess (pocket inside bush) and non-recess (without pocket inside bush) journal bearings. Non recess bearings are further classified as hole-entry and slot-entry hydrostatic/hybrid journal bearings. In the hole-entry hydrostatic/hybrid journal bearing configuration, holes are made symmetrically around the periphery of bearing with pressure compensating devices in it called restrictors, such as capillary restrictor. The supply hole size and number of holes significantly affect the bearing static and dynamic performance. Performance of the bearing is greatly affected by the type of compensating device used in the system [4].

## II. LITERATURE REVIEW

**Stout And Rowe [1] [1974]:** Provided design for manufacture for externally pressurised bearing. They have given the information relating to the selection of configuration geometry, control devices and materials for both gas and liquid feed bearings. Also they provided additional guidance concerning the achievement of total system reliability.The design of liquid feed journal bearings is discussed and is illustrated by design examples by Stout and Rowe in 1974 [2],Tolerancing procedures for both recessed and non-recessed configurations were presented which enable bearings to be designed for economic manufacture combined with low total power dissipation, high load capacity and high stiffness. Recessed and non-recessed bearings were compared, showing that slot entry bearings offer greatest load capacity up to 0.5 eccentricity ratio although flow-rates are increased to achieve minimum power dissipation.

**Salem and Khalil[7] [1978]:**Presented theoretical and experimental investigations of thermal and inertia effects on the performance of externally pressurized conical thrust bearings. They showed that the increase in oil temperature due to pad rotation has a detrimental effect on the load carrying capacity, while it increases the flow rate. Also depending on the recess dimensions bearing load carrying capacity increases or decreases with increase in rotational speed.

**Prabhu and Ganesan[8] [1981]:**Studied the static and dynamic characteristics of annular recess conical hydrostatic bearings with capillary and orifice restrictors. The effect of rotational lubricant inertia was considered. Computations for various aspect and resistance ratios and speeds were tabulated in a form useful to designers. Further in 1983 [9], they studied the characteristics of multi-recess conical hydrostatic thrust bearings theoretically taking into account the effect of rotational lubricant inertia. Load capacity, flow, stiffness and damping characteristics were computed for the practically useful aspect and resistance ratios for capillary and orifice compensations.

**Rowe and Xu [10][1982]:**Reported that non recess hybrid journal bearings offer better performance than recess bearing. They concluded that hole-entry bearings may be particularly effective when compared with other bearing configurations for good load support and low energy consumption, when used in any of the four modes of operation including: zero-speed hydrostatic mode; high-speed hydrodynamic mode; zero and high-speed hybrid mode; and jacking mode where areas are pressurized for start-up.

**Yoshimoto and Rowe [11] [1988]:** Presented a theoretical analysis of hole entry hybrid bearing employing capillary restrictor. The Reynolds equation was solved using finite difference techniques, replacing negative pressure by P=0 for cavitation region. They showed that the load carrying capacity of such bearings is greatly affected by the pocket size at zero speed and at high speed.

**Rowe [12] [1989]:** Reported the advances in hydrostatic and hybrid journal bearings from early plane and cylindrical designs to the wide range of configurations now utilized. Applications discussed range from measuring and machine tools to aerospace and heavy power generation equipment. Aspects covered include load coefficients, film stiffness, flow control, hydrodynamic effects and dynamic behavior.

**Ettles and Svobada [13] [1975]:** Studied the application of double conical journal bearings in high speed centrifugal pump. They showed that the double inclined journal bearing with low pressure lubricant supply is incapable of supporting combination of axial and radial load greater than the tangent of half the cone angle, due to circumferential symmetry of conical surfaces. Conical journal bearings are generally used in precision machine tool applications such as lathes and in grinding machines [1], [2].

**Sharma et al.[14] [ 1993]:** Studied analytically the performance characteristics of externally pressurized hole-entry flexible journal bearings with capillary compensation. The finite element method was used to solve the Reynolds equation governing the lubricant flow in the clearance space of a journal bearing and three-dimensional elasticity equations governing the displacement field in the bearing shell. The bearing performance characteristics were presented for a wide range of values of deformation coefficient (Cd) which takes into account the flexibility of the bearing shell. The performance characteristics were compared for two hole-entry bearing configurations for the same values of bearing geometric and operating parameters.

**Cheng and Rowe [6][ 1995]:** Presented selection strategy for the externally pressurized journal bearing in terms of bearing type, configuration, fluid feeding devices, and bearing material. Selection criteria were formulated for the choice of the bearing material. A number of issues were discussed related to the manufacture of the bearing and tolerances which need to be specified. The strategy forms the basis for a computerized bearing design procedure.

**Yoshimoto, Kume and Shitara [15] [1998]:**Investigated two types of water-lubricated hydrostatic conical bearings with spiral grooves for high speed spindles. The static characteristics of these bearings are theoretically predicted and calculated results are compared with experimental results. It was found that the compliant surface bearing had a larger load capacity in a relatively large bearing clearance than the rigid surface bearing, and lower bearing power consumption in a small bearing clearance although the load capacity is reduced.

**Hong et al.[16][2009]:**Presented a theoretical study and experimental method to recognize the dynamic performance (stiffness and damping coefficients) of an externally pressurized deep/shallow pockets hybrid conical bearing compensated by flat capillary restrictors. The results showed that the hybrid conical bearing has the advantages of high load carrying capability and high stability under small eccentricity.

**Basavaraja and Sharma[17] [2010]:**Presented results which indicate that the effect of journal misalignment is, in general, to cause a reduction in bearing dynamic characteristics parameters whereas the effect of pocket size is to slightly compensate this loss. Performance of a two lobe four recessed journal bearing, a proper selection of bearing offset factor along with type of restrictor (capillary or orifice) is essential.

**Guo et al.[18] [2009]:**Tudied the dynamic performance of an externally pressurized deep/shallow pocket hybrid conical journal bearing compensated by flat capillary restrictors. They did analytical and experimental work and showed the stability parameters of hybrid, hydrodynamic, and hydrostatic conical journal bearings. In their work, they observed that the hybrid conical journal bearing has the advantages of high load carrying capability and high stability under small eccentricity.

**Sharma et al. [19] [2011]:** Presented the static and dynamic performance characteristics for the influence of wear on the performance of a multirecess conical hybrid journal bearing, compensated with orifice restrictor for various values of external load, semicone angles, and wear depth. In their work, they reported that the performance of the conical bearing is greatly affected by the influence of wear defect. The bearing static and dynamic performance characteristics have also been presented by Sharma et al. [20], for multirecess capillary compensated conical hydrostatic journal bearing for the values of external load and for the semicone angles. Their results indicated that the lubricant flow rate is significantly reduced in case of conical journal bearing vis-a-vis the corresponding similar circular hydrostatic journal bearing.

## III. GEOMETRIC MODEL

Conical Journal Bearing having twelve holes each at 30 degrees is considered. Diameter of the hole is 2mm and thickness of the bearing is considered 10mm. conical journal having mean radius of 50mm. Various bearing configuration by varying the semicone angles are considered viz. 5, 10, 15, 20, 25 degrees. Journal is having eccentricity with the bearing. Various eccentricity ratios considered are 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8 and 0.9. Radial Clearance of 50 micron is considered.

Figure below shows the bearing configuration for 10 degrees semicone angle.

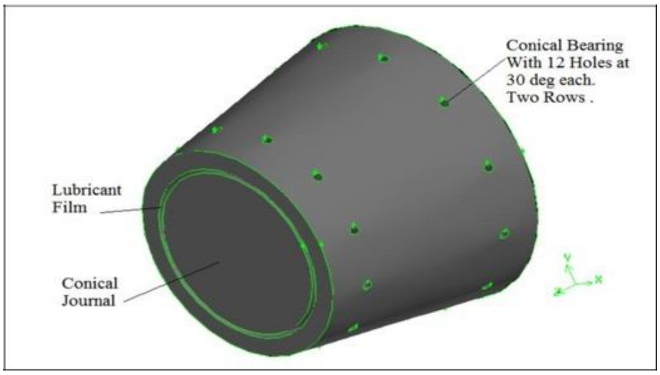

*Figure 3-1 Conical Journal Bearing Configuration for semicone angle =10 deg.*

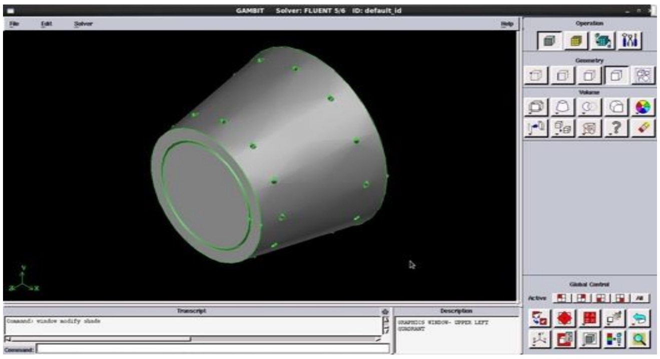

*Figure 3-2 Graphic Window of GAMBIT*

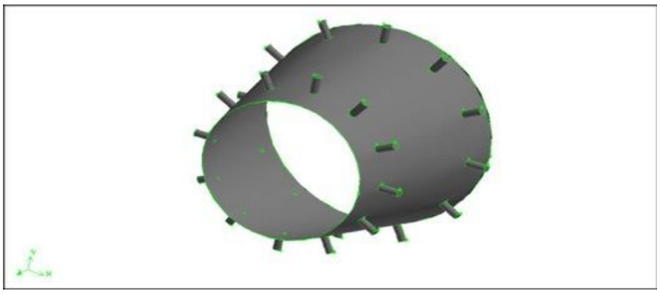

*Figure 3-3 Lubricant Fluid Film between Journal and Bearing*

### *A.Calculations of Dimensions*

Journal is modeled as 'Frustum' in GAMBIT having radius R1 and R3 calculated by considering the semicone angles and the mean journal radius as 50mm. Table below shows the values of R1 and R3 for different semicone angle α.

$1 = 50 * (1 + \quad \alpha)$

$2 = 50 * (1 - \quad \alpha)$

For Ex:

R1 for α=10

$R1= 50*(1+\tan 10)$

$= 58.8163$ mm.

*Table 3-1 Large and Small Radius of Journal in mm*

| Sr. No. | Semicone Angle in Deg (α) | Large Radius in mm (R1) | Small Radius in mm (R2) |
|---|---|---|---|
| 1 | 5 | 54.3744 | 45.6255 |
| 2 | 10 | 58.8163 | 41.1836 |
| 3 | 15 | 63.3974 | 36.6025 |
| 4 | 20 | 68.1985 | 31.8014 |
| 5 | 25 | 73.3158 | 26.6846 |

Similarly Large and small radius of the bearing considering it to be a 'Frustum' is calculated by adding the radial clearance value i.e. c=50micron to that of journal dimensions. So the table below provides the values of small and large radius of bearing in mm.

*Table 3-2 Small and large Radius of Bearing considering it as 'Frustum' in mm.*

| Sr. No. | Semicone Angle in Deg (α) | Large Radius in mm (R1) | Small Radius in mm (R2) |
|---|---|---|---|
| 1 | 5 | 54.4244 | 45.6755 |
| 2 | 10 | 58.8663 | 41.2336 |
| 3 | 15 | 63.4474 | 36.6525 |
| 4 | 20 | 68.2485 | 31.8514 |
| 5 | 25 | 73.3658 | 26.7346 |

The holes are drilled into bearing at l/6 ratio from each end of the bearing. Length of the bearing considered as 100 mm. So holes are at a distance of 16.66 mm and 83.33 mm from the large end of the bearing. Diameter of the hole is 2 mm. and its height is equal to the thickness of the bearing considered i.e. 10 mm. Eccentricity provided in x and y direction, for various eccentricity ratio, depends on the attitude angle φ as given below. Eccentricity is considered in fourth quadrant as journal rotation is considered to be in anticlockwise direction;

Eccentricity in x-direction,

$$= \quad * \quad \varphi = \varepsilon * \quad * \quad \varphi$$

Eccentricity in y-direction,

$$= - \ * \quad \varphi = -\varepsilon * \ * \quad \varphi$$

*Table 3-3 Eccentricity in x and y-direction for various eccentricity ratios*

| Sr. No. | Eccentricity Ratio (ε) | Attitude Angle in degree (φ) | Eccentricity in x-direction in mm (ex) | Eccentricity in y-direction in mm (ey) |
|---|---|---|---|---|
| 1 | 0.1 | 83.46 | 0.004967 | -0.000569 |
| 2 | 0.2 | 78.02 | 0.00978 | -0.0020743 |
| 3 | 0.3 | 72.86 | 0.01433 | -0.00442 |
| 4 | 0.4 | 65.30 | 0.01817 | -0.008357 |
| 5 | 0.5 | 58.73 | 0.02137 | -0.01297 |
| 6 | 0.6 | 54.53 | 0.02443 | -0.01740 |
| 7 | 0.7 | 46.35 | 0.02533 | -0.02415 |
| 8 | 0.8 | 36.14 | 0.02359 | -0.03230 |
| 9 | 0.9 | 31.30 | 0.02337 | -0.03845 |

### *B. Mesh Generation*

After geometric model of lubricant film is developed in GAMBIT, next step is grid generation. Grid should be as much structured as possible for getting better results in solver. For this purpose geometry is split into twenty four volumes by eliminating the shape having extruded cylinders i.e. fluid in the twelve holes of bearing. This is done by using volume split command. The Fluid film volume after the split is as shown in figure below.

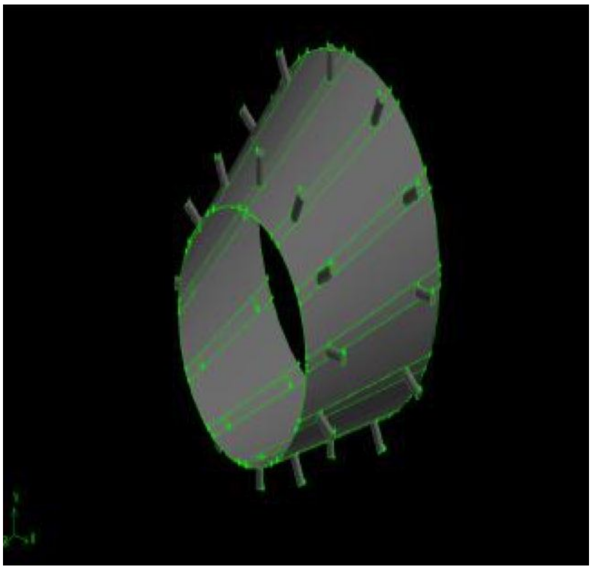

*Figure 3-4 Fluid Film Volume afterVolume Split*

Plain volume is meshed by using the 'Hex' element and 'Map' meshing scheme. Edge mesh is done to divide the film thickness in five parts. Element size considered was 1. The grid generated in plain volume is as in fig 3-5

*Table 3-4 Mesh Volume Details*

| Sr. No. | Volume | Mesh Details |
|---|---|---|
| 1 | Plain Volumes | Element Type- Hex<br>Meshing Scheme- Map<br>Element Size- 1 |
| 2 | Volumes with Extruded cylinders | Element Type- Hex/Wedge<br>Meshing Scheme- Cooper<br>Element Size- 0.4 |

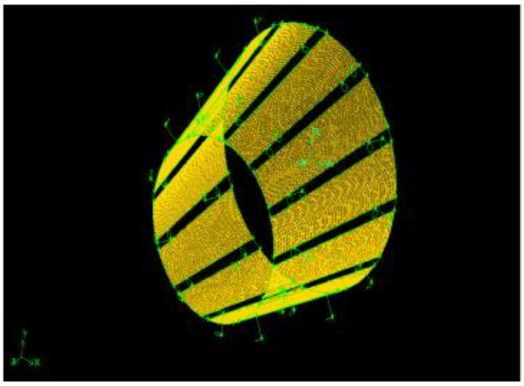

*Figure 3-5 Grid Generated in plain Volume*

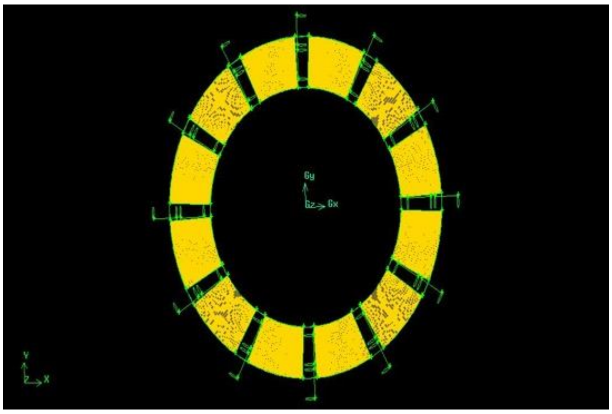

*Figure 3-6 Grid Generated in Plain Volume- Z + View*

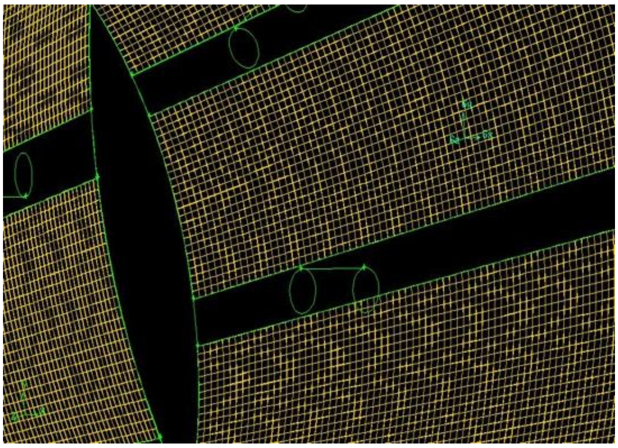

*Figure 3-7 Hex mesh generated in plain volume*

For the remaining volume the meshing element used is Hex/Wedge and meshing scheme applied is ‘Cooper.’ Spacing specified as element size equal to 0.4. The grid generated is as in fig 3-8 below.

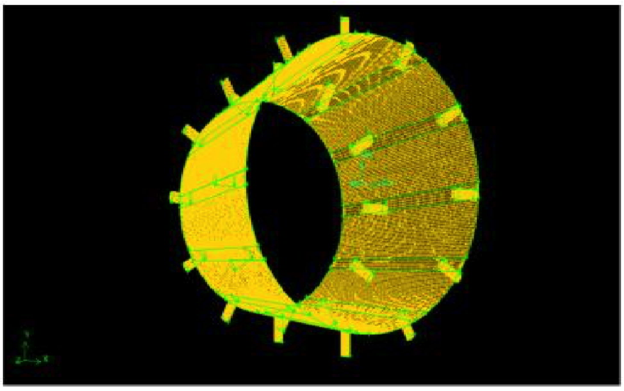

*Figure 3-8 Grid generated in whole volume*

Figure below shows the difference created due to use of two different meshing scheme in shaded view.

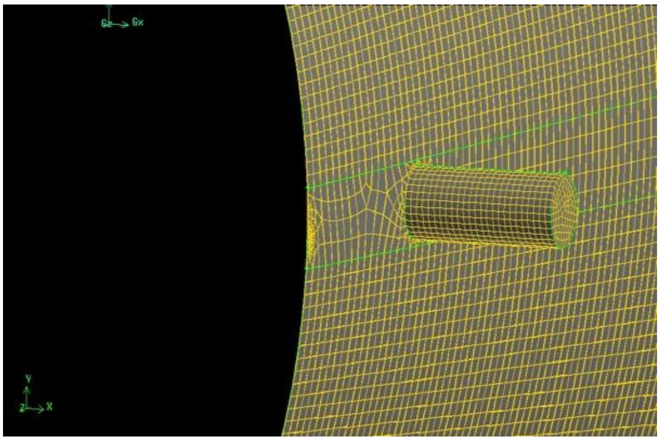

*Figure 3-9 Difference in Hex Map and Hex/Wedge Cooper mesh - Shaded view*

## IV. ANALYSIS AND. RESULT

### A.Assumption

1. A rigid aligned bearing with the geometry as in fig 3-1.
2. A steady-state operation is assumed.
3. Viscosity and density of the lubricant do not vary with temperature.
4. The flow is laminar and isothermal.
5. A constant external vertical load W is applied to the journal.

### B.Result

Contours of Static Pressure generated on the journal bearing are plotted for the various bearing configurations. The contours for specific case of 10 degree semi cone angle bearing having eccentricity ratios from 0.1 to 0.9 and journal rotation speed of 1000 rpm are as shown in the figures below.

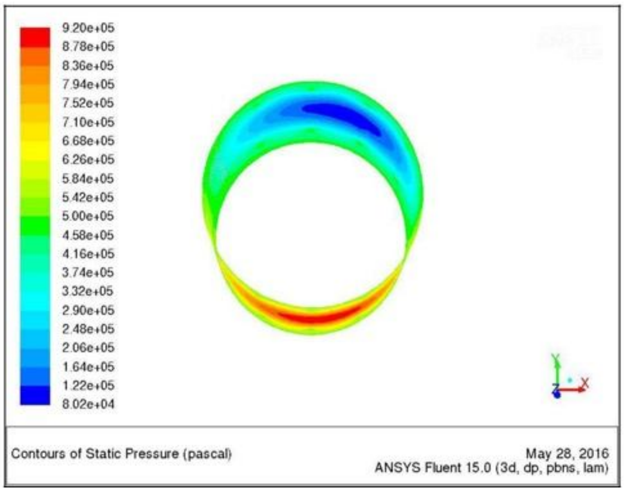

*Figure 4-1 Static Pressure Developed on Journal wall for γ=10, ε=0.1, ω=1000rpm*

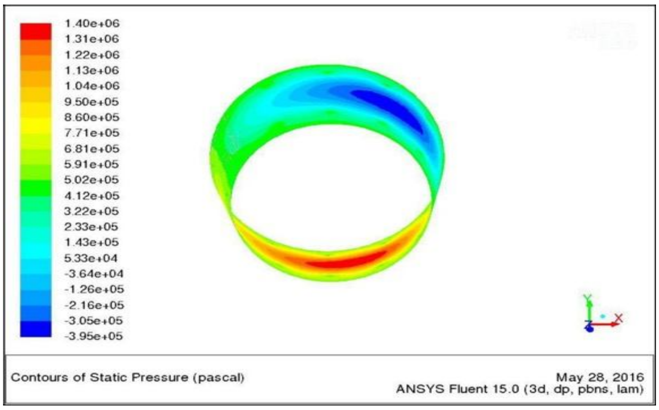

*Figure 4-2 Static Pressure Developed on Journal wall for $\gamma$=10, $\varepsilon$=0.2, $\omega$=1000rpm*

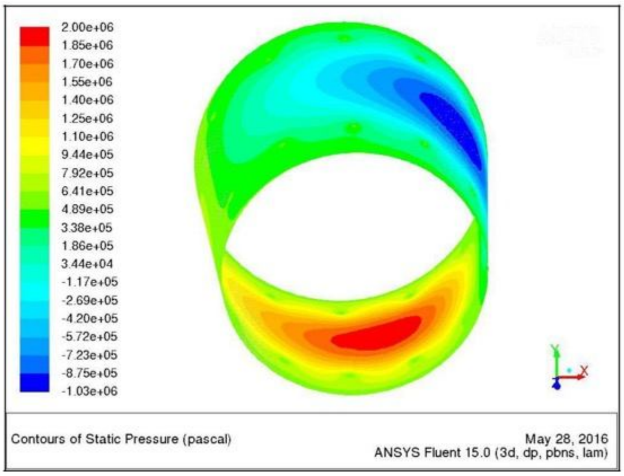

*Figure 4-3 Static Pressure Developed on Journal wall for $\gamma$=10, $\varepsilon$=0.3, $\omega$=1000rpm*

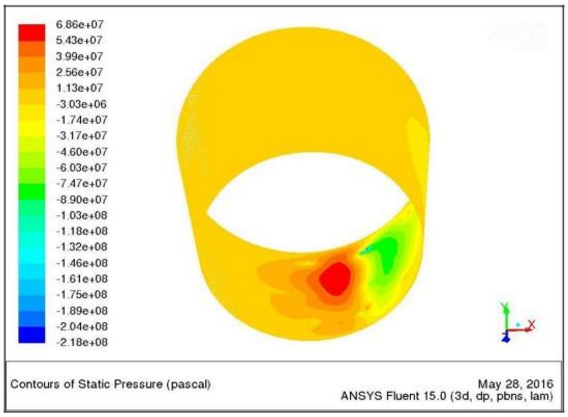

*Figure 4-9 Static Pressure Developed on Journal wall for $\gamma$=10, $\varepsilon$=0.9, $\omega$=1000rpm*

To obtain the solution for performance characteristics of nonrecessed hole-entry hybrid conical journal bearing CFD analysis tool Ansys Fluent 6.3 is used. Results in terms of maximum pressure generated on the journal surface are obtained. Max pressure generated for two cases viz. hole with diameter 1mm and 2mm are observed for certain eccentricity ratio and it is observed that max pressure developed when hole diameter is 1 mm is more so other results are obtained for hole diameter equals to 1mm.Also variation in axial and radial load carrying capacity vs. the eccentricity ratio is observed.

### C. Variation of Maximum Pressure with Hole Diameter

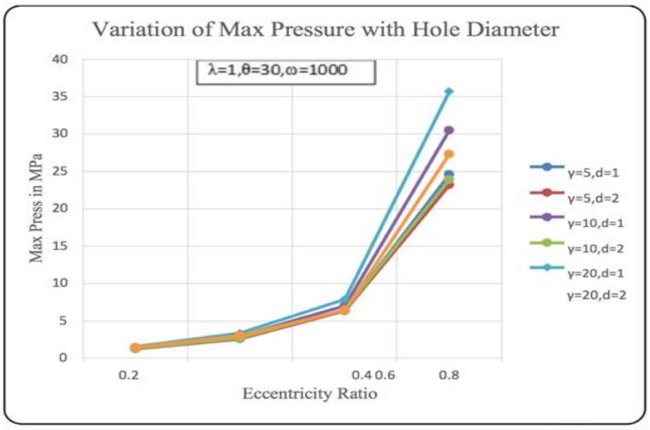

*Figure 5-1 Variation of Max Pressure vs Hole Diameter =1mm, 2mm*

Two specific cases of hole diameter equal to 1mm and 2mm are considered to check the variation in max pressure developed on journal surface. Results are obtained for bearing having semicone angle 5, 10, 20 degrees. It is observed that maximum pressure developed is more in case of hole having 1mm diameter as compared with that of 2mm diameter. This could be accounted for more hydrodynamic action in case of 1mm diameter hole as more bearing surface is available

### D. Variation of Maximum Pressure with Semicone Angle

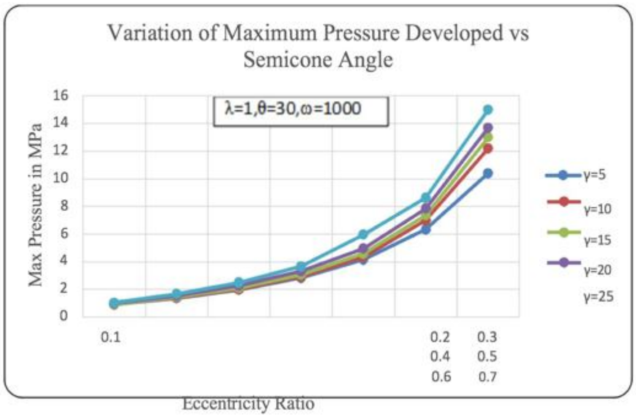

*Figure 5-2 Variation of Maximum Pressure with Semicone Angle*

### E. Variation of Maximum Pressure with Journal Speed

Speed of journal rotation is changed for checking its effect on the maximum pressure developed on journal surface of nonrecessed hole-entry hybrid conical journal bearing. Three journal rotation speed are considered viz. 1000, 1500, 2000 rpm. Journal is set at corresponding eccentricities in x and y-direction depending upon the eccentricity ratio while doing the analysis in Ansys Fluent 6.3 software. It is observed that maximum pressure developed increases as the speed of journal rotation increases as expected. Figure 5-3 shows this variation.

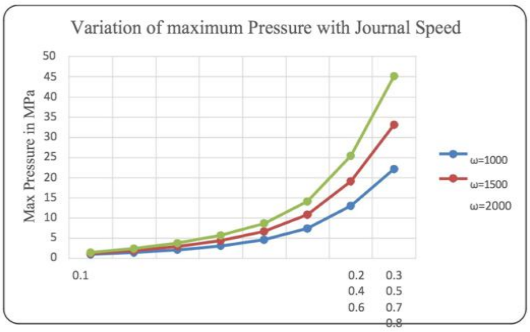

*Figure 5-3 Variation of Maximum Pressure with Speed of Journal Rotation*

## V. CONCLUSION

CFD analysis of nonrecessed conical journal bearing is performed by using the analysis tool Ansys Fluent 6.3. Results are obtained in terms of maximum pressure developed for various semicone angle bearings viz. 5, 10, 15, 20, 25 and eccentricity ratio from 0.1 to 0.9. It is observed that maximum pressure developed increases with eccentricity ratio and semicone angle. Results obtained might be useful to designer.

## REFERENCES

[1] K. J. Stout and W. B. Rowe, "Externally Pressurised Design for Manufacture: part-1- Journal Bearing Selection," Tribology International, vol. 7, no. 3, pp. 98-106, 1974.

[2] K. J. Stout and W. B. Rowe, "Externally Pressurized Bearings Design for Manufacture: Part-3—Design for Liquid Externally Pressurized Bearings for Manufacture Including Tolerancing Procedures," Tribol. Int, vol. 7, no. 5, p. 195–212. 1974.

[3] S. Hirohito, F. Kazuyoshi, F. Akio and F. Yasuhiro, "Development of an Axial Flow Blood Pump with Hydrodynamic Conical Bearing,"ASAIO Journal, Vols. March/April-volume51, no. issue 2, p. 34, 2005.

[4] S. C. Sharma and J. Basavaraja, "Influence of Pocket Size on Hole-Entry Journal Bearing," Ind. Lubr. Tribol.vol. 62, no. 5, pp. 263-274, 2010.

[5] W. B. Rowe, "Restrictors and Compensation of Hydrostatic Bearings," in Encyclopedia of Tribology, Springer, pp. 2759-2766.

[6] K. Cheng and W. B. Rowe, "A Selection Strategy for Design of Externally Pressurised Journal Bearings," Tribology International, vol. 28, no. 7, pp. 465-474, 1995.

[7] E. Salem and F. Khalil, "Thermal and Inertia Effects in Externally Pressurized Conical Thrust Oil Bearings," Appl. Sci. Res, vol. 34, no. 4, p. 341–366, 1978.

[8] J. T. Prabhu and N. Ganesan,1981, "Characteristics of Conical Hydrostatic Thrust Bearings Under Rotation,," Wear, vol. 73, no. 1, p. 95–122, 1981.

[9] J. T. Prabhu and N. Ganesan, "Analysis of Multirecess Conical Hydrostatic Thrust
Bearings Under Rotation," Wear, vol. 89, no. 1, p. 29–40, 1983.

[10] W. B. Rowe and S. X. Xu, "Hybrid Journal Bearing With Particular Reference to Hole-
Entry Configuration" Tribol. Int, vol. 15, no. 6, p. 339–348, 1982.

[11] S. Yoshimoto and W. B. Rowe, "A Theoretical Investigation of the Effect of Inlet Pocket-Size on the Performance of Hole-Entry Hybrid Journal Bearing Employing Capillary Restrictors," Wear, vol. 127, no. 3, p. 307–318, 1988.

[12] W. B. Rowe, "Advances in Hydrostatic and Hybrid Journal Bearing Technology," Proc. IMechE, vol. 203, no. 4, p. 225–242, 1989.

[13] C. Ettles and O. Svoboda,"The Application of Double Conical Journal Bearings in
High Speed Centrifugal Pumps—Parts 1 and 2" Proc. Inst. Mech. Eng., vol. 189, no. 1, p. 221–230, 1975.

[14] S. C. Sharma, R. Sinhasan and S. C. Jain, " An Elastohydrostatic Study of Hole-Entry Hy-brid Flexible Journal Bearing With Capillary Restrictors," Tribol. Int., vol. 26, no. 2,93–107, 1993.

[15] S. Yoshimoto, T. Kume and T. Shitara, "Axial Load Capacity of Water-Lubricated Hydrostatic Conical Bearings With Spiral Grooves for High Speed Spindles," Wear,vol. 31, no. 6, p. 331–338, 1998.

[16] G. Hong, L. Xinmin and C. Shaoqi, " Theoretical and Experimental Study on Dynamic Coeffi-cients and Stability for a Hydrostatic/ Hydrodynamic Conical Bearing," Journal

[17] S. C. Sharma, V. M. Phalle and S. C. Jain, " Influence of Wear on the Performance of a Multirecess Conical Hybrid Journal Bearing Compensated With Orifice Restrictor" Tribol. Int, vol. 44, no. 12, p. 1754–1764, 2011.

[18] S. C. Sharma, V. M. Phalle and S. C. Jain, “Performance Analysis of a Multirecess Capil-lary Compensated Conical Hydrostatic Journal Bearing,” Tribol. Int., vol. 45, no. 5, p. 617–626, 2011.

[19] P. Gertzos K, G. Nikolakopoulos P and A. Papadopoulos C, “CFD analysis of journal bearing hy-drodynamic lubrication by Bingham lubricant,” Tribology International, vol. 41, p. 1190– 1204, 2008.