ENGINEERING RESEARCH JOURNAL (ERJ)
Vol. 1, No. 45 July. 2020, pp 49-53
Journal Homepage: http://erj.bu.edu.eg

Numerical Analysis of Hydrostatic Bearing under Various Oil Film Thicknesses

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Abstract. The flow through a rectangular pocket is described using 2D numerical model and studied by computational fluid dynamics ANSYS fluent 20. It's known that the hydrostatic thrust bearing play a vital role in the design and operation of industrial equipment. The purpose of present work is to study the influence of film thickness change of rectangular hydrostatic pad thrust bearing at constant recess depth of deep and shallow aspect ratios. Numerical simulations of pressure distribution were performed to study the bearing performance under this change. It was clearly established that both for the deep (e/h_0 = 100, 152, 233 and 300)and shallow (e/h_0 = 2, 4, 8 and 16) aspect ratios the pressure distribution be more stable and uniform with film thickness decreases, while the maximum static pressure be constant. Increasing film thickness values out of standard range can take non uniform pressure distribution.

Key words: Bearing, Hydrostatic, CFD, Aspect ratio.

1. INTRODUCTION

Hydrostatic thrust bearing has been much interest due to its wide use in industrial applications. This interest was appeared in many recent researches, which also illustrated that the performance of the hydrostatic bearing changed according to recess aspect ratios. Numerically investigated the recess geometry effect on the pressure pattern in the hydrostatic thrust oil pad journal bearing pocket using e/h_0 (33, 100, 166, 233 and 300) with pocket shapes (elliptical, square, sector and annular). Results were showed that pocket depth has an influence of flow pattern [1]. Pressure pattern of 2D pocket of hybrid journal bearing has been parametric studied based on Navier-Stoke equations. Six values of depth to film thickness ratios were considered, ranging from shallow (4, 8 and 16) to deep (32, 64 and152). Results were noticed that it's difficult to get a net difference between inertia effect and viscous intervening in a recess flow [2]. Numerically, circular and square recesses of hydrostatic bearing have been studied with laminar flow. The relative error for circular hydrostatic bearing was lower than 0.6% and can go up to 15% for rectangular hydrostatic bearing [3]. Quantitative study of film thickness rules on static and seawater thrust bearing dynamic performance was illustrated. Results were showed that as oil film thickness increases load carrying capacity, power losses and static stiffness decreased conversely [4]. The heat pipe effect in aspect of hydrostatic thrust bearing on thermal balance has been examined. Results were presented that oil pad was fabricated with a structure of pipe cooling [5]. By CFD, 3 dimensional pressure distributions have been analyzed using fluent software. Results were showed that when oil film thickness given the dynamic pressure first increased and then decreased with deepening of oil cavity [6]. By using 2D model, the difference between shallow pocket and deep pocket design of hydrostatic thrust bearing have been examined. The pocket depth was increased beyond the nominal film thickness and the effect of depth on capacity diminishes [7]. Land width ratios, pocket depth and restrictions parameters effect on a Jeffcott rotor stability and load carrying capacity has been studied with six pocket hybrid bearing. Simulated results were indicated that to get good performance small land sizes were necessary for shallow bearing and the restrictions parameter increases the capacity and stability [8].

Despite all this great knowledge, yet no study in the literature pointed out the effect of change film thickness at constant aspect ratio on the pressure distribution (stability and capacity) of rectangular oil pad hydrostatic thrust bearing. The present work aims to fill this gap and to study the film thickness effect on shallow recess (e/h_0 = 2, 4, 8 and 16) with e/L= 0.05 and on deep recess ((e/h_0 = 100, 152, 233 and 300) with e/L = 1.3.Using CFD ANSYS FLUENT 20, pressure distribution is presented and compared with similar past researches. The typical geometry of a square recess of a hydrostatic bearing is shown in Fig.1[9].

2. PHYSICAL MODEL

The need for optimum performance of high capacities, low wear, minimum friction at zero speeds, high accuracy and long life, hydrostatic bearing is used in many applications. In the current work, physical model of rectangular hydrostatic pad bearing is presented as a partial section model by using dimensions which are presented in Fig.1.

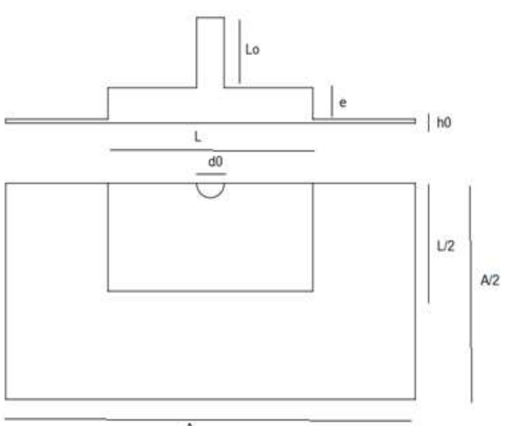

Fig 1: Square Recess of Rectangular Hydrostatic Bearing Flat Pad

Table 1. Various recess design dimensions

Square recess of rectangular pad bearing (A)	37 mm
Deep recess depth to thickness (e/h_0)	100, 152, 233and 300
Shallow recess depth to thickness (e/h_0)	2, 4, 8 and 16
Aspect ratios (deep and shallow)	1.3 and 0.05
Type of control device	orifice
Orifice diameter (d_0)	2.49 mm
Orifice length (L_0)	6 mm
Recess length (L)	18.5 mm

3. NUMERICAL ANALYSIS

Numerical simulations using Ansys Fluent software were run with a 2D model of Square bearing with dimensions illustrated in Table 1. This study included four various depth to thickness ratios of shallow and deep recesses all of them have the same hydraulic diameter as shown in Fig.2.

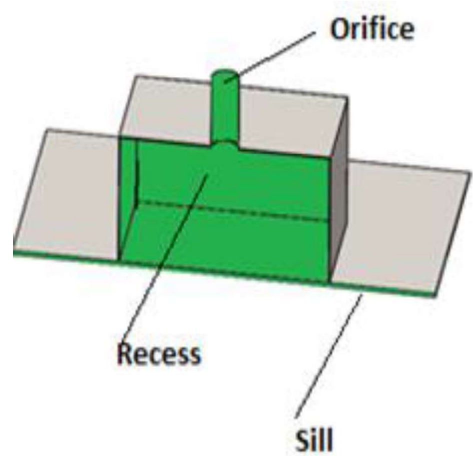

Fig 2: rectangular pad

Boundary conditions are applied as: pressure inlet at the entrance orifice entrance the constant supply pressure at inlet and pressure outlet of zero (Pascal) at outlet. As a result of symmetry between the axial ends of the square bearing, half of the bearing was studied with applied symmetry and no slip boundary conditions. The cell zone condition is set as engine-oil with density of 889 kg/m3 and viscosity of 0.12347 Pa.s.

The pressure field is linked to velocity through SIMPLE algorithm. Turbulence intensity of 5 % set for both inlet and outlet boundary conditions as the flow at this level is considered fully developed. The Tolerance value has been set to reduce the scaled residual all flow parameters fell below the value of 10−5.

4. MODEL VALIDATION

Validation technique examines the reliability of the physical models used in CFD simulations. ANSYS FLUENT 20 using K-ω SST turbulent model is validated by using the numerical results for the recess static pressure and recess Reynolds number of square shape reported in [9] as shown in Figs.3 and 4. On the basis of the results there is a fair agreement between the present CFD work and the published results with acceptable difference

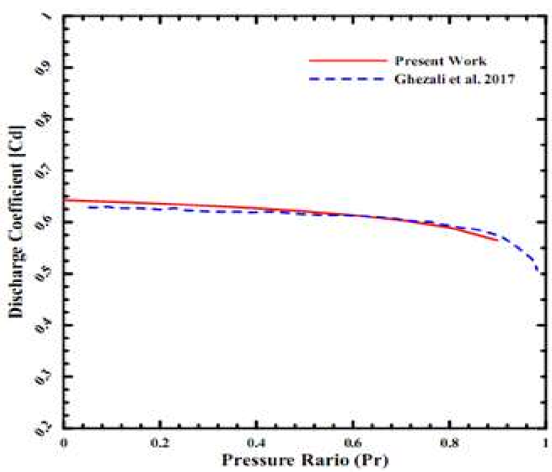

Fig 3:Variation of Discharge Coefficient with Pressure Ratio at

$(P_s = 4bar, \mu = 0.12347\ Pa.s\ and\ e/h_0 = 4)$.

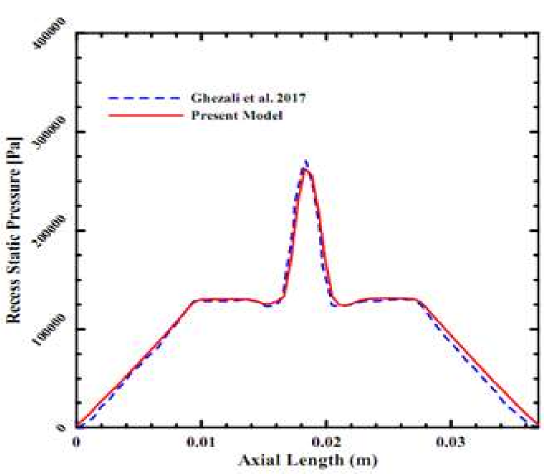

Fig 4: Recess Static Pressure at

$(P_s = 3bar, \mu = 0.12347\ Pa.s\ and\ e/h_0 = 4)$.

5. RESULTS AND DISCUSSION

Performance characteristics of bearing are affected by the bearing capacity and stability which can present by pressure distribution. In this part the pressure distribution are studied under variation recess aspect ratios of deep and shallow and recess depth to thickness ratios. The recess pressure value is calculated by taking the pressure distribution at the exit line of the recess.

5.1 Effect of Film Thickness on Deep Recess Pressure Distribution

The effect of film pressure on recess pressure at different recess depth -to- film thickness ratios (e/h_o) has been studied as the following: e/h_0 = 100, 152, 233 and 300 as shown in Figs 5. There are three regions; first one is the restrictor region where the pressure distribution trend is high pressure uniform in all ratios. The second one is recess region, the pressure distribution in this region be stable and e/h_0=300 is the most stable of all which has the lowest film thickness. The third one is land area; the pressure distribution is decreased linearly in all ratios as shown in figs 6.We can explain that the most favorable capacity and stability are for deep recess with the minimum film thickness.

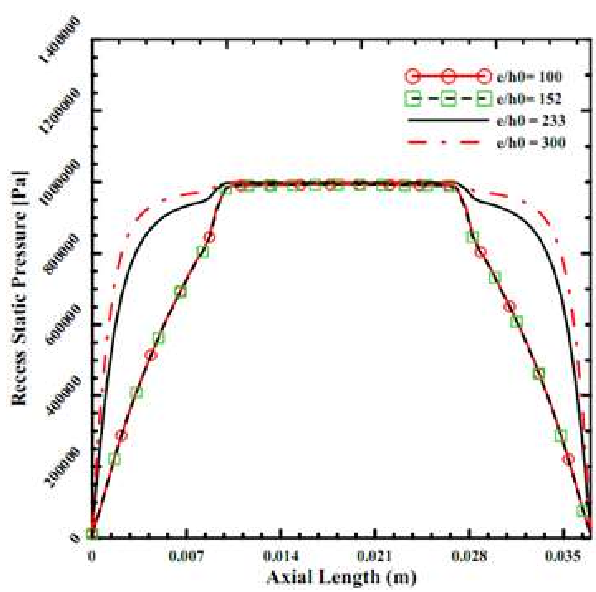

Fig 5: Effect of Film Thickness on the Recess Static Pressure at Deep Aspect Ratios (e/h_0=100, 152, 233 and 300).

5.2 Effect of Film Thickness on Shallow Recess Pressure Distribution

The effect of film pressure on recess pressure at different recess depth -to- film thickness ratios (e/h_o) has been studied as the following: e/h_0 = 2, 4, 8 and 16 as shown in Figs 6.There are three regions; first one is the restrictor region where the pressure distribution trend is pressure little peak that is due to the large increase in feeding Reynolds number as shown in figs7. In this region, this peak decreased with film thickness decreased. The second and third region, the pressure distribution takes the same trend of deep recess.

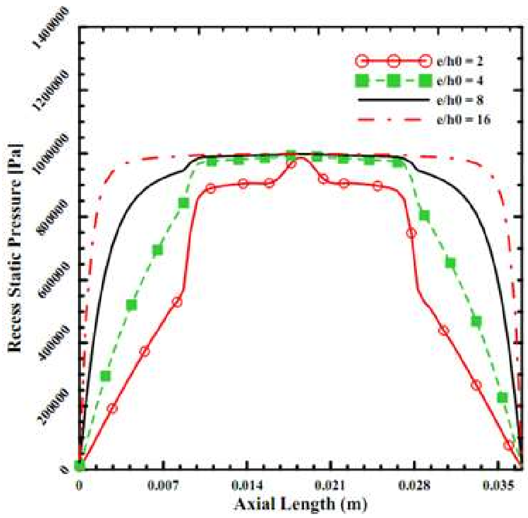

Fig 6: Effect of Film Thickness on the Recess Static Pressure at Shallow Aspect Ratios (e/h_0=2, 4, 8 and 16).

Comparing between shallow and deep aspect ratio, we can notice that by decreasing film thickness at constant recess depth this enhance the stability of bearing as the pressure distribution be more uniform. The capacity of the bearing is almost the same for all ratios as the static pressure value (the maximum) don't change. All of these film thickness in standard range (0.025:0.25)mm and if select value minimum of this range the pressure distribution be non-uniform that's because of solid contact over the range of operating condition [10].

Through previous researches of both shallow and deep recess which uses the same depth to film thickness ratios[1],[2] at constant film thickness, reported that the increase of this ratio give good stability, which also the same of us. they reported that the shallow recess give high capacity than deep but deep recess give high stability and uniform distribution than shallow recess. From fig.7 we can notice that the shallow recess with minimum film thickness gives best performance than deep recess from aspect to stability and uniform distribution.

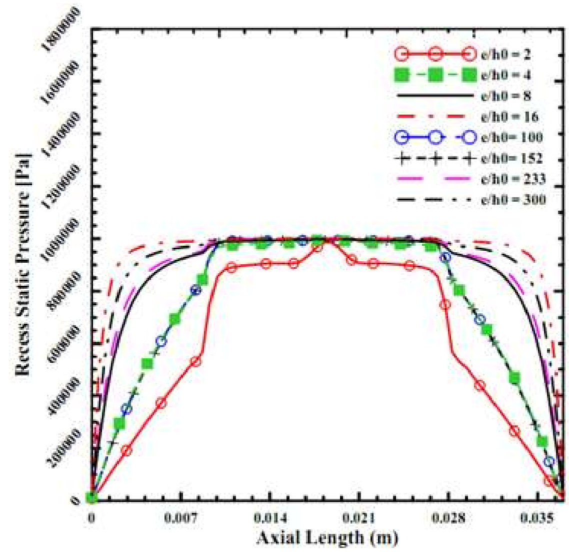

Fig 7: Comparison between Deep and Shallow Recess at $(P_s = 10\ bar \& \mu = 0.12347\ Ps.a)$.

6. CONCLUSION

In this study, various recess depth to film thickness ratios were designed to study the performance of hydrostatic bearing under constant recess depth and various film thickness ratios. Using 2D numerical model and studied using computational fluid dynamics ANSYS fluent 20. Aspect ratios of shallow recess (e/h_0 = 2, 4, 8 and 16) equal 0.05 and on deep recess ((e/h0 = 100, 152, 233 and 300) equal 1.3. By decreasing the film thickness at constant recess depth, above 0.025 mm, shallow recess has more stability than deep recess but the all have the same capacity. So we recommended using small film thickness for all shallow recess and if use deep recess, recommended partly large film thickness.

ACKNOWLEDGMENTS

I'm gratefully acknowledging my professors and thank their efforts.

References

[1] Shen, F., Chen, C. L., & Liu, Z. M. (2014). Effect of pocket geometry on the performance of a circular thrust pad hydrostatic bearing in machine tools. *Tribology Transactions*, *57*(4), 700-714.

[2] Helene, M., Arghir, M., &Frene, J. (2003). Numerical study of the pressure pattern in a two-dimensional hybrid journal bearing recess, laminar, and turbulent flow results. *J. Trib.*, *125*(2), 283-290.

[3] Lin, Y. T., Liao, C. C., Lin, T. Y., & Lin, C. A. (2014). Simulations of flow resistances in circular and square hydrostatic bearings. *Procedia Engineering*, *79*, 114-118.

[4] Jianhua, Z., Dianrong, G., &Qiang, W. (2016, June). Effect of Film Thickness on Load-Carrying Property of Seawater Dynamic-Hydrostatic Hybrid Thrust Bearing.In *International Conference on Intelligent and Interactive Systems and Applications* (pp. 59-65).Springer, Cham.

[5] Li, X., Li, W., Chen, X., Li, M., Chen, H., &Yue, X. (2018). Design and performance analysis on heat pipe hydrostatic thrust bearings based on rectangular oil pad. *Industrial Lubrication and Tribology*.

[6] Shao, J., Zhou, L., Li, H., Yang, X., Zhang, Y., & Chi, M. (2009, August). Influence of the oil cavity depth on dynamic pressure effect of hydrostatic thrust bearing. In *2009 International Conference on Intelligent Human-Machine Systems and Cybernetics* (Vol. 2, pp. 11-14).IEEE.

[7] Johnson, R. E., &Manring, N. D. (2003, January). Sensitivity studies for the shallow-pocket geometry of a hydrostatic thrust bearing. In *ASME International Mechanical Engineering Congress and Exposition* (Vol. 37173, pp. 231-238).

[8] Chen, C. H., Kang, Y., Huang, Y. N., Chu, C. H., &Teng, J. T. (2002). The restrictive effects of capillary compensation on the stability of the Jeffcott rotor-hybrid bearing system. *Tribology international*, *35*(12), 849-855.

[9] Ghezali, F., Bouzidane, A., & Thomas, M. (2017). 3D Numerical investigation of pressure field of an orifice compensated hydrostatic bearing. *Mechanics & Industry*, *18*(1), 101.

[10] Mott, R. L., & Tang, J. (2004). *Machine elements in mechanical design* (Vol. 4). Upper Saddle River: Pearson Prentice Hall.