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Effect of Geometrically Imperfect Journal and Recess Geometry on the Performance of Two Lobe/ Circular 4 Pocket Hybrid Journal Bearing System

Category: Fluid Film Bearings

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Abstract- The present work is aimed to study the performance of a two lobe geometrically imperfect hybrid journal bearing system having different geometric shapes of recess. The finite element method has been used to numerically compute the performance characteristic parameters of a two lobe 4 pocket bearing system which include minimum fluid film thickness and fluid film stiffness coefficient. In the present work four different geometric shape of recess, i.e. circular, elliptical, square and triangular, and a geometrically imperfect journal, i.e. barrel shape journal have been analyzed. The comparative performance of all bearings has been made on the basis of the same bearing operating and geometric parameters for the same ratio of bearing to pocket area. The numerically simulated results indicate that an elliptical recessed shaped two lobe bearing provides the largest value of direct fluid film stiffness coefficient in vertical direction vis a vis other bearings studied in the present study.

1.Introduction- Bearings plays a crucial role on the overall operation of the machines. The plain cylindrical journal bearing which is generally used in the rotating machinery do not meet the stability requirements of high speed machinery. Under such conditions the plain circular bearings are replaced by non-circular journal bearings. Multilobe journal bearings are widely used to suppress whirl instability conditions. In recent times the multilobe bearings have been studied extensively. Many investigators have carried out theoretical and experimental studies to predict the performance of multilobe bearings. The pioneering work concerning the multilobe bearing has been carried out by Pinkus [1, 2]. He calculated the static characteristics of two lobe and three lobe bearings for different aspect ratio. Studies [4,5] details the comparative study of two lobe hybrid worn/unworn journal bearings compensated with different flow control devices. Nevertheless, the bulk of the studies deals with four pocketed hydrostatic/hybrid journal bearing system having a rectangular form of recess due to the ease in its fabrication. Now a days it becomes possible to successfully manufacture various geometric shapes of recess to be used in the bearing systems. In recent times, many researchers dedicated their research activities to investigate the influence of the geometric shapes of recess on the performance of hydrostatic/ hybrid journal bearing. An early study by Franchek and Childs [6] experimentally determined the static and dynamic performance characteristics of four type of hybrid journal bearings: a square, a circular, a triangular and a square recessed with angled-orifice bearings. Studies [7-10] dealing with the various shapes of recess were mainly confined to circular hydrostatic/hybrid journal bearings. Further, the majority of theoretical studies assumes journal surfaces to be perfectly smooth. However, in machining field, the periodic surface disturbance on the a machined surface is exist which directly influence the bearing performance.On a macro scale level, journal surface are accompained with periodic surface disturbanceses and referred to as geometric irregularities of journal (i.e. barrel shape). Various researcher have incorporated the geometric irregularities of journal in the analysis to evaluate the bearing performance. Studies [11-16] examined the behavior of wavy journals and its influence on the performance of hydrodynamic/hybrid journal bearing theoretically and experimentally. A thorough review of literature indicates that noncircular bearings are used quite widely. The shape of recess used in the multirecess journal bearings is mainly a rectangular one. No study has yet been reported in literatures which studies the influence of geometric shape of recess in multirecess noncircular hydrostatic/hybrid journal bearings. Thus, in the present study the combined influence of geometric shape of recess and geometric irregularity of the journal on the bearing performance has been studied. Sothat a designer can make better use of geometric shape of recess in design process.

2.Analysis

The modified Reynolds equation for flow of lubricant in the clearance space of the bearing(Fig.1) in a non-dimensional form is expressed as follows[2,4,10].

$$\frac{\partial}{\partial\alpha}\left[\frac{\bar{h}^3}{12}\left(\partial\bar{p}/\partial\alpha\right)\right]+\frac{\partial}{\partial\beta}\left[\frac{\bar{h}^3}{12}\left(\partial\bar{p}/\partial\beta\right)\right]=\frac{\Omega}{2}\left[\frac{\partial\bar{h}}{\partial\alpha}\right]+\frac{\partial\bar{h}}{\partial\bar{t}} \qquad (1)$$

2.1. Fluid-film thickness

The fluid film thickness for a geometrically imperfect two lobe hybrid journal bearing is expressed as follows [7,8,15].

$$\bar{h} = \frac{1}{\delta} - \left[\bar{X}_j - \bar{X}_L^{\,i}\right]\cos\alpha - \left[\bar{Z}_j - \bar{Z}_L^{\,i}\right]\sin\alpha + \bar{h}_{ir} \qquad (2)$$

where $\bar{h}_{ir}$ is contribution of geometric errors to the film thickness ($\bar{h}$)[12,13]

$$\bar{h}_{ir} = -\bar{a}_1 \sin\left(\frac{\pi\beta}{2\lambda}\right) \quad \text{(For barrel shape journal)} \qquad (3)$$

2.2 Finite element formulation

The lubricant flow field domain has been discretized using four-noded quadrilateral isoparametric elements. Following the usual assembly procedure for the elements in the entire discretized flow field, the following global system equation is obtained:

$$\left[\bar{F}\right]\{\bar{p}\} = \{\bar{Q}\} + \Omega\{\bar{R}_H\} + \dot{\bar{X}}_J\{\bar{R}_X\} + \dot{\bar{Z}}_J\{R_z\} \qquad (4)$$

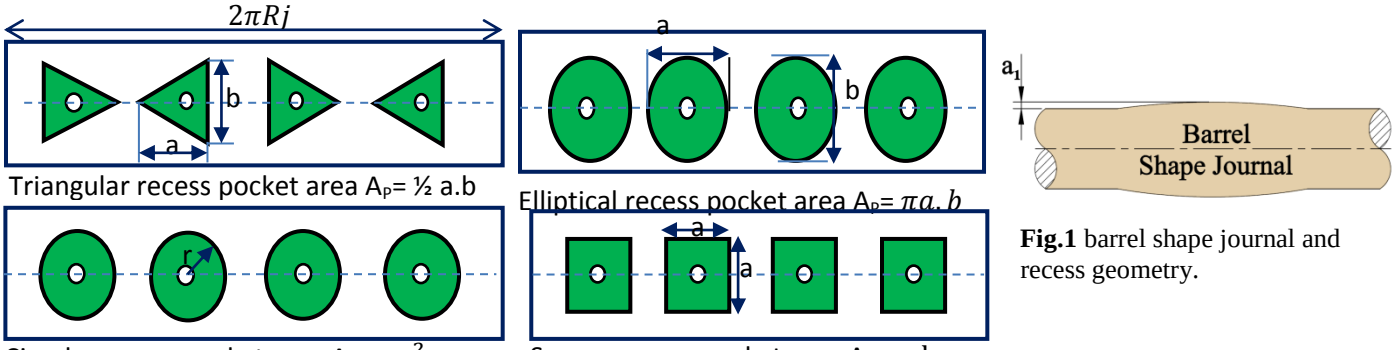

Fig.1 barrel shape journal and recess geometry.

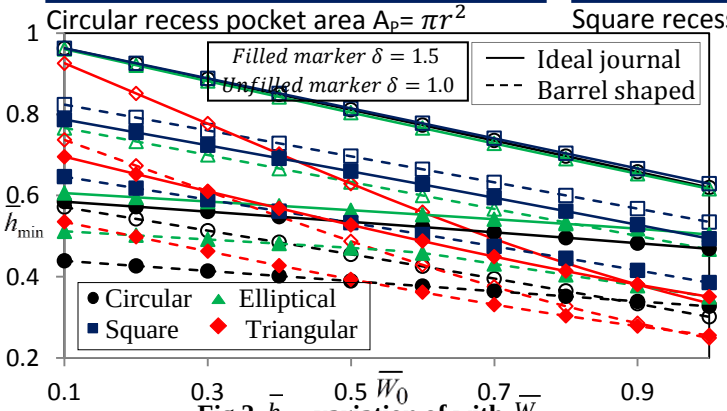

Fig.2 $\bar{h}_{min}$ **variation of with** $\bar{W}_0$

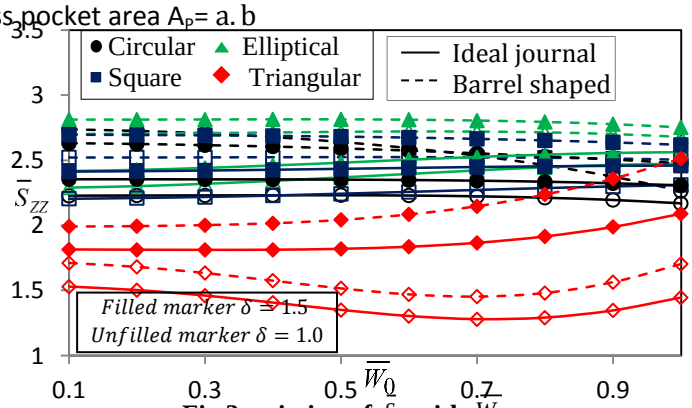

Fig.3variation of $\bar{S}_{ZZ}$ **with** $\bar{W}_0$

3.Result and discussion

The governing global system equation (4) has been solved using FEM incorporating appropriate boundary conditions. A computer program based on FORTRAN 77 has been developed to compute the performance of a capillary compensated two lobe hybrid journal bearing system. The values of geometric and operating parameters have been judiciously selected from the available literatures $(\lambda = 1.0, \bar{C}_{S2} = 0.5, \bar{a}_b = 0.14, \Omega = 0.5, \theta = 18^0, \bar{a}_1 = 0.2)$[2,4,8,11].Results from the present study have been validated with the previously published study[3].The performance characteristics of two lobe bearing viz. fluid film thickness, direct stiffness/damping coefficients and stability threshold speed margin with respect to external load have been computed and illustrated as follows.

Minimum fluid film thickness($\bar{h}_{min}$ **)** Fig.2 shows the variation of $\bar{h}_{min}$ against the external load. It may be observed that a two lobe bearing provides the lower value of $\bar{h}_{min}$ as compared to circular bearing for various types of recess shape. Barrel shape journal exhibits lower value of $\bar{h}_{min}$ than ideal journal for a given range of external load. When two lobe bearing operates with barrel shape journal, a square recessed bearing exhibits the larger value of $\bar{h}_{min}$, whereas circular recessed bearing provides the lowest value of $\bar{h}_{min}$ upto $\bar{W}_0$ =0.5 and beyond that triangular recessed bearing provide the lowest value of $\bar{h}_{min}$ among all the bearing configurations studied. Thus, a bearing designer may select a proper shape of a recess to ensure safe operating value of $\bar{h}_{min}$ to avoid metal to metal contact.

Fluid film stiffness($\overline{S}_{ZZ}$) Fig. 3 depicts that two lobe bearing provides the highest value of $\overline{S}_{ZZ}$ as compared to circular bearing for all types of recessed bearing configurations. It is found that the barrel shape journal with elliptical recessed bearing configuration provide the largest value $\overline{S}_{ZZ}$ for two lobe and circular bearings. A two lobe elliptical recessed bearing with barrel shape journal provides the higher value of $\overline{S}_{ZZ}$ than that of circular bearing. In case of barrel shape journal, the value of $\overline{S}_{ZZ}$ is observed to be increased by a percentage of 25.45% for two lobe elliptical recessed bearing as compared to square recessed circular bearing configuration at a specified value of load $\overline{W}_0$ =0.5

4.Conclusion

1. The performance characteristic parameters (static and dynamic) of two lobe and circular hybrid journal bearings change significantly due to the combined influence of geometric shape of the recess and geometric irregularity of journal.
2. In case of two lobe bearing,from the minimum fluid film thickness ($\overline{h}_{\min}$) point of view, square recessed bearing with barrel shaped journal has less probability of metal to metal contact among all the bearings studied.

   $\overline{h}_{\min}|_{square} > \overline{h}_{\min}|_{circular} > \overline{h}_{\min}|_{elliptical} > \overline{h}_{\min}|_{triangular}$ (for circular bearing with ideal journal)

   $\overline{h}_{\min}|_{square} > \overline{h}_{\min}|_{elliptical} > \overline{h}_{\min}|_{circular} > \overline{h}_{\min}|_{triangular}$ (for circular bearing with barrel shaped journal)

   $\overline{h}_{\min}|_{square} > \overline{h}_{\min}|_{elliptical} > \overline{h}_{\min}|_{circular} > \overline{h}_{\min}|_{triangular}$ (for two lobe bearing with barrel shaped and ideal journal)
3. Among all the recessed shape used in the study, the elliptical recessed two lobe/circular hybrid journal bearing with barrel shape journal is observed to provides the largest value of fluid film stiffness($\overline{S}_{ZZ}$).

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