

## Surface roughness effect on the Performance of 3-lobe symmetric hole entry hybrid journal bearings

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**Keywords:** 3-lobe, Surface roughness, Hybrid, Journal bearing

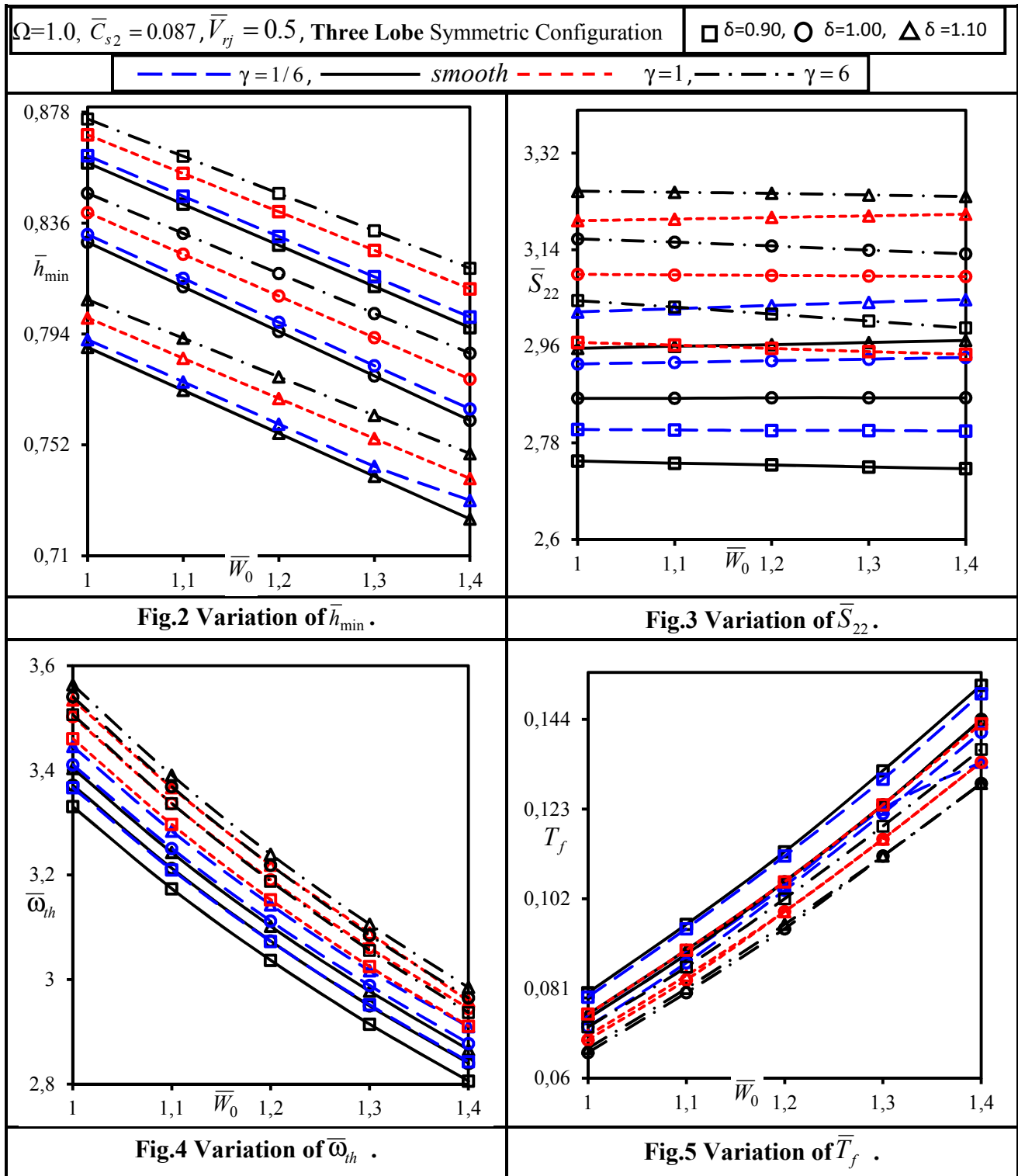
**Abstract:** The present paper, evaluates the effect of surface roughness on the performance characteristics of capillary compensated 3-lobe symmetric hole entry hybrid journal bearing. The effect of surface roughness patterns viz; transverse, isotropic, longitudinal and smooth, on bearing performance is presented for different values of offset factor. A modified form of Reynold's equation in conjunction with restrictor flow equation is solved by using Galerkin's technique of FEM. The numerically simulated results of the study indicate that the surface roughness orientation patterns affect the performance of 3-lobe hybrid journal bearing system significantly. Further, it is noticed that the longitudinal roughness pattern provides enhanced value of rotor dynamic coefficient. To have an improved dynamic performance, a judicious selection of offset factor and surface roughness pattern parameter is essential.

**Introduction:** The circular journal bearings are prone to oil whirl or self-excited vibrations. If the amplitude of these self-excited vibrations increases, it may cause a serious problem. From the time when bearing instability was noticed, many multilobe bearing configurations have been developed by the bearing designer to improve the stability of bearing systems. As a consequence of this, many studies related to non-circular journal bearing have been reported in the literature [1-10]. The literature related non-circular hydrodynamic journal bearings is quite exhaustive [1-5]. Schuller [2] carried out experimental stability study of tilted 3-lobe grooved and ungrooved plain journal bearing. They reported the more stability for tilted 3-lobe grooved bearing. A scan of available literature concerning the non-circular hybrid journal bearings reveals that there exists very few studies reported in the published literature [6-10]. Ghosh et al. [6] evaluated the rotordynamic coefficients of multilobe recessed hybrid journal bearing by using a small amplitude perturbation analysis. Phalle et al. [8] carried out an analytical study concerning the influence of wear on the performance of a membrane compensated 2-lobe four-pocket hybrid journal bearing system. The result of their study indicates that the performance of the bearing is greatly affected by wear. Very recently Kushare et al. [9,10] performed an analytical study of two lobes worn non-recessed hybrid journal bearing operating with non-Newtonian lubricant. They reported that the non-linear behavior of the lubricant and wear have a significant effect. Further, the reported studies in available literature assumed that bearing surfaces are smooth, however, even though, the advancement in manufacturing of finishing processes; finished surface exhibits imperfections which makes journal and bearing surfaces rough. The surface roughness heights are found to be the order as that of the fluid-film thickness of the journal bearing. As a result of this, it alters the performance of the bearing. Therefore, to have a realistic bearing performance data, it becomes imperative to consider the effect of surface roughness in the analysis. Last few years many studies related to the influence of surface roughness on the multilobe hydrodynamic [11-13] and circular hybrid bearing journal bearing [14] reported in the literature. Patir and Cheng [11] studied influence of rough surface on bearing performance by developing an average Reynold's equation for the rough surface in terms of

**Analysis:** The modified average Reynolds equation expressed in terms of flow factors and average nominal fluid-film thickness is expressed in non-dimensional form as:[14,15]

where  $\overline{F}_0$ ,  $\overline{F}_1$ , and  $\overline{F}_2$  are the cross-film viscosity integrals. the factors  $\phi_x, \phi_y$  and  $\phi_s$  are known as the flow factors and shear flow factor.

$$\bar{h}_T = \begin{cases} \frac{\bar{h}}{2} \left( 1 + \operatorname{erf} \left( \frac{\Lambda \bar{h}}{\sqrt{2}} \right) \right) + \frac{1}{\Lambda \sqrt{2\pi}} e^{-(\Lambda \bar{h})^2/2} & \text{for } \Lambda \bar{h} < 3 \\ \bar{h} & \text{for } \Lambda \bar{h} \geq 3 \end{cases} \quad (2)$$
$$\bar{h} = \frac{1}{\delta_l} - (\bar{X}_J - \bar{X}_L^i) \cos \alpha - (\bar{Z}_J - \bar{Z}_L^i) \sin \alpha + \Delta \bar{h} \quad (3)$$



**Result and discussion:** The performance of 3-lobe journal bearing have been presented in terms of  $\bar{h}_{\min}$ ,  $\bar{S}_{22}$ ,  $\bar{\omega}_{th}$  and  $T_f$ . The validity of the developed numeric model and computed results is established by comparing the results with published results of Ramesh et al[13]. Figure 2 depicts the variation of nominal minimum fluid-film thickness ( $\bar{h}_{\min}$ ). The value of  $\bar{h}_{\min}$  for a rough journal bearing is higher than the smooth surface bearing. It shows the increased trend when the value of surface roughness pattern parameter changes from smooth surface to  $\gamma=6$  for all the values of offset factor. The value of  $\bar{h}_{\min}$  is significantly affected due to the surface roughness orientation. The bearing with offset factor  $\delta=1.1$  operates at lower value of  $\bar{h}_{\min}$  for smooth surface than the other

surface orientation. The longitudinal roughness pattern  $\gamma = 6$  restrict axial flow of the lubricant and permits the lubricant flow in circumferential direction only, as a consequence of this, bearing operates at a higher value of  $\bar{h}_{\min}$  for all the values of offset factor. Therefore, to maintain the required value of minimum fluid film thickness ( $\bar{h}_{\min}$ ), the designer may use the following criterion for all the values of  $\delta$ .  $\bar{h}_{\min}|_{\text{smooth}} < \bar{h}_{\min}|_{\gamma=1/6} < \bar{h}_{\min}|_{\gamma=1.0} < \bar{h}_{\min}|_{\gamma=6}$ . Fig.3 shows the variation of fluid-film stiffness coefficient ( $\bar{S}_{22}$ ) with respect to external load ( $\bar{W}_0$ ). At constant value of external load  $\bar{W}_0$ , the value of  $\bar{S}_{22}$  is get increased as the bearing becomes more rough for 3- lobe symmetric hole-entry journal bearing. The longitudinal roughness pattern  $\gamma = 6$  with  $\delta = 1.1$  provides largest value of  $\bar{S}_{22}$  than smooth and transverse roughness pattern bearing. The increase in the value of  $\bar{S}_{22}$  is observed of the order of 14.25% when the roughness pattern changes from smooth surface to longitudinal surface  $\gamma = 6$ . A 3-lobe bearing with offset factor  $\delta = 0.9$  provides reduced value of  $\bar{S}_{22}$  for all roughness orientation patterns. The following pattern of increase in the value of  $\bar{S}_{22}$  is noticed for all the values of offset factor.  $\bar{S}_{22}|_{\gamma=6} > \bar{S}_{22}|_{\gamma=1} > \bar{S}_{22}|_{\gamma=1/6} > \bar{S}_{22}|_{\text{smooth}}$ . The variation of the threshold speed ( $\bar{\omega}_{th}$ ) with respect to external load ( $\bar{W}_0$ ) is shown in Fig.4. From Fig.4, it may be noticed that for the value of offset factor, longitudinally oriented roughness pattern ( $\gamma = 6$ ) provides the enhanced value of the stability threshold speed margin  $\bar{\omega}_{th}$ . The bearing with offset factor  $\delta = 0.9$  provides reduced value of the stability threshold speed margin  $\bar{\omega}_{th}$  when bearing surface is smooth. As the value of the external load increases the stability threshold speed margin decreases, however change in bearing geometry defined by offset factor  $\delta \geq 1.0$  and roughness orientation pattern ( $\gamma = 1/6, 1, 6$ ) compensates the loss occurred by enhancing the value of  $\bar{\omega}_{th}$ . Fig. 5 depicts the variation of frictional torque ( $T_f$ ). It may be noticed that for a specified value of  $\bar{W}_0$ , the value of  $T_f$  is higher for smooth surface bearing than rough bearing. The transverse ( $\gamma = 1/6$ ) and isotropic ( $\gamma = 1$ ) surface patterns have a substantial effect on the value of frictional torque. For a smooth and transverse surface pattern, the value of  $T_f$  gets increased in the edict of 17% at while at the value of offsets factor  $\delta = 1.1$ , the longitudinal roughness pattern orientation shows the decrease in the value of by a factor of 15% when compared with smooth bearing.

### Conclusion:

From the results of the study, the following conclusions have been made:

- The transverse roughness pattern provides the lower value of  $\bar{h}_{\min}$  while longitudinal roughness pattern provides enhanced value of  $\bar{h}_{\min}$ .
- The longitudinal roughness pattern provides enhanced value of fluid-film stiffness coefficient ( $\bar{S}_{22}$ ) than transverse and isotropic roughness pattern.
- The value of offset factor more than one provides the improved value of threshold speed margin for all the orientation of roughness patterns.
- Therefore, to have enhanced value of bearing performance characteristics proper selection of offset factor  $\delta$  and roughness orientation  $\gamma$  is required.

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