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Research Article

STUDIES ON THE EFFECT OF POSITIVE FULL WAVE TYPE TRANSVERSE TEXTURES ON THE PERFORMANCE OF POROUS JOURNAL BEARINGS

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ABSTRACT
Present investigation involves a sensible approach for the formulation of a texture pattern to predict the performance of a porous journal bearing. In this article, an investigation has been made to compare the performance of a porous journal bearing by considering the type of textures, i.e., positive full wave in transverse direction. The Governing equations adopted are solved numerically through finite difference approach for the analysis. The parameters such as texture depth, permeability parameters, shaft speed, eccentricity ratios etc. are varied to find the results. The results indicate that the incorporation of textures on the bearing surface deprive the performance. The performance characteristics viz., load carrying capacity decreases significantly, however, increase in shaft speed increases the load carrying capacity.

Keywords: *Texture, Porous Journal Bearing, Transverse, Positive Full Wave*

INTRODUCTION
Hydrodynamic bearings have been used in smaller as well as larger capacities for wide range of applications since long time. The increasing range of tribological applications from the industrial machinery to recent applications in micro fabrication has re-energized its importance. Researchers have adopted suitable considerations for enhancing fluid film bearings performance. In this manuscript, a texture pattern i.e., positive full wave type in transverse direction has been incorporated on the full porous bearing surface to inspect the performance behaviours.

From the literature study, a number of texture patterns have been devised by various researchers to test the reliability of various machine elements to investigate the performance of different machine elements such as bearings, shafts, axles, seals etc. A number of authors worked with the effects of roughness on the bearing performance (Gururajan and Prakash, 1999; Elsharkawy, 2005; Naduvinamani and Patil, 2009). Kango *et al.,* (2012), Naduvinamani *et al.,* (2002), Sharma and Pandey (2010) showed the texture studies to find the overall performance of the journal bearings. Siripuram *et al.,* (2004) presented a numerical study of the effects of different shapes of micro asperities in sliding surface lubrication for hydrodynamic films. Positive and negative asperities of constant heights are considered with circular, square, diamond, hexagonal, and triangular asperities give the smallest leakage rate whereas, the square asperities provide the largest. Lu *et al.,* (2007) investigated the dimple effect on the Stribeck curve of journal bearings experimentally. Authors pointed out that the typical friction a characteristic of a dimpled journal bearing is similar in trend to that of a conventional bearing, as prescribed by Stribeck curve. Further they reported that proper dimple size, shape and depth are essential to improve the friction performance and that it becomes more pronounced if oil with lower viscosity is utilized. Tala-ighil *et al.,* (2007) analyzed two cases, first one in which the shaft is assumed to be smooth and rigid and the second one in which the bearing surface is numerically textured with spherical dimples. The numerical results indicate that textures affect the most important bearing characteristics viz., film thickness, pressure distributions, axial film flow, and frictional torque. The analysis of spherically dimpled surface indicates that appropriate selection of size, depth, and number of dimples may affect bearing characteristics. De Kraker *et al.,* (2004) found that the use of a Reynolds equation to study the effects of texture will be valid if dimple depth is greater than minimum film thickness of the lubricant in the fluid film lubrication. Kango and Sharma (2010) investigated the effect of positive micro-grooving at different locations on the journal bearing surface. The authors have also performed a comparative study of sinusoidal, full and half wave positive micro grooving and observed that longitudinal sinusoidal roughness is best suited for decreasing the friction force. Sharma *et al.,* (2014) studied the combined influence of surface texturing with couple stress fluids for a finite journal bearing with JFO boundary conditions. It has been observed from their study that load carrying capacity gets increased with couple stresses for smooth journal bearings at different eccentricity ratios. However, the increase in load carrying capacity with texture marks only at low eccentricity ratios. Moreover, at low eccentricity ratio and for low values of dimple depth, the combined effects of texturing with couple stress fluids improves the load capacity of journal bearing while it decreased the load capacity at about 20% in case of high values of dimple depth and couple stress parameter.

Bujurke *et al.,* (2014) investigated the effect of surface roughness on the squeeze film characteristics of long porous partial journal bearings with couple stress fluids as lubricant. The Stokes couple stress fluid model was included to account for the additives effects of lubricant. The Christensen's stochastic of rough surfaces was used to derive the stochastic Reynolds type equation accounting for the surface roughness. The non-linear first order differential equation governing the journal center movement is solved numerically by using the fourth order Runge-Kutta method. They found that the effect of couple stresses was to increase the load carrying capacity and to increase the response time and the effect of roughness was to increase (decrease) the load carrying capacity and the response time for transverse (longitudinal) roughness pattern. Naduvinamani *et al.,* (2006) also described a theoretical investigation of the narrow porous journal bearing operated with couple stress fluids and showed a significant increase in load carrying capacity and decrease in coefficient of friction when compared to simple Newtonian case. The introduction of texturing in porous bearings was given by Sharma *et al.*, [2014] (Naduvinamani *et al.*, 2002) and compared the three different zones with combined influences of surface texturing and non-Newtonian fluid effects. A combination of different configurations on the bearing surfaces were taken and are compared for the performance characteristics. In this article, a numerical study is being accomplished to find the influence of positive full wave transverse type of texture on the performance characteristics of porous journal bearing i.e., fluid film pressures, load carrying capacity, coefficient of friction etc. The results are also compared with smooth case.

Mathematical Modelling

Figure 1 shows schematic representation of a smooth porous journal bearing. The mathematical and numerical model for the journal-bearing system has been given by Reynolds equation. Finite difference method has been used for calculating the pressure & other parameters numerically by changing the differential Reynolds equation into discretised form. For the surface texturing, the positive full wave equation has been considered.

The Reynolds equation for an incompressible, iso-viscous fluid rheology of the bearing system for a combination of flow in the bearing clearance and that within the porous wall is given by Sharma *et al.*, (2014)

$$\frac{\partial}{\partial x}\left(\frac{h^3}{\eta}\frac{\partial p}{\partial x}\right)+\frac{\partial}{\partial z}\left(\frac{h^3}{\eta}\frac{\partial p}{\partial z}\right)=6U\frac{dh}{dx}-12v_0$$

The fluid flow through porous region is governed by Darcy's law and is given by Naduvinamani *et al.*, (2002)

$$v_0=-\frac{\partial p}{\partial y}\frac{\varphi}{\eta}$$

The equation for positive full wave type surface roughness can be given from Kango and Sharma (2010) as

$$\delta_f=-\left(\frac{4*A}{\pi}\right)\left[\sum_{q=2,4,6,..\infty}\frac{\cos(qC)}{q^2-1}\right]+\left(\frac{2*A}{\pi}\right)$$

For transverse roughness

$$C = \frac{\pi * r * \theta}{w}$$

Where w is the wavelength of asperity and A is the amplitude, r is the radius of shaft and q is the even integers.

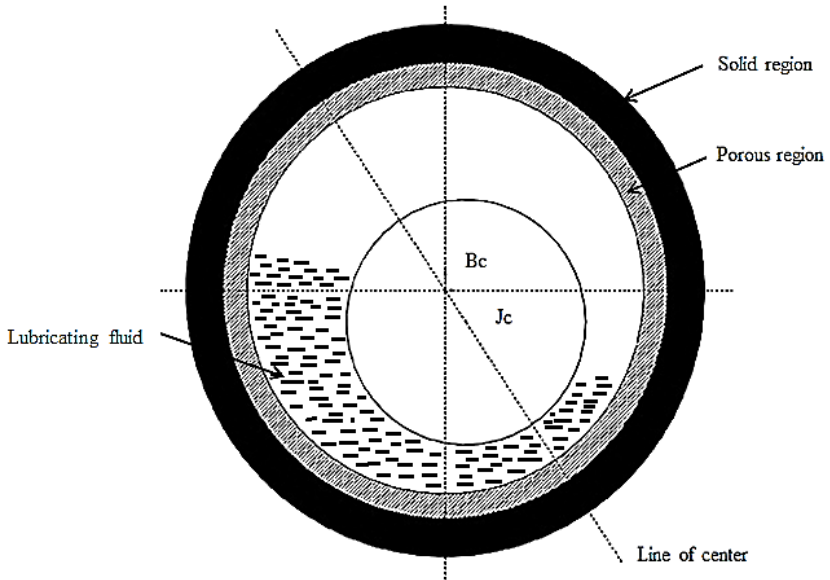

Figure 1: Schematic Representation of a Smooth Porous Journal Bearing

The type of wave type of texture adopted in this work is shown in Figure 2. The film thickness equation for a smooth journal bearing and a textured bearing can be given as:

$$h = c(1 + \varepsilon\cos\theta)$$

$$h_s = h - \delta_s$$

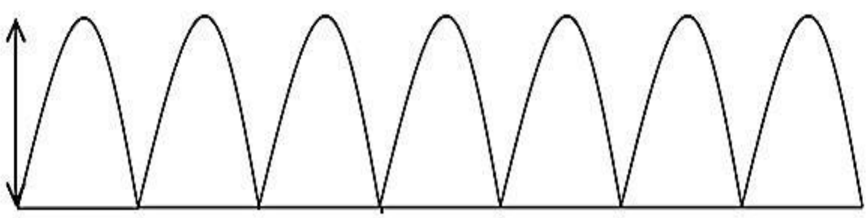

Figure 2: Typical Representation of a Positive Full Wave Type Texture

Boundary Conditions: Reynolds boundary conditions are taken for the present model

$$p = 0 \text{ at } \theta = 0\ ,\ 360^{o}$$

$$p = 0 \text{ and } \frac{\partial p}{\partial \theta} = 0 \text{ at } \theta = \theta_c, \theta_c = \pi + \delta$$

Where $0 < \delta < 90^{\circ}$

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The load carrying capacity can be numerically calculated with the equation given below as

$$W = \int_0^1 \int_0^{2\pi} p\, r\, d\theta\ dz$$

In the numerical analysis, finite difference method has been adopted to achieve the solution through 150 nodes in circumferential direction and 48 nodes in axial direction. The modified Reynolds equations for both models are solved numerically by using Gauss- Seidel method with an over relaxation factor of 1.5-1.7. The following convergence criterion has been adopted for the numerical solution:

$$\sum\sum\left|\frac{\left(p_{i,j}\right)_k-\left(p_{i,j}\right)_{k-1}}{\left(p_{i,j}\right)_k}\right| < 0.0001$$

RESULTS AND DISCUSSION

The input parameters used in this work have been taken from Sharma and Kango (2010) and are presented in Table 1. Results obtained through the present work have been validated with the corresponding results of Jang and Chang (1988) for smooth bearing. The results presented in Figure 3 have been found to be matching considerably well. While validating due care has been taken for considering all the input parameters and other conditions.

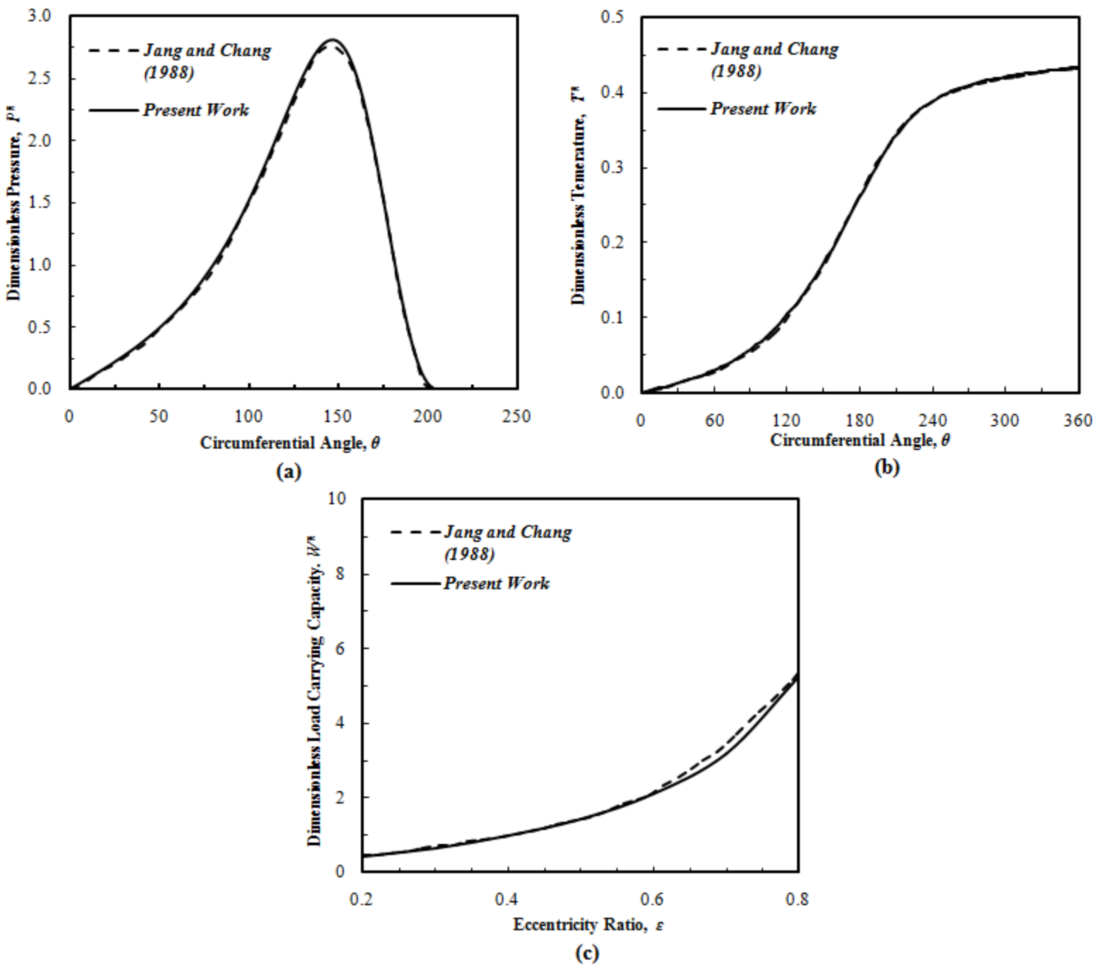

Figure 3: Validation of the Present Work (a) Dimensionless Pressure, (b) Dimensionless Temperature, (c) Dimensionless Load Carrying Capacity with the Work of Jang and Chang (1988)

Table 1: Input Data

Parameters	**Value**
Inside diameter of the Bearing bush (m)	0.04
Length of bearing (m)	0.04
Radial clearance (m)	0.00005
Radius of shaft (m)	0.02
Porous wall thickness (m)	0.008
Dynamic viscosity (Pa s)	0.08
Amplitude (µm)	5
Shaft speed (rpm)	1500, 3000
Eccentricity ratio	0.1, 0.2, 0.3, 0.4, 0.5
No. of asperities	10, 50
Permeability parameters	0.005, 0.01, 0.05, 0.1

Before calculating the final results, a comparison has been made to find which configuration gives maximum enhancement in fluid pressure which further results in finding the best configuration for other bearing performance parameters such as load carrying capacity, coefficient of friction etc. Figure 4 presents the comparison between all configurations and trend clearly shows that the configuration for partial texture (48º to 120º) gives maximum enhancement in fluid film pressures among all cases. It has also been interesting to find that the full texture (0º to 360º) gives poorer performance than smooth surface case. So, it has been observed that the location of texture is an important parameter in improving the performance of the porous bearing.

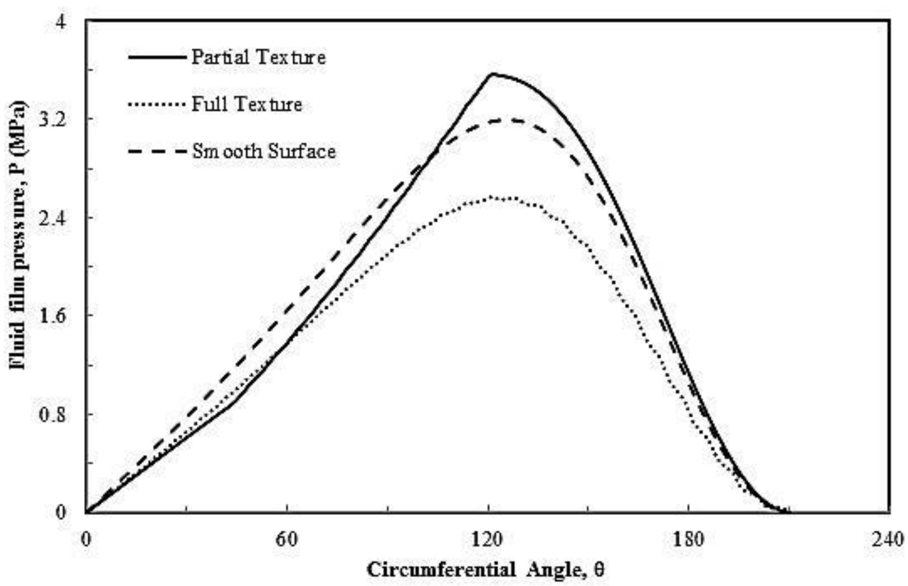

Figure 4: Comparison for Fluid Film Pressure Distribution for Smooth, Fully Textured (0º to 360º) and Partially Textured (48º to 120º) [N=3000 rpm, ε = 0.3, µ=0.08, ψ=0]

The results are calculated at two different shaft speed (N=1500 rpm, 3000 rpm). The permeability parameter is also an important parameter for analyzing the performance of porous journal bearing. The combined influence of texturing and permeability parameter has been taken into account to find performance parameters such as load carrying capacity (*W*), coefficient of friction (*COF*) etc. Figure 5 depicted the load carrying capacity at different permeability parameters for low shaft speed (N=1500 rpm). The permeability parameter is varied from 0 to 0.1 as suggested by many authors. It has been observed that the load carrying capacity reduces significantly with increase in permeability parameters and reduction is larger at high values. Similar, trends has been obtained for coefficient of friction (*COF*), with increasing permeability parameter, *COF* also increases. The results are also calculated for high shaft speed as shown in Figure 6. It has been observed that the load carrying capacity is higher in case of high shaft speed (3000 rpm) comparable with low shaft speed (1500 rpm). However, there is no much significant difference in coefficient of friction values for both cases.

Figure 5 and 6 reveals that the performance of a porous journal bearing is more advantageous in case of optimized texture location (48º to 120º), high value of shaft speed (*N*=3000 rpm) and an intermediate value of permeability parameter (ψ=0.01). So, additional results are investigated on the basis of these observations.

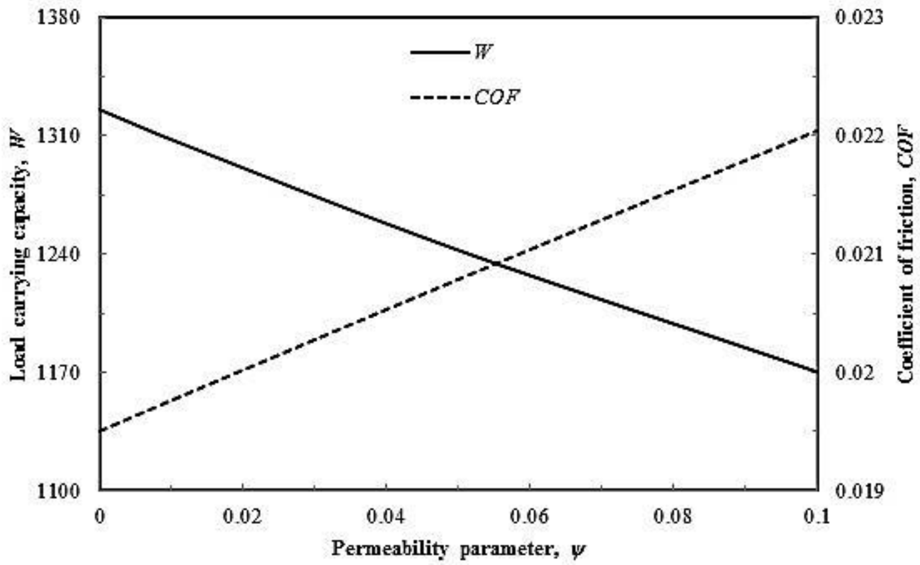

Figure 5: Influence of Permeability Parameters on Load Carrying Capacity (*W*) and Coefficient of Friction (*COF*) at Low Shaft Speed (N=1500 rpm, ε=0.3)

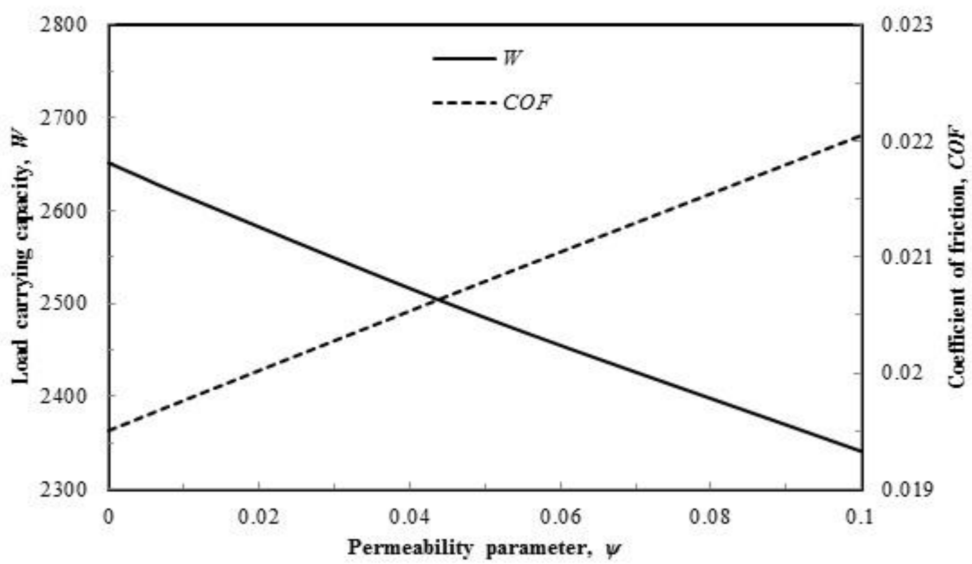

Figure 6: Influence of Permeability Parameters on Load Carrying Capacity (*W*) and Coefficient of Friction (*COF*) at Low Shaft Speed (*N*=3000 rpm, ε=0.3)

Figure 7 presents the load carrying capacity and coefficient of friction by including these input parameters (location, shaft speed, permeability parameter etc.) with the variation in the values of eccentricity ratios. It has been found that the load carrying capacity enhances with increase in value of eccentricity ratio. Moreover, the coefficient of friction values reduce with increase in eccentricity ratios.

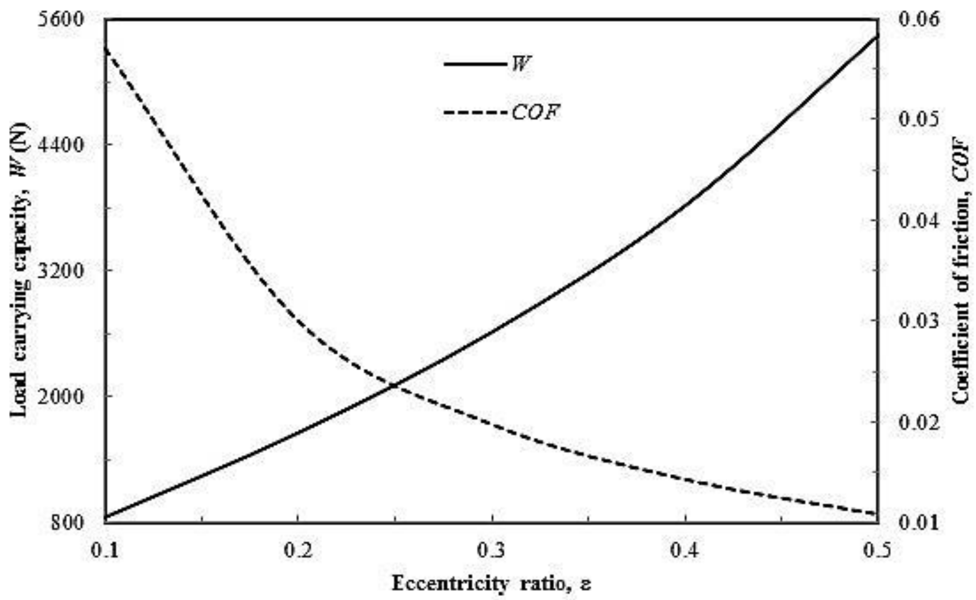

Figure 7: Influence of Eccentricity Ratio on Load Carrying Capacity (*W*) and Coefficient of Friction (*COF*) at Best Location (48° to 120°), Shaft Speed (3000 rpm) and Permeability Parameter (0.01)

Conclusion

Various bearing performance characteristics such as fluid film pressures, load carrying capacity, coefficient of friction etc. are calculated for investigating the influence of positive full wave type texture incorporated partially on the bearing surface at different locations (fully and partially textured) to investigate the performance of a finite porous journal bearing. The following conclusions have been obtained on the basis of calculated results:

- The fluid film pressures developed are more pronounced with the texture effects as compared to the smooth bearing case and also in case of full textured surface.
- The best location of texture was observed at the angular location (48° to 120°).
- The load carrying capacity in case of consideration of partial texturing gets improved. With increase in permeability parameter, load carrying capacity reduces while coefficient of friction increases. Moreover, shaft speed also enhances load carrying capacity, but there is a marginal change in coefficient of friction.
- The eccentricity ratio also plays an important role in improving the bearing performance. With increase in value of eccentricity ratio, load carrying capacity progresses noteworthy and coefficient of friction reduces.

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