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Research Article

INVESTIGATION ON THE INFLUENCE OF POSITIVE HALF WAVE TYPE TEXTURES ON THE PERFORMANCE OF POROUS JOURNAL BEARING

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ABSTRACT
The present study reveals the hydrodynamic lubrication of porous journal bearing with the effects of surface roughness/texture. The modified Reynolds equation for porous journal bearing and randomized surface texture arrangement are mathematically derived. The Darcy's equation is used to account for the effects of porous region of the bearing. The modified Reynolds equation is solved numerically through finite difference approach for analysis of surface roughness and Simpson's 1/3rd method and over relaxation methods are used in computing the various bearing characteristics by changing various bearing parameters such as eccentricity ratio, shaft speed and size of the roughness. The transverse half wave type of surface texture is considered in this study and it has been observed that the performance of bearing gets improved.

Keywords: *Positive Full Wave, Roughness, Texture, Porous Bearing*

INTRODUCTION
In the last two decades, researchers have devised different techniques to enhance the performance of fluid film bearings. Some have worked on their lubrication aspects and others created textured areas on different locations of the bearing surface. Most have showed improved results on the performance. It may be noted that the combination of both aspects may either give more improved results or reduced performance when compared using these aspects separately.
Porous bearing have number of advantages. They are easily fitted, available in a wide range of stock sizes at relatively low costs, force feed lubrication is eliminated, often they offer simplified design involving less space, maintenance is reduced and oil contamination is reduced. Such bearings are widely used in industrial applications where other plain metal bearings are impractical due to the lack of space or inaccessible to lubrication. Porous bearings are widely used in home appliances, small motors, machine tools, aircraft and automotive accessories, food and textile industry, business machines, medical apparatus, instruments, and farm and construction equipments (Hori, 2006; Cameron, 1966).
The theoretical study for porous journal bearings was given first by Morgan and Cameron (Morgan and Cameron, 1957) which further extended by the works of Rouleau and Steiner (1974), Shir and Joseph (1966) and Murti (1973). All these studies were based on the Darcy model (DM), in which Darcy's equation was used to guide the oil motion through the porous medium, and the no-slip condition was assumed at the porous bearing/clear oil interface.
A critical review on various types and aspects of porous metal bearings was made by Kumar (1980). Many researchers have worked in the field of plain journal and porous journal bearings. They have found the bearing performance parameters with both theoretical and experimental investigation by using some principles of lubrication and appropriate boundary conditions. In addition to this, authors have also found the effects of surface roughness on the performance of bearing parameters. In recent, there is also some work performed on the thermal investigations on the hydrodynamic lubrication of porous journal bearing (Kumar, 1980).
A number of authors work on the texturing aspects of bearings (Prakash and Tiwari, 1982; Prakash and Tiwari, 1983; Naduvinamani and Patil, 2009; Naduvinamani *et al.,* 2002; Gururajan and Prakash, 1999; Kango and Sharma, 2010). A comparative study has been reported by Kango and Sharma (2010) between three different roughnesses models using transverse and longitudinal both type of roughness with power

law model for non-Newtonian lubricant. They used sinusoidal wave equation for bearing surface while considering different configurations with different asperity amplitude and wavelength at various eccentricity ratios. They found that the load carrying capacity and friction force increases with increasing the flow behaviour index whereas, friction coefficient decreases with increasing the flow behaviour index. They concluded that the longitudinal sinusoidal roughness is best suited for decreasing the friction force.

Kango *et al.*, (2012) numerically investigated the micro cavities on journal bearing and found that the effects of texture are noticeable if the dimple depth is greater than minimum film thickness of the lubricant.

Kango *et al.*, (2014) also investigated the microtextured journal bearing including non-Newtonian fluid effects and JFO (Jakobsson, Floberg and Olsson) boundary conditions. They also performed the thermal analysis in their study i.e. viscous heat dissipation to find the performance parameters. The authors found that the average temperature of the lubricant gets reduced in case of texturing surface in comparison to smooth surface/ without texturing. Kango *et al.*, (2014) again investigated on different type of textures, i.e. dimpled surface and grooved surface and gave a brief comparative study on the effect of these types of textured journal bearings. The numerical results for these types of textures suggest that the micro-grooving type of texture reduces the average temperature and friction coefficient in comparison with spherical texture.

Tala-Ighil *et al.*, (2007) studied the effect of surface texture for hydrodynamic journal bearings. In case of investigations on journal bearing, the shaft has been assumed smooth and rigid as first case. However, in the second case, bearing surface has been textured with spherical dimples. The authors have reported that the film thickness, pressure distribution, side leakage, and frictional torque are significantly affected due to presence of surface texture. It has also been reported that the attributes of dimples (size, depth, density, and orientation) affect the bearing characteristics significantly. The type of geometry of texture (spherical dimples) has been taken from the author’s work. In the present investigation, spherical types of dimples are incorporated on the bearing surface on a particular location and performance is investigated.

Sharma *et al.*, (2015, 2014) presented the influence of sinusoidal wave textures on three different locations of the surface of bearing and obtain the best configuration among all. They also gave a comparison for the performance of a textured porous bearing for different configurations with the combined effects of two different non-Newtonian fluid models. Sharma *et al.*, (2014, 2015) also considered the combined influence of surface texturing with couple stress fluids for a finite journal bearing with JFO boundary conditions and reported 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 improve the load capacity of journal bearing while it decreased the load capacity by about 20% in case of high values of dimple depth and couple stress parameter.

In the present work, a numerical study is being accomplished to find the influence of positive half 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.

Numerical Procedures

In case of Porous region, the flow through the sinter is governed by Darcy’s law which can be given mathematically as

$$v = \frac{-\partial p}{\partial y}\frac{\phi}{\eta}$$

Where v is the velocity of flow across unit area, ϕ is the permeability and η is the viscosity. There is a negative sign as the flow is in the direction of decreasing pressure.

As v_H is the velocity of fluid flowing out of the porous region, so, it becomes zero and v_o is velocity of fluid flowing inside the porous region, so, we have

$v_H = 0$ and $v_0 = -\frac{\partial p}{\partial y}\frac{\phi}{\eta}$

So, now the equation becomes,

$$\frac{\partial}{\partial x}\left(h^3\frac{\partial p}{\partial x}\right)+\frac{\partial}{\partial y}\left(h^3\frac{\partial p}{\partial z}\right)=6\eta\left[U\frac{dh}{dx}+2\left(\frac{\partial p}{\partial y}\right)_{y=0}\frac{\phi}{\eta}\right]$$

By simplifications,

$$\left.\frac{\partial p}{\partial y}\right|_{y=0}=-\left[\frac{\partial^2 p}{\partial x^2}+\frac{\partial^2 p}{\partial z^2}\right]H$$

Therefore, Reynolds Equation for Porous Journal Bearing can be given as:

$$\frac{\partial}{\partial x}\left(h^3\frac{\partial p}{\partial x}\right)+\frac{\partial}{\partial z}\left(h^3\frac{\partial p}{\partial z}\right)=6\eta\left[U\frac{dh}{dx}-2\left(\frac{\partial^2 p}{\partial x^2}+\frac{\partial^2 p}{\partial z^2}\right)\frac{\phi H}{\eta}\right]$$

The typical representation of a positive full wave type texture is shown in Figure 1. The equation for positive full wave type surface roughness can be given from the work of Kango and Sharma (2010) as

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

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.

A typical positive half wave type texture is represented in Figure 1. The film thickness equation for a smooth journal bearing and a textured bearing can be given as:

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

$$h_s=h-\delta_s$$

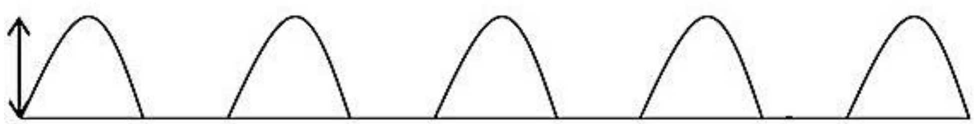

Figure 1: Typical Representation of a Positive Half Wave Type Texture

Boundary Conditions:

Reynolds boundary conditions are taken for the present model

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

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

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

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

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

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 DISCUSSIONS

The input data for the model has been cited in Table 1. To validate the present model, validations are presented in graphical form in Figure 2. The trends match considerably well with the previous work. The study on porous bearing with the influence of sinusoidal wave type texture is also validated with the work of Sharma *et al.*, (2015) which is shown in Figure 2.

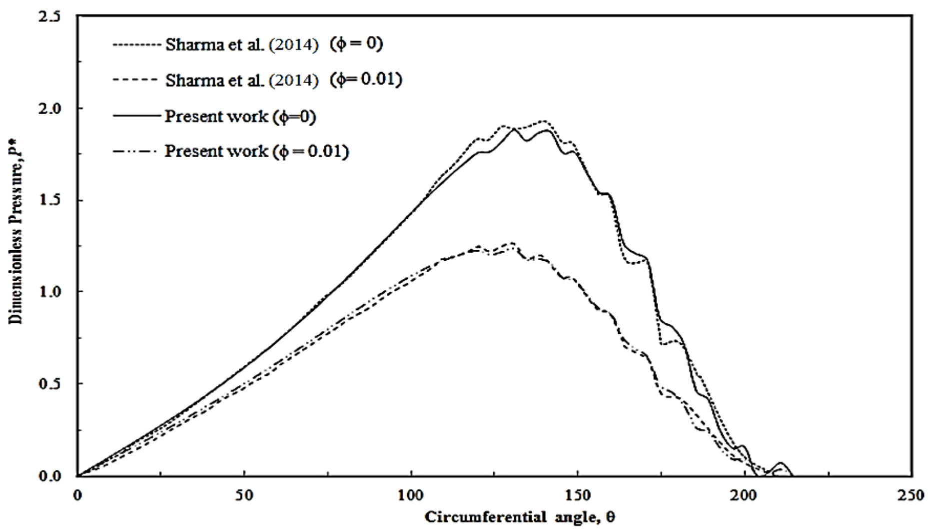

Figure 2: Validation of Present Work with the Work of Sharma *et al.*, (2015) for Dimensionless Pressure Influenced with Permeability Parameter and Sinusoidal Texture

Table 1: Input Parameters

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

A comparison has been made to find that which location is helpful in improving the performance by giving maximum enhancement in fluid pressure which leads to result in finding the best location for other bearing performance parameters such as load carrying capacity, coefficient of friction etc.

Figure 3 presents the comparison between all configurations and trend clearly shows that the configuration for partial texture (36° to 108°) gives maximum enhancement in fluid film pressures among all cases. It has also been remarkable to find that the full texture (0° to 360°) gives poorer performance among all cases. So, it has been observed that the location of texture is an important parameter in improving the performance of the porous bearing.

As shaft speed is also an important parameter in influencing bearing performance, the results are calculated at two different shaft speed, low (1500 rpm) and high (3000 rpm) speed. 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 consideration to find load carrying capacity (*W*), coefficient of friction (*COF*) etc.

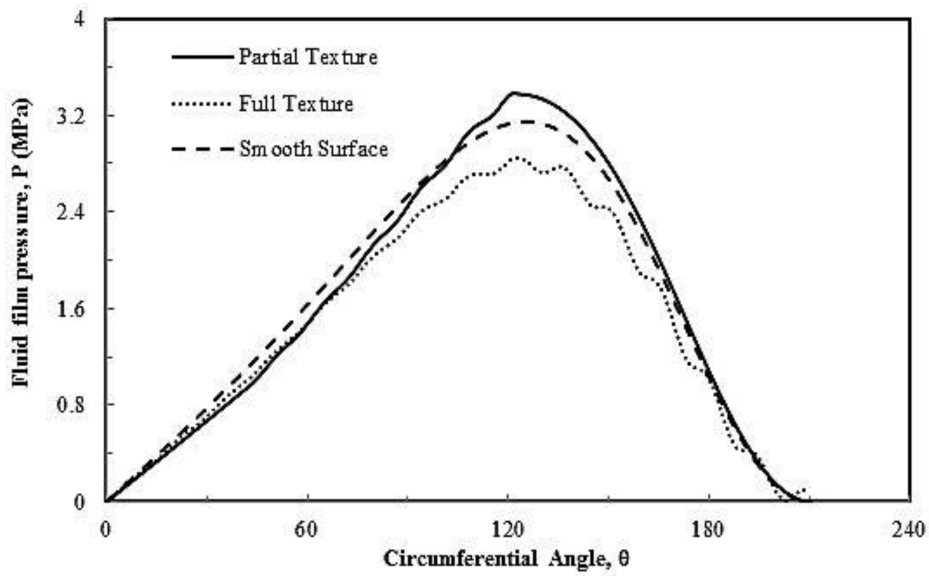

Figure 3: Comparison for Fluid Film Pressure Distribution for Smooth, Fully Textured (0° to 360°) and Partially Textured (36° to 108°) [*N*=3000 rpm, ε = 0.3, μ=0.08, ψ=0]

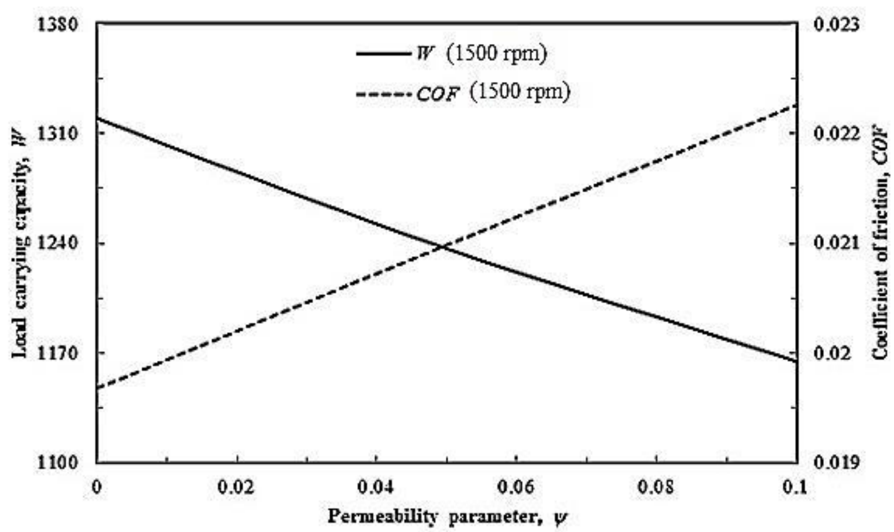

Figure 4: Effect of Permeability Parameters on Load Carrying Capacity (*W*) and Coefficient of Friction (*COF*) at Low Shaft Speed (N=1500 rpm, ε=0.3)

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Figure 4 represented the effect on 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 proposed by many authors (Kango *et al.*, 2012; Sharma *et al.*, 2015, 2014). It has been observed that the load carrying capacity reduces significantly with increase in permeability parameters and reduction is larger at high values. At smaller values, the influence is negligible.

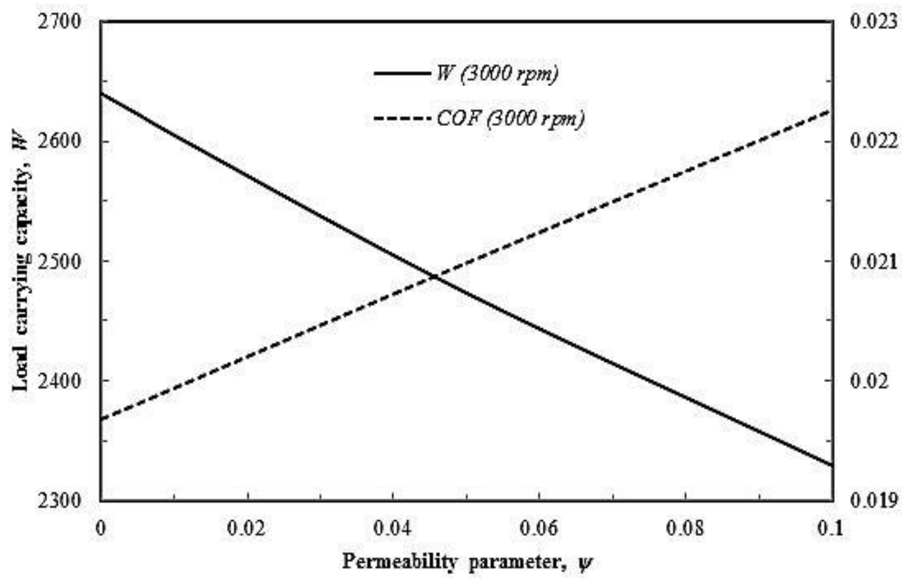

Figure 5: Effect of Permeability Parameters on Load Carrying Capacity (*W*) and Coefficient of Friction (*COF*) at Low Shaft Speed (*N*=3000 rpm, ε=0.3)

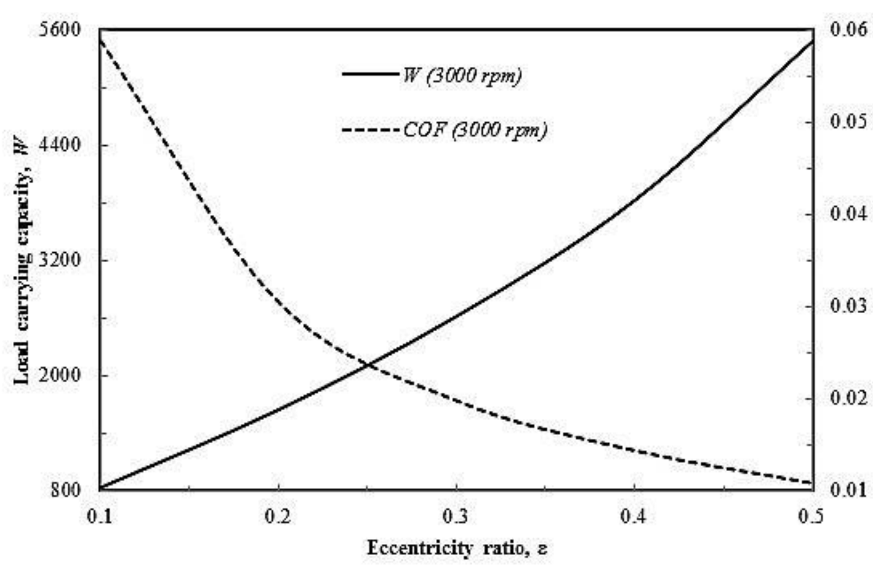

Figure 6: Effect of Eccentricity Ratio on Load Carrying Capacity (*W*) and Coefficient of Friction (*COF*) at Optimized Location (36° to 108°), Shaft Speed (3000 rpm) and Permeability Parameter (0.01)

Similar trends have 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 5. It has been observed that the load carrying capacity is higher in case of high shaft speed (3000 rpm) compared with low shaft speed (1500 rpm). However, there is no much significant difference in coefficient of friction values for both cases.

Figure 4 and 5 expresses that the performance of a porous journal bearing is more advantageous in case of optimized texture location (36º to 108º), high value of shaft speed (N=3000 rpm) and an intermediate value of permeability parameter (ψ=0.01).

In view of these observations, Figure 6 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 established that the load carrying capacity enhances with increase in value of eccentricity ratio. Moreover, the coefficient of friction values reduces with increase in the value of eccentricity ratios.

Conclusion

The mathematical model developed is numerically analyzed with the help of some numerical techniques. The texture equations for this type of texture are also combined in mathematical model to find the combined effect. The influence of positive half wave texture on the bearing characteristics is significant. It has been observed on comparison that the addition of textures on a suitable location gives enhanced performance than fully textured surface and smooth porous bearing surface.

The following conclusions are drawn on the basis of present study:

- The fluid film pressures developed are more pronounced with the texture effects as compared to the smooth bearing case and also poorer in case of full textured surface.
- From design point of view, the optimized location of texture was observed at the angular location (36º to 108º).
- 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 minimal change in coefficient of friction value.
- The eccentricity ratio also plays a significant role in improving the bearing performance. With increase in value of eccentricity ratio, load carrying capacity progresses remarkable and coefficient of friction decreases.

REFERENCES

Cameron A (1966). *The Principles of Lubrication*, (Longmans, London, UK).

Gururajan K and Prakash J (1999). Surface roughness effects in infinitely long porous journal bearings. *Journal of Tribology- ASME* **121** 139-147.

Hori Y (2006). *Hydrodynamic Lubrication*, (Springer, Tokyo, Japan).

Kango S and Sharma RK (2010). Studies on the influence of surface texture on the performance of hydrodynamic journal bearing using power law model. *International Journal of Surface Science and Engineering* **4** 505-524.

Kango S, Sharma RK and Pandey RK (2014). Thermal analyses of micro-textured journal bearings using non-Newtonian rheology of lubricant and JFO boundary conditions. *Tribology International* **69** 19-29.

Kango S, Singh D and Sharma RK (2012). Numerical investigation on the influence of surface texture on the performance of hydrodynamic journal bearing. *Meccanica* **47** 469-482.

Kumar V (1980). Porous metal bearings - a critical review. *Wear* **63** 271-287.

Morgan VT and Cameron A (1957). Mechanism of lubrication in porous metal bearings, *Proceedings of the Conference on Lubrication and Wear, Institution of Mechanical Engineers, London* 151 - 157.

Murti PRK (1973). Lubrication of finite porous journal bearings. *Wear* **26** 95-104.

Naduvinamani NB and Patil SB (2009). Numerical solution of finite modified Reynolds equation for couple stress squeeze film lubrication of porous journal bearings. *Computers and Structures* **87** 1287-1295.

Naduvinamani NB, Hiremath PS and Gurubasavaraj G (2002). Surface roughness effects in a short porous journal bearing with a couple stress fluid. *Fluid Dynamics Research* **31** 333-354.

Prakash J and Tiwari K (1982). Lubrication of a Porous Bearing with Surface Corrugations. *Journal of Lubrication Technology- ASME* **104** 127-134.

Prakash J and Tiwari K (1983). Roughness effects in porous circular squeeze-plates with arbitrary wall Thickness. *Journal of Lubrication Technology- ASME* **105** 90-95.

Rouleau WT and Steiner LS (1974). Hydrodynamic Porous Journal Bearings. Part 1-Finite Full Bearings. *Journal of Lubrication Technology, Transactions of ASME* **96** 346-353.

Sharma N, Kango S, Sharma RK and Sunil (2014). Investigations on the effects of surface texture on the performance of a porous journal bearing operating with couple stress fluids. *International Journal of Surface Science and Engineering* **8**(4) 392-407.

Sharma N, Kango S, Tayal A, Sharma RK and Sunil (2014). Investigation on the influence of surface texturing on a couple stress fluid based journal bearing by using JFO boundary conditions. *Tribology Transactions* **59** 579-584.

Sharma N, Sharma RK, Sunil and Kango S (2015). A comparative study for lubrication of surface textured porous journal bearing with two different non-Newtonian fluid models. *International Journal of Surface Science and Engineering*.

Shir CC and Joseph DD (1966). Lubrication of a porous bearing – Reynolds solution. *Journal of Applied Mechanics*, 66-APM-IJ.

Tala-Ighil N, Maspeyrot P, Fillon M and Bounif A (2007). Effects of surface texture on journal bearing characteristics under steady state operating conditions. Proceedings of Institutions of Mechanical Engineers, Part J. *Journal of Engineering Tribology* **221** 623-633.