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3D surface roughness effects on porous journal bearing performances

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ABSTRACT – Influence of 3D surface roughness parameters on performance characteristics of porous journal bearing is studied. The modified form of average Reynolds equation is developed for the porous bearing to include 3D surface roughness effect and its solution is obtained using finite element method. The influence of roughness orientations and roughness characteristics of opposing surfaces on load carrying capacity, coefficient of friction, fluid-film stiffness and damping coefficients of porous journal bearing are studied. Stationary roughness and transverse roughness pattern combination was found to provides maximum enhanced load carrying capacity, fluid-film stiffness and damping coefficients.

1. INTRODUCTION

The plain metal journal bearings are replaced by porous journal bearings due to their favorable self-lubricating properties. From last few decades, considerable amount of studies have been made in the area of porous journal bearings. Notably among these, some studies focus on the influence of couple stress fluids [1], flexibility of porous liner [2] and thermal [3] effects on porous bearing performances based on the smooth surface assumption.

Only few studies [4-7] address the influence of roughness on porous journal bearing performances. These studies used the stochastic Reynolds equation which is limited to one-dimensional roughness patterns. Since these are the limiting cases of roughness found in real engineering surfaces, consideration of area distributed 3D surface roughness effects on porous journal bearing performances is most essential.

Therefore, the present study is aimed to develop an average Reynolds equation to predict the influence of 3D surface roughness on performance characteristics of porous journal bearing.

2. MATHEMATICAL FORMULATION

For the fluid-film region of porous journal bearing with thin walled porous matrix, the modified average Reynolds equation in nondimensional form is given by:

$$\frac{\partial}{\partial\alpha}\left[\phi_x\left(\frac{\bar{h}^3}{12}+\frac{\bar{k}\bar{h}}{2}\right)\frac{\partial\bar{p}}{\partial\alpha}\right]+\frac{\partial}{\partial\beta}\left[\phi_y\left(\frac{\bar{h}^3}{12}+\frac{\bar{k}\bar{h}}{2}\right)\frac{\partial\bar{p}}{\partial\beta}\right] = \frac{\Omega}{2}\frac{\partial\overline{h_T}}{\partial\alpha}+\frac{\Omega}{2\Lambda}\frac{\partial\phi_s}{\partial\alpha}+\Omega\frac{\partial\bar{h}}{\partial\bar{t}} \quad (1)$$

Where ϕ_x, ϕ_y are the pressure flow factors and ϕ_s is the shear flow factors. $\bar{h}_T$ is the average film thickness. These can be obtained from Patir and Cheng [8].

Frictional force at journal surface is expressed as

$$\bar{F}_{\tau j}=\int_{-\lambda}^{\lambda}\int_{0}^{2\pi}\left\{\frac{\Omega}{\bar{h}}\left(\phi_f+\phi_{fs}\right)+\phi_{fp}\frac{h}{2}\frac{\partial\bar{p}}{\partial\alpha}\left(\frac{2\bar{k}}{\bar{h}^2}+1\right)\right\}d\alpha\, d\beta \quad (2)$$

The factors ϕ_f, ϕ_{fs} and ϕ_{fp} can also be obtained from [8]. The linearized fluid film stiffness and damping coefficients are defined as

$$\bar{S}_{ij}=-\frac{\partial\bar{F}_i}{\partial\bar{q}_j} \text{ and } \bar{C}_{ij}=-\frac{\partial\bar{F}_i}{\partial\dot{\bar{q}}_J}\ \left(i=x,z\right) \quad (3)$$

Equation (1) is solved using finite element method to get fluid-film pressure. Load carrying capacity of bearing is obtained by integrating this pressure over the area of porous bush. The other bearing performance characteristics are computed from Eqs. (2) and (3).

3. RESULTS AND DISCUSSION

Results showing the influence of transversely $(\gamma = 1/6)$ and longitudinally ($\gamma = 6$) oriented roughness patterns and roughness characteristics of opposing surfaces such as stationary (rough porous bush and smooth journal, $\bar{V}_{rj} = 0$), two-sided (both surfaces rough, $\bar{V}_{rj} = 0.5$) and moving (smooth porous bush and rough journal, $\bar{V}_{rj} = 1$) on performance characteristics of a finite porous journal bearing are computed and these results are compared with the results of smooth bearing (a curve with 's' in each figures).

Figure 1 indicates that the load carrying capacity of smooth bearing decreases as permeability increases. Except stationary roughness and transverse roughness combination, all other roughness combinations considered in this study provides enhanced load carrying capacity for all values of permeability. These roughness combinations provide the same load carrying capacity as that of smooth bearing with permeability 0.0001 even for higher permeability approximately between 0.0015 to 0.007 (i.e. between point A and B). As seen in Figure 2, the stationary roughness with both transverse and longitudinal roughness patterns provides reduced coefficient of viscous friction than that of a smooth bearing for entire range of permeability while moving roughness shows opposite trend.

Except moving roughness and transverse

roughness pattern combination, all other roughness combinations provide enhanced fluid-film stiffness coefficient ($\bar{S}_{xx}$) for entire range of permeability as shown in Figure 3. Even at higher permeability approximately between 0.0015 to 0.007, these roughness combinations provide $\bar{S}_{xx}$ as that provided by smooth bearing at lower permeability of 0.0001. As compared to the influence of roughness orientations (γ), the influence of $\bar{V}_{rj}$ on $\bar{C}_{xx}$ is small (Figure 4). Especially for longitudinal type roughness pattern the influence of $\bar{V}_{rj}$ is observed to be negligible.

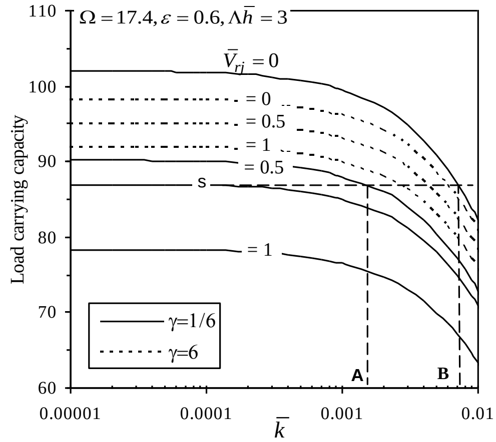

Figure 1 Load carrying capacity.

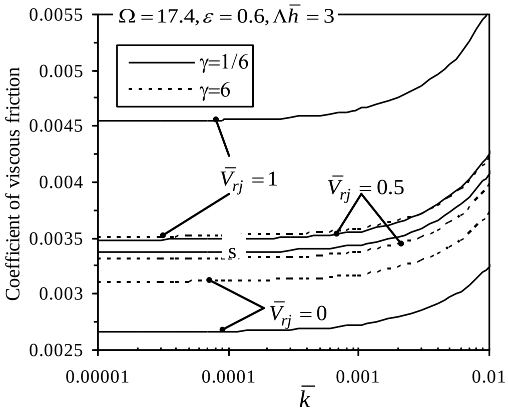

Figure 2 Coefficient of viscous friction.

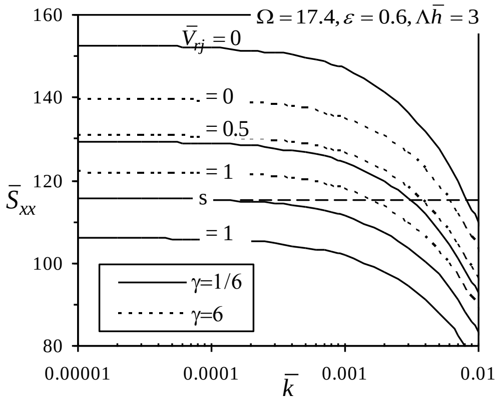

Figure 3 Fluid-film stiffness coefficient.

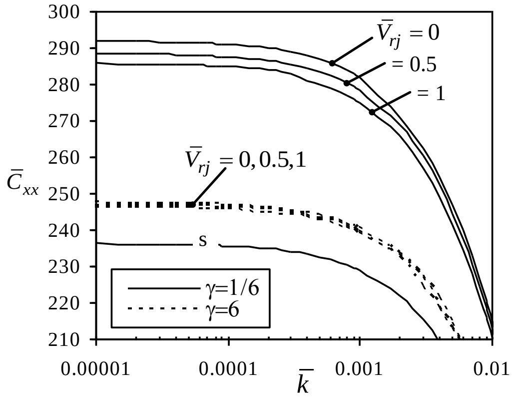

Figure 4 fluid-film damping coefficient.

4. CONCLUSIONS

The reduced load carrying capacity, fluid-film stiffness and damping coefficients and increased coefficient of friction of a smooth porous journal bearing due to increased permeability can be compensated by the proper roughness combination. Stationary roughness and transverse roughness pattern combination provides maximum enhanced load carrying capacity, fluid-film stiffness and damping coefficients with maximum reduction in coefficient of friction.

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