DYNAMIC CHARACTERISTICS OF FINITE HYDRODYNAMIC POROUS OIL JOURNAL BEARINGS IN TURBULENT REGIME WITH TANGENTIAL VELOCITY SLIP

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Abstract

A theoretical investigation has been made to predict the dynamic characteristics ofhydrodynamic porous bearings in turbulent regime considering the presence of tangentialvelocity slip. The threshold of instability is obtained for a system consisting of a balanced rigidrotor supported symmetrically in two bearings. Effect of various independent parameters on thecritical mass and stability have been investigated. Constantinescu’s turbulent lubrication hasbeen applied in the analysis.

Introduction

With the advent of powder metallurgy, porous materials as bearing surface are finding increasingly wider application in industry. The use of process fluid of low kinematic viscosity as lubricant and the ever increasing demand for surface speeds cause turbulence of the process fluid in the clearance space. there is also a presence of tangential velocity slip at the stationary porous surface.

Theoretical research on porous bearing was first stated by Morgan and Cameron[1]. Beavers and Josheph[2] were first to report the presence of tangential velocity slip at the stationary porous surface and constructed a mathematical criterion of velocity slip. Many other author [3-7] latter mad valuable contribution in this field but these were confide to laminar flow regime. Kumar and Rao [6,8] investigated the steady and dynamics characteristics of porous bearing in turbulent regime but without considering slip.

The aim of the present work is to investigate and predict the dynamic characteristics of hydrodynamic porous journal bearings in turbulent regime considering tangential velocity-slip. The effect of various parameters on the critical mass and stability have been obtained.

Analysis

The flow through the porous matrix is obtained by Darcy's law, assuming the flow to viscous and laminar. The oil film in the clearance space of the bearing is turbulent. With these assumption the generalized different equation for porous bearing can be written in dimensional from as

$$\overline{\mathrm{K}_x}\frac{\partial^2\overline{p\prime}}{\partial\theta^2}+\left(\frac{R}{H}\right)^2\frac{\partial^2\overline{p\prime}}{\partial\bar{y}^2}+\left(\frac{D}{L}\right)^2\overline{K_z}\frac{\partial^2\overline{p_1}}{\partial\bar{y}^2}=0 \quad (1)$$

For porous matrix and

$$\frac{\partial}{\partial\theta}\left[\bar{h}^3(1+\varepsilon_x)G\theta\frac{\partial\bar{p}}{\partial\theta}\right]\left(\frac{D}{L}\right)^2\frac{\partial}{\partial\overline{\overline{z^2}}}\left[\bar{h}^3(1+\varepsilon_z)Gz\frac{\partial\bar{p}}{\partial z}\right]$$

$$=\frac{1}{2}\frac{\partial}{\partial\theta}\left[\bar{h}(1+\varepsilon_{0x})\right]-\left(\frac{\partial\emptyset}{\partial T}\right)\left(\frac{\partial\bar{h}}{\partial\theta}\right)+\lambda\frac{\partial\bar{h}}{\partial\theta}+\frac{\beta}{12}\left(\frac{\partial\overline{p_1}}{\partial y}\right) \quad (2)$$

in the film region, where $G\theta$ and $Gz$are the turbulent co-efficients. constantinescu [9] suggested the following expressions for $G\theta$ and Gz

$$\frac{1}{G\theta}=12+0.0260(Re^*)^{0.0265} \quad (3)$$

$$\frac{1}{Gz}=12+0.0198(Re^*)^{0.741} \quad (4)$$

if the journal whirls about its mean steady state position given by eccentricity ratio ε_0 with amplitude $R_e\left(\varepsilon_1e^{iT}\right)$ and $R_e\left(\varepsilon_0\phi_1e^{iT}\right)$, for first order perturbation which are valid for small oscillation, the pressure and the local film thickness can be expressed as

$$\overline{p'}=\overline{p_0'}+\varepsilon_1e^{iT}\overline{p_1'}+\varepsilon_0\phi_1e^{iT}\bar{p}_2'$$

$$\bar{p}=\overline{p_0}+\varepsilon_1e^{iT}\overline{p_1}+\varepsilon_0\phi_1e^{iT}\overline{p_2}$$

$$\bar{h}=\overline{h_0}+\varepsilon_1e^{iT}\cos\theta+\varepsilon_1e^{iT}\sin\theta \quad (5)$$

the components of dynamic load along the line of centers and perpendicular to the line of center corresponding to perturbed pressure can written as

$$(w_d)re^{i\omega pt}=-2\int_0^{L/2}\int_0^{\theta_2}\varepsilon_1p_1R\cos\theta e^{i\omega pt}d\theta dz$$

$$(w_d)\phi e^{i\omega pt}=-2\int_0^{L/2}\int_0^{\theta_2}\varepsilon_1p_1R\cos\theta e^{i\omega pt}d\theta dz \quad (6)$$

Since the journal executes small harmonic oscillation about its steady state position in an elliptical orbite, dynamic load carrying capacity can be expressed as a spring force and a viscous damping force as given below:

$$(w_d)re^{i\omega pt}=\mathrm{K}_{rr}C\varepsilon_r+D_{rr}C\frac{d\varepsilon_r}{dt}$$

$$(w_d)\phi e^{i\omega pt}=\mathrm{K}_{\phi r}C\varepsilon_r+D_{\phi r}C\frac{d\varepsilon_r}{dt}$$

$$\varepsilon_r=\varepsilon_1e^{i\omega pt} \quad (7)$$

thenon dimensional components of stiffness and damping co-efficients are obtained. These are further used to study the stability of a rigid rotor. The critical mass parameter, whirl ratio and the journal speed corresponding to critical mass is obtained.

Result and Discussion

fig 2 shows a comparison of the obtained by the present analysis for no slip case with the published result of Anjani and Rao[8] which are excellent agreement.

the critical mass parameter, $\overline{m_{cr}}$ depends on parameter like σ_y, α and L/D. also stability curve have been drawn with respect to sommerfeld number, so considering permeability of porous matrix.

a) Effect of σ_y

Fig 3 shows that for better stability the value of σ_y should kept as small as possible. A lower value of σ_y will give better stability in turbulent porous journal bearings.

b) Effect of α

It is seen from fig 4 that stability is adversely affectedfor lower value of α $i.e$ for $\alpha = 0.05, 0.1$ when compared with no slip condition. But for higher value of α $i.e$ $\alpha > 0.5$ the stability increases in α.

c) effect of L/D

Fig 5 shows that any increase in aspect ratio, L/D adversely affects the stability.

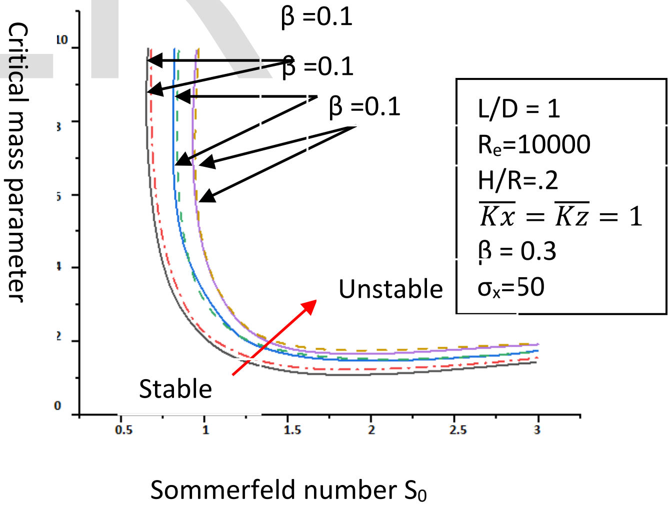
d) Effect of anisotropy of porous material

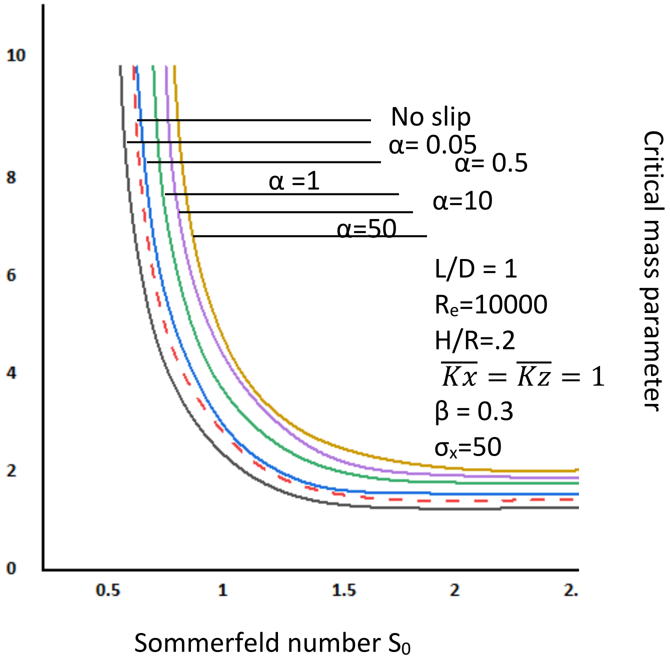
The permeability of bearing along the axial direction will be less than that in the other direction. Taking $\overline{\mathrm{K}_x} = 1$ and $\overline{\mathrm{K}_z} = 0.8$ the result has been depicted in fig 6. it is observed that anisotropy slightly improves the stability.

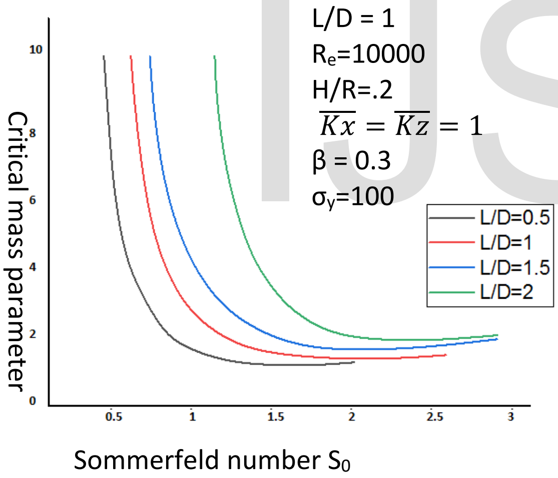
Conclusion

The following conclusion may be drawn from the foregoing analysis and discussions.

1) For better stability of turbulent hydrodynamic porous bearings, the value of σ_y should be kept as small as possible.
2) An increase in α, in general, increases the stablity but for lower value of α the stability may deteriorate if compared with no slip case.
3) A decrease in L/D ratio of the turbulent porous bearing improves the stability of the rotor.
4) The effect of anisotropy of oil whirl is not significant. Anisotropy of porous material slightly improves the stability.







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