Stability of double porous and surface porous layer journal bearing

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ABSTRACT – The purpose of this paper is to present the linearized stability analysis of journal bearing with double porous and surface porous layer lubricant film. The Brinkman model is employed to model the flow in the porous region. The porous layer with infinite permeability is analyzed in this study as surface layer. The load capacity, threshold speed and critical whirl frequency ratio coefficients (C_w, C_ω, C_Ω) are computed for double porous and surface porous layer configurations. Higher threshold speed is obtained for (i) double porous layer lubricant film with low permeability porous layer over high permeability bearing adsorbent porous layer, and (ii) surface porous layer lubricant film.

1. INTRODUCTION

Journal bearing performance characteristics are influenced by properties of lubricant additives. The steady state analysis of journal bearing with lubricant additives [1-2] are presented based on thin porous film on bearing surfaces. The stability analysis of journal bearing under the influence double porous and surface porous layer lubricant film is presented based on the methodologies of (i) linearized perturbation method for evaluation of linear stability [3] and double layer film model [4], (ii) derivation of coefficients (C_w, C_ω, C_Ω) for two-layered fluid film journal bearing [5] and (iii) derivation of coefficients (Δ_s, Δ_p) for long journal bearing with double porous layer and surface porous layer lubricant film [6].

The schematic of journal bearing with double porous (surface porous) layer lubricant film is shown in Fig. 1.

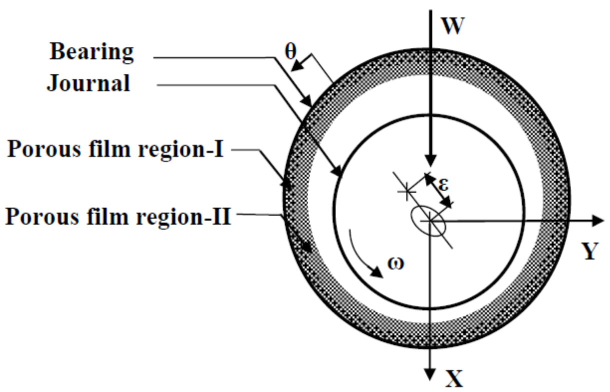

Figure 1 Journal bearing with double porous (surface porous) layer lubricant film.

2. ANALYSIS

The coefficients in the modified dynamic Reynolds equation using long bearing approximation for double porous layer lubricant film are:

$$\Delta_s = 2F_1H_1^* + 2(F_1+F_3)H_2^* + (F_3+1)(1-\gamma_1-\gamma_2) \quad (1)$$

$$\Delta_p = 12F_2H_1^* + 12(F_2+F_4)H_2^* + \left(6F_4 + (1-\gamma_1-\gamma_2)^2 - \lambda^2\right)(1-\gamma_1-\gamma_2) + 12K_1\left(\gamma_1 - 2H_1^*\right) + 12K_2\left(\gamma_2 - 2H_2^*\right) \quad (2)$$

$$F_1 = \frac{-E_{12}E_{231}}{E_{11}E_{22}-E_{21}E_{12}},\ F_2 = \frac{E_{22}E_{13}-E_{12}E_{232}}{E_{11}E_{22}-E_{21}E_{12}},$$
$$F_3 = \frac{E_{11}E_{231}}{E_{11}E_{22}-E_{21}E_{12}},\ F_4 = \frac{-E_{21}E_{13}+E_{11}E_{232}}{E_{11}E_{22}-E_{21}E_{12}} \quad (3)$$

$$E_{11} = \frac{1}{\sqrt{K_1}}\coth\left(\frac{\gamma_1}{\sqrt{K_1}}\right) + \frac{1}{\sqrt{K_2}}\coth\left(\frac{\gamma_2}{\sqrt{K_2}}\right),$$

$$E_{22} = \frac{1}{\sqrt{K_2}}\coth\left(\frac{\gamma_2}{\sqrt{K_2}}\right) + \frac{1}{(1-\gamma_1-\gamma_2)},$$

$$E_{12} = E_{21} = -\frac{1}{\sqrt{K_2}}\operatorname{csch}\left(\frac{\gamma_2}{\sqrt{K_2}}\right) \quad (4)$$

$$E_{13} = H_1^* + H_2^*,\ E_{231} = \frac{1}{(1-\gamma_1-\gamma_2)},$$

$$E_{232} = H_2^* + \frac{1}{2}(1-\gamma_1-\gamma_2) \quad (5)$$

$$H_i^* = \sqrt{K_i}\left(\coth\left(\frac{\gamma_i}{\sqrt{K_i}}\right) - \operatorname{csch}\left(\frac{\gamma_i}{\sqrt{K_i}}\right)\right) \text{ for } i=1,2,$$

$$H = 1+\varepsilon\cos\theta \quad (6)$$

For the surface porous layer lubricant film, the parameters E_{11} in Eq. (4) and H_1^* in Eq. (6) are:

$$E_{11} = \frac{1}{\gamma_1} + \frac{1}{\sqrt{K_2}}\coth\left(\frac{\gamma_2}{\sqrt{K_2}}\right),\ H_1^* = \frac{\gamma_1}{2} \quad (7)$$

For the surface porous layer lubricant film, the parameter Δ_p is modified as

$$\Delta_p = 12F_2H_1^* + 12(F_2+F_4)H_2^* + \left(6F_4 + (1-\gamma_1-\gamma_2)^2\right)(1-\gamma_1-\gamma_2) + 12K_2\left(\gamma_2 - 2H_2^*\right) + \gamma_1^3 \quad (8)$$

The coefficients (C_w, C_ω, C_Ω) are determined as

$$C_w = W_l/W_h = \Delta_s/\Delta_p,\ C_\omega = \omega_{s,l}/\omega_{s,h} = 1/\Delta_s,\ C_\Omega = \Omega_{s,l}/\Omega_{s,h} = \Delta_s \quad (9)$$

3. RESULTS AND DISCUSSION

The parameters used in the analysis are: non-dimensional permeability of porous layers (K_1, K_2)=10^{-2}, 10^{-4}; non-dimensional thickness ratio of porous (surface) layer adjacent to bearing surface (γ_1, γ_2)=0.05-0.25; and non-dimensional thickness ratio of intermediate porous layer (γ_2)=0.05-0.15. Results of the coefficients (C_w, C_ω, C_Ω) are presented as a function of bearing adjacent porous (surface) layer thickness ratio (γ_1). The influence of (i) permeability and thickness of porous layers and (ii) thickness of surface layer on the coefficients (C_w, C_ω, C_Ω) are analyzed.

Figures 2-4 show the load capacity, threshold speed and critical whirl frequency ratio coefficients (C_w, C_ω, C_Ω) of a journal bearing under influence of thickness ratio of porous layer I and surface layer adjacent to bearing (γ_1). The load capacity and threshold speed ratio coefficients (C_w, C_ω) increases with increase in γ_1, γ_2 and decrease in K_1, K_2. Lower K_2 has significant effect on decrease in critical whirl frequency ratio coefficient (C_Ω). Higher load capacity and threshold speed coefficients (C_w, C_ω) and lower critical whirl frequency ratio coefficient (C_Ω) are obtained with increase in thickness ratio of porous layer I or surface layer (γ_1), decrease in the nondimensional permeability of porous layer II (K_2= 10^{-4}), and increase in thickness ratio of porous layer II (γ_2).

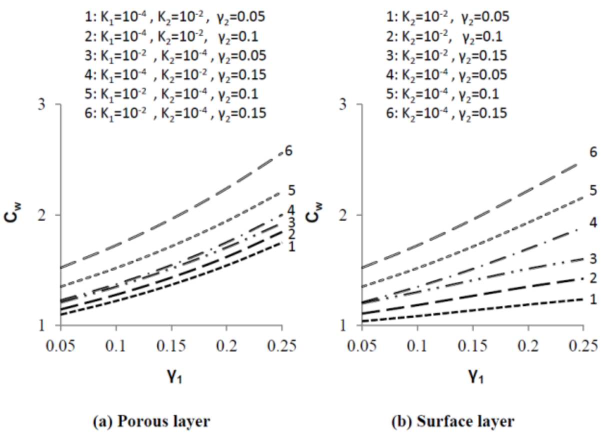

Figure 2 Load capacity coefficient.

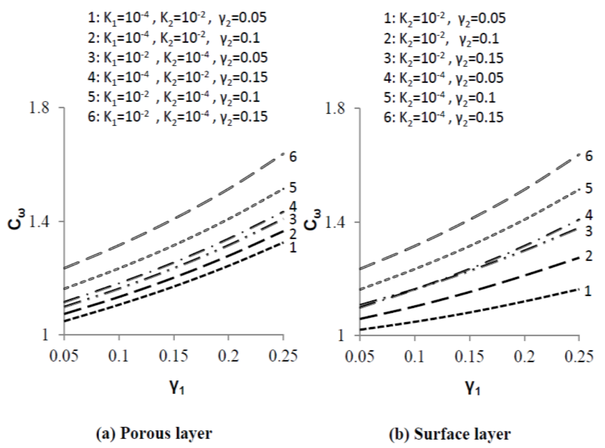

Figure 3 Threshold speed coefficient.

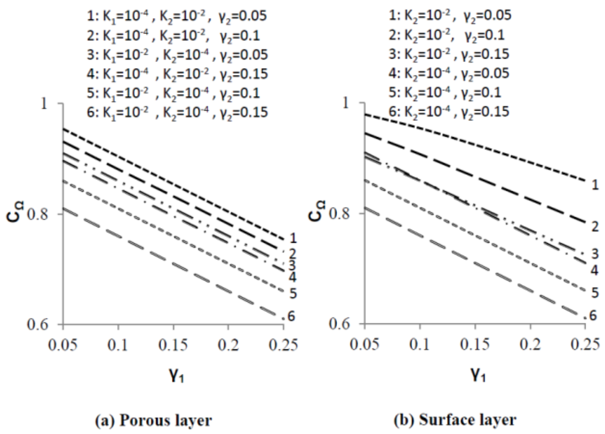

Figure 4 Critical whirl frequency ratio coefficient.

4. CONCLUSION

This study evaluates the influence of (i) permeability and thickness of porous layers, and (ii) thickness of surface layer on the improvement in journal bearing stability. Journal bearing operating with (i) double porous layer lubricant film with low permeability porous layer over high permeability bearing adsorbent porous layer (K_1=10^{-2}, K_2=10^{-4}), and (ii) surface porous layer (K_2=10^{-4}) lubricant would result in improvement in the stability.

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