

# Stability of double porous and surface porous layer journal bearing

T.V.V.L.N. Rao\*, A.M.A. Rani, M. Awang, T. Nagarajan, F.M. Hashim

Department of Mechanical Engineering, Universiti Teknologi PETRONAS,  
31750 Tronoh, Perak Darul Ridzuan, Malaysia

\*Corresponding e-mail: tadimalla\_v@petronas.com.my

**Keywords:** Stiffness and damping coefficients; threshold speed; critical whirl frequency ratio

**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 ( $C_w$ ,  $C_\omega$ ,  $C_\Omega$ ) 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 ( $C_w$ ,  $C_\omega$ ,  $C_\Omega$ ) for two-layered fluid film journal bearing [5] and (iii) derivation of coefficients ( $\Delta_s$ ,  $\Delta_p$ ) 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.

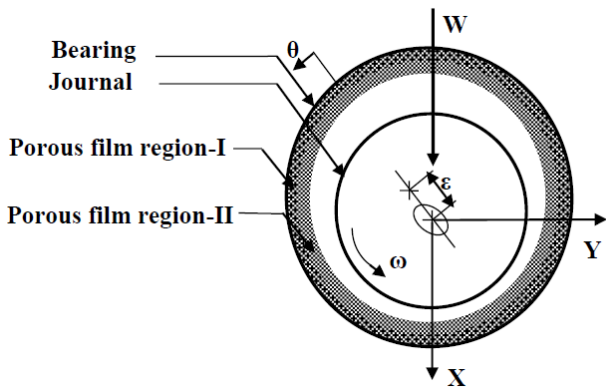


Figure 1 Journal bearing with double porous (surface porous) layer lubricant film.

## 2. ANALYSIS

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

$$\Delta_s = 2F_1 H_1^* + 2(F_1 + F_3) H_2^* + (F_3 + 1)(1 - \gamma_1 - \gamma_2) \quad (1)$$

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

$$F_1 = \frac{-E_{12}E_{231}}{E_{11}E_{22} - E_{21}E_{12}}, \quad F_2 = \frac{E_{22}E_{13} - E_{12}E_{232}}{E_{11}E_{22} - E_{21}E_{12}},$$

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

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

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

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

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

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

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

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

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

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

For the surface porous layer lubricant film, the parameter  $\Delta_p$  is modified as

$$\Delta_p = 12F_2 H_1^* + 12(F_2 + F_4) H_2^* + (6F_4 + (1 - \gamma_1 - \gamma_2)^2) (1 - \gamma_1 - \gamma_2) + 12K_2(\gamma_2 - 2H_2^*) + \gamma_1^3 \quad (8)$$

The coefficients ( $C_w$ ,  $C_\omega$ ,  $C_\Omega$ ) are determined as

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

$$C_\Omega = \Omega_{s,l}/\Omega_{s,h} = \Delta_s \quad (9)$$

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 ( $\gamma_1, \gamma_2$ )= $0.05-0.25$ ; and non-dimensional thickness ratio of intermediate porous layer ( $\gamma_2$ )= $0.05-0.15$ . Results of the coefficients ( $C_w, C_\omega, C_\Omega$ ) are presented as a function of bearing adjacent porous (surface) layer thickness ratio ( $\gamma_1$ ). The influence of (i) permeability and thickness of porous layers and (ii) thickness of surface layer on the coefficients ( $C_w, C_\omega, C_\Omega$ ) are analyzed.

Figures 2-4 show the load capacity, threshold speed and critical whirl frequency ratio coefficients ( $C_w, C_\omega, C_\Omega$ ) of a journal bearing under influence of thickness ratio of porous layer I and surface layer adjacent to bearing ( $\gamma_1$ ). The load capacity and threshold speed ratio coefficients ( $C_w, C_\omega$ ) increases with increase in  $\gamma_1, \gamma_2$  and decrease in  $K_1, K_2$ . Lower  $K_2$  has significant effect on decrease in critical whirl frequency ratio coefficient ( $C_\Omega$ ). Higher load capacity and threshold speed coefficients ( $C_w, C_\omega$ ) and lower critical whirl frequency ratio coefficient ( $C_\Omega$ ) are obtained with increase in thickness ratio of porous layer I or surface layer ( $\gamma_1$ ), decrease in the nondimensional permeability of porous layer II ( $K_2=10^{-4}$ ), and increase in thickness ratio of porous layer II ( $\gamma_2$ ).

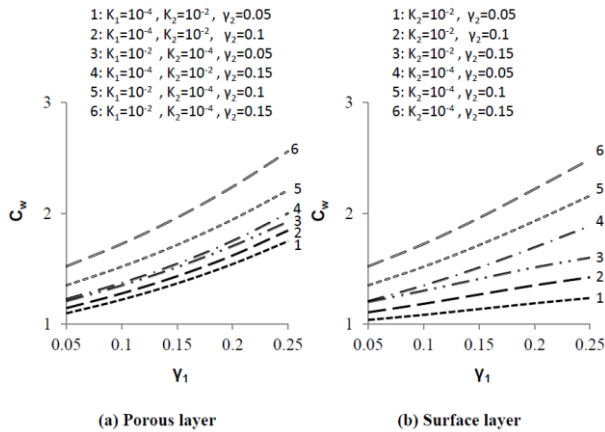


Figure 2 Load capacity coefficient.

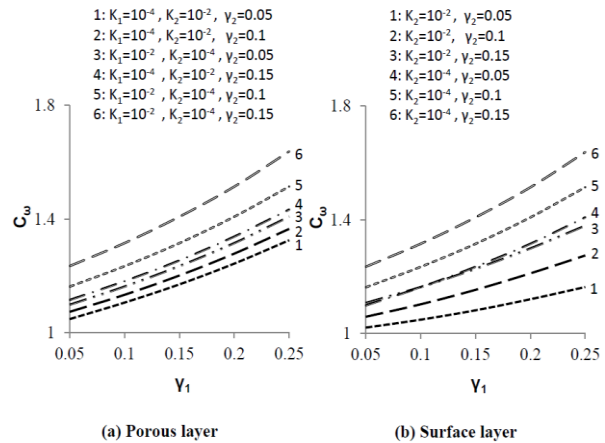


Figure 3 Threshold speed coefficient.

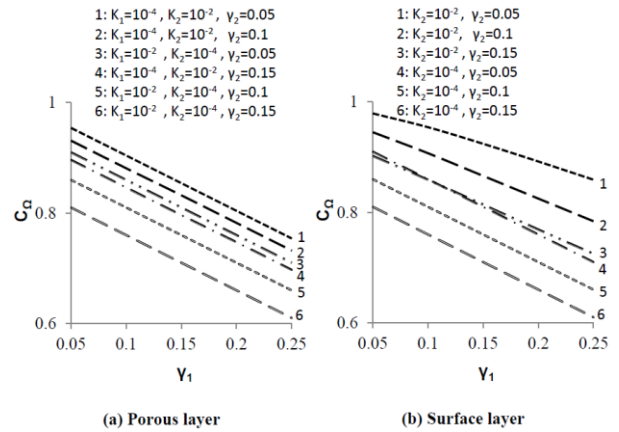


Figure 4 Critical whirl frequency ratio coefficient.

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.

5. ACKNOWLEDGEMENTS

This research work is funded by Ministry of Education (MOE) Malaysia under FRGS-2015 and ERGS-15-8200-153 grants. The author greatly appreciates the support provided by Universiti Teknologi PETRONAS for this research.

6. REFERENCES

- [1] W-L. Li, and H-M. Chu, "Modified Reynolds Equation for Couple Stress Fluids – A Porous Media Model," *Acta Mechanica*, vol. 171, pp. 189-202, 2004.
- [2] A.A. Elsharkawy, "Effects of Lubricant Additives on the Performance of Hydrodynamically Lubricated Journal Bearings," *Tribology Letters*, vol. 18, pp. 63-73, 2005.
- [3] J.W. Lund, "Review of the Concept of Dynamic Coefficients for Fluid Film Journal Bearings," *ASME Journal of Tribology*, vol. 109, pp. 37-41, 1987.
- [4] A.Z. Szeri, "Composite-film Hydrodynamic Bearings," *International Journal of Engineering Science*, vol. 48, no. 11, pp. 1622-1632, 2010.
- [5] T.V.V.L.N. Rao, "Stabilization of Journal Bearing using Two-layered Film Lubrication" *ASME Journal of Tribology*, vol. 134, p. 014504, 2012.
- [6] T.V.V.L.N. Rao, A.M.A. Rani, T. Nagarajan, F. M. Hashim, "Analysis of Journal Bearing with Double-Layer Porous Lubricant Film: Influence of Surface Porous Layer Configuration", *Tribology Transactions*, vol. 56, no. 5, pp. 841-847, 2013.