

# Effect of Poisson's Ratio for Liner Material on Performance of Journal Bearing under Micropolar Lubrication

Pikesh Bansal<sup>1\*</sup>, Manish Saraswat<sup>2</sup>, Kamal Sharma<sup>3</sup>, Nathiram Chauhan<sup>4</sup>

<sup>1,2</sup> Department of Mechanical Engineering ABES Engineering College, Ghaziabad, AKTU, Lucknow, India

<sup>3</sup> Professor, Department of Mechanical Engineering, GLA University, Mathura, India

<sup>4</sup> Associate Professor, Department of Mechanical and Automation Engineering, IGDTUW, Delhi, India

<sup>2</sup>er.manishsaraswat@gmail.com

## I. Introduction

Journal bearing is integral part of rotating machinery in order to support load of components and provide proper alignment to machinery. Failure of bearing is evident because of metal to metal contact under certain operating conditions. However, bearing are provided with flexible liners in order to reduce cost of failure. This leads to deformation of liner during operation of machinery. Performance characteristics are influenced due to this deformation of bearing liner.

Hingison [1] was pioneer researcher to have worked on calculation for effect of changing liner material on performance characteristics of journal bearing. Researchers [1-5] have worked in this relevant area taking basic assumption of fluid as Newtonian. The results produced have significant effect in building equations for these calculations. Behavior of real life lubricants is predicted more accurately by considering assumptions based on theory of micropolar fluids as suggested by Eringen [6]. Allen and Kline [7] presented the application of micropolar fluid model to theory of lubrication taking practical aspects in to picture.

Prakash and Sinha [8] and further Singh and Sinha [9] contributed for development 3-D modified Reynolds equation for journal bearing under micropolar lubrication. Various researchers [10-21] have studied several configurations of bearing during their studies.

Present scope of work presents the effect of Poisson's ratio ( $\nu$ ) for Liner Material on steady state characteristics of Hydrodynamic Journal Bearing (HJB) taking micropolar lubrication. To best of our knowledge no work has yet discussed this aspect of Journal Bearing. Result presented in present study are useful to designer involved in optimization of Journal Bearing and researchers working in this field.

## II. Analysis

Journal bearing of radius R and length L is assumed in present work which is presented schematically in Fig. 1.

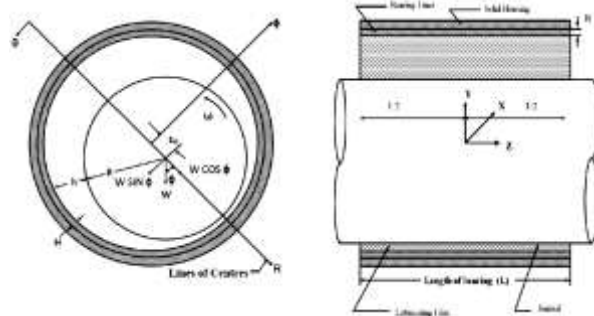


Fig 1 Schematic diagram of Journal Bearing

### A. Governing equation

Modified Reynolds equation [9] assuming lubricant as micropolar fluids is as follows:

$$\frac{\partial}{\partial x} \left[ \frac{h_0^3}{\eta} \Phi \frac{\partial p_0}{\partial x} \right] + \frac{\partial}{\partial z} \left[ \frac{h_0^3}{\eta} \Phi \frac{\partial p_0}{\partial z} \right] = 6U \frac{\partial h_0}{\partial x} \quad (1)$$

where

$$\Phi = \left\{ 1 + 12 \frac{\Lambda^2}{h_0^2} - 6 \frac{N \Lambda}{h_0} \coth \left( \frac{N h_0}{2 \Lambda} \right) \right\}, \Lambda = \left( \frac{\gamma}{4 \eta} \right)^{1/2}, N = \left( \frac{\chi}{2 \eta + \chi} \right)^{1/2}$$

Eq. 1 in non-dimensional form:

$$\frac{\partial}{\partial \theta} \left[ \bar{g}(\bar{l}_m, N, \bar{h}_0) \frac{\partial \bar{p}_0}{\partial \theta} \right] + \left( \frac{D}{L} \right)^2 \frac{\partial}{\partial \bar{z}} \left[ \bar{g}(\bar{l}_m, N, \bar{h}_0) \frac{\partial \bar{p}_0}{\partial \bar{z}} \right] = \frac{1}{2} \frac{\partial \bar{h}_0}{\partial \theta} \quad (2)$$

substitutions

$$\theta = \frac{x}{R}, \bar{z} = \frac{2z}{L}, \bar{h}_0 = \frac{h_0}{C}, \bar{p}_0 = \frac{p_0 C^2}{\eta \omega R^2}, \bar{l}_m = \frac{C}{\Lambda} \quad \text{where}$$

$$\bar{g}(\bar{l}_m, N, \bar{h}_0) = \frac{\bar{h}_0^{-3}}{12} + \frac{\bar{h}_0^{-2}}{2 \bar{l}_m} - \frac{N \bar{h}_0^{-2}}{2 \bar{l}_m} \coth \left( \frac{N \bar{l}_m \bar{h}_0}{2} \right)$$

Expanding Eq. 2

$$C_B \left[ \frac{\partial^2 \bar{p}_0}{\partial \theta^2} + \left( \frac{D}{L} \right)^2 \frac{\partial^2 \bar{p}_0}{\partial \bar{z}^2} \right] + C_A \left[ \frac{\partial \bar{h}_0}{\partial \theta} \frac{\partial \bar{p}_0}{\partial \theta} + \left( \frac{D}{L} \right)^2 \frac{\partial \bar{h}_0}{\partial \bar{z}} \frac{\partial \bar{p}_0}{\partial \bar{z}} \right] = \frac{1}{2} \frac{\partial \bar{h}_0}{\partial \theta} \quad (3)$$

where

$$C_A = \frac{\bar{h}_0^{-2}}{4} + \frac{1}{l_m^2} - \frac{N \bar{h}_0}{l_m} \coth \left( \frac{N l_m \bar{h}_0}{2} \right) + \frac{N^2 \bar{h}_0^{-2}}{4} \operatorname{cosech}^2 \left( \frac{N l_m \bar{h}_0}{2} \right)$$

$$C_B = \frac{\bar{h}_0^{-3}}{12} + \frac{\bar{h}_0}{l_m^2} - \frac{N \bar{h}_0^2}{2 l_m} \coth \left( \frac{N l_m \bar{h}_0}{2} \right)$$

### Boundary Conditions

Relevant boundary conditions:

1. Steady state pressures at ends Zero.

$$\bar{p}_0(\theta, \bar{z}) = 0, \text{ at } \bar{z} = \pm 1$$

2. Symmetry pressure distribution.

$$\frac{\partial \bar{p}_0(\theta, \bar{z})}{\partial \bar{z}} = 0, \text{ at } \bar{z} = 0$$

3. Cavitation conditions.

$$\bar{p}_0(\theta_2, \bar{z}) = \frac{\partial \bar{p}_0(\theta_2, \bar{z})}{\partial \bar{z}} = 0$$

$$\bar{p}_0(\theta, \bar{z}) = 0, \text{ for } \theta_2 \leq \theta \leq \theta_1$$

4. Periodic boundary conditions.

$$\bar{p}_0(\theta, \bar{z}) = \bar{p}_0(\theta + 2\pi, \bar{z})$$

Film thickness for flexible bearing.

$$\bar{h}_0 = 1 + \varepsilon_0 \cos \theta + \delta \quad (4)$$

$$\bar{h}_0 = \frac{h_0}{C}, \varepsilon_0 = \frac{e_0}{C}, \delta = \frac{\delta}{C}$$

$\delta$  is steady state radial deformation of bearing liner surface. Values of  $\delta$  are calculated as per procedure provided in Bansal [19].

### III. Results and Discussion

Effect of Poisson's Ratio for liner material is studied in terms of steady state performance characteristics of HJB taking micropolar lubrication regime.

Simulated results of computer program are checked by comparing results of current program with already prevalent results. Comparison is made with Majumdar et al. [5].

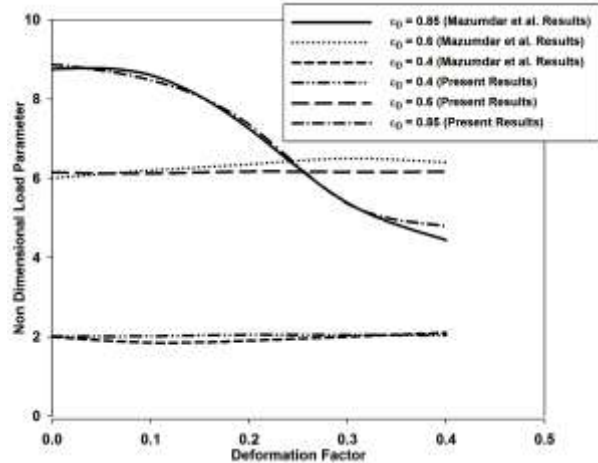


Fig. 2 Comparison with Mazumdar et al. [5].

Mazumdar et al. [5] have predicted results for effect of liner material considering Newtonian fluids. Present results are generated considering Newtonian fluid and compared with already published results. Comparison of results show agreement which authenticates program.

Figs 3-6 present result for effect of Poisson's Ratio for liner material on steady state characteristics.

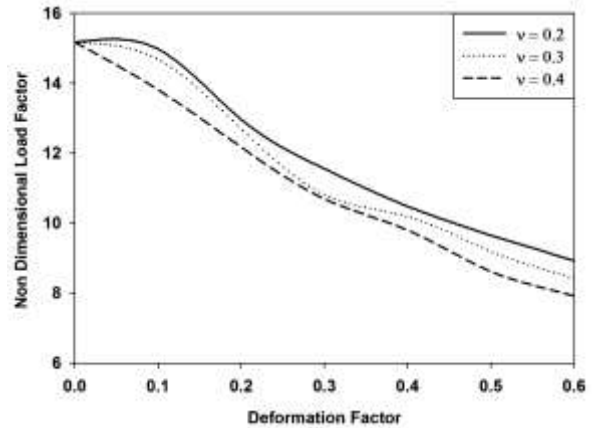


Fig 3 Load Factor Vs Deformation factor for various Poisson's Ratio.

**Effect of Poisson's ratio on Load Carrying Capacity**  
Variation of load parameter w.r.t. deformation factor for various Poisson's ratio at  $\varepsilon_0 = 0.8, \frac{L}{D} = 1.0, N^2 = 0.5, l_m = 40.0, \frac{H}{R} = 0.3$  is as per figure 3. From graph it can be observed that load decreases with increase in Poisson's ratio of material of bearing liner.

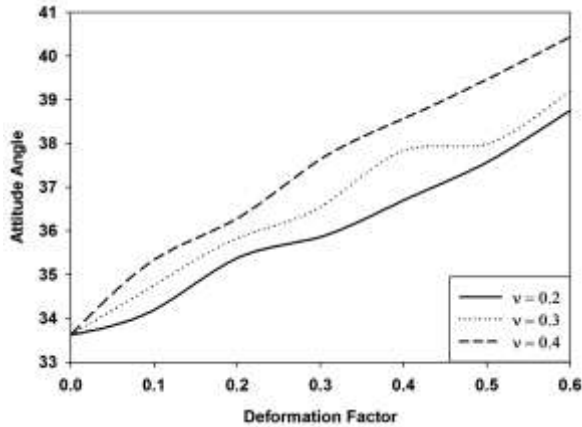


Fig 4 Attitude Angle Vs Deformation factor for various Poisson's Ratio

#### Effect of Poisson's ratio Attitude Angle

Effect of Poisson's ratio on attitude angle considering deformation of liner in micropolar regime is shown in figure 4. Scrutiny of figure reveals that attitude angle increases with increase in Poisson's ratio. It is also observed that attitude angle increases with increase in deformation factor.

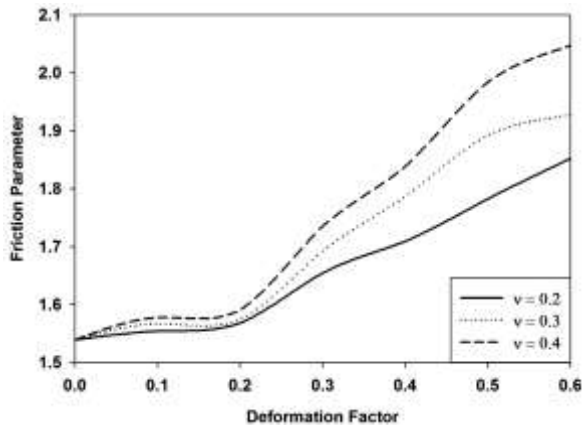


Fig 5 Friction Parameter Vs Deformation factor for various Poisson's Ratio

#### Effect of Poisson's ratio Friction Parameter

Friction parameter versus deformation factor for change in Poisson's ratio is shown in figure 5. Nature of graph predicts that friction parameter shows better results at higher Poisson's ratio. Friction parameter increases with increase in deformation factor. It is also evident that increase in friction parameter is sharp as F is increased beyond 0.2.

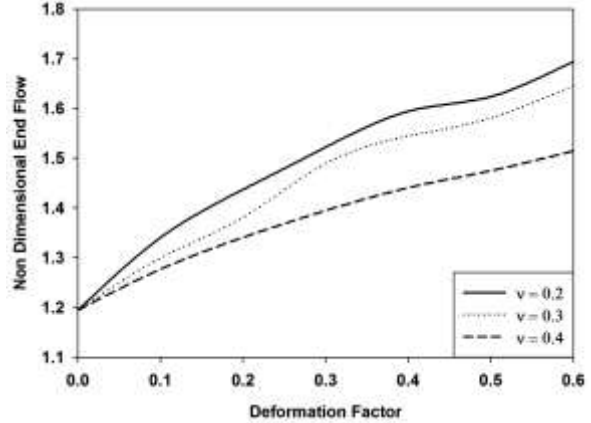


Fig 6 End Flow Vs Deformation factor for various Poisson's Ratio

#### Effect of Poisson's ratio End Flow

$\bar{Q}_Z$  Vs F for change in Poisson's ratio is shown in fig.6 for  $\varepsilon_0 = 0.8, \frac{L}{D} = 1.0, N^2 = 0.5, l_m = 40.0, \frac{H}{R} = 0.3$ . While analyzing graph it can be observed that value of  $\bar{Q}_Z$  decreases with increase in Poisson's ratio. Non-dimensional end flow increases with increase in deformation factor.

#### IV. Conclusion

The paper shows simulated results for change in Poisson's ratio of liner material Performance characteristics of HJB taking lubricant as micropolar fluid. Conclusions from results presented:

- Load carrying capacity under steady state conditions decreases with increase in Poisson's ratio of bearing liner material. This leads to conclusion that to get higher value of load parameter we should select material of liner for which Poisson's ratio is less.
- Higher Attitude angle is observed when Poisson's ratio increases.
- Friction parameter value decreases with increase in Poisson's ratio.
- End flow increases with decrease in Poisson's ratio.

#### References

- G.R. Hingison, "The theoretical effects of elastic deformation of the bearing liner on journal bearing performance". Proc. Symp. Elastohydrodynamic Lubrication IMechE London (UK) 180 31-37 (1966).
- J. O'Donoghue, D.K. Brighton, C.J.K. Hooke, "The effect of elastic distortions on journal bearing performance". J. Lubr. Tech. 89 409-415 (1967).
- D.K. Brighton, C.J.K. Hooke, J. O'Donoghue, "Theoretical and experimental investigation of the effect of elastic distortions on the performance of journal bearing". Trib. Conv., Proc. IMechE 182 192-200 (1967).
- H.D. Conway, H.C. Lee, "The analysis of the lubrication of a flexible journal bearing". J. Lubr. Tech. 97 599-604 (1975).

- [5] B.C. Majumder, D.E. Brewster, M.M. Khonsari, "Stability of a rigid rotor supported on flexible oil journal bearing". Trib. 16 1-18 (1966).
- [6] A.C. Eringen, "Theory of micropolar fluids". J. Math. Mech. 16 1-18 (1966).
- [7] S. Allen, K. Kline, "Lubrication theory of micropolar fluids". J. Lubr. Tech. 38 646-650 (1971).
- [8] J. Prakash, P. Sinha, "Lubrication theory of micropolar fluids and its application to a journal bearing". Int. J. Engng. Sci. 13 217-232 (1975).
- [9] C. Singh, P. Sinha, "The three dimensional Reynolds equation for micropolar fluid lubricated bearings". Wear 76 199-209 (1982).
- [10] M.M. Khonsari, D.E. Brewster, "On the performance of finite journal bearings lubricated with micropolar fluids". STLE Trib. Trans. 32 155-160 (1989).
- [11] S. Das, S.K. Guha, A.K. Chattopadhyay, "On the conical whirl instability of hydrodynamic journal bearings lubricated with micropolar fluids". Proc. Inst. Mech. Engng. part-J, J. Engng. Trib. 215 431-439 (2001).
- [12] S. Das, S.K. Guha, A.K. Chattopadhyay, "On steady state performance of misaligned hydrodynamic journal bearings lubricated with micropolar fluids". Trib. Int. 35 201-210 (2002).
- [13] X.L. Wang, K.Q. Zhu, "A study of the lubricating effectiveness of micropolar fluids in a dynamically loaded journal bearing". Trib. Int. 37 481-490 (2004).
- [14] X.L. Wang, K.Q. Zhu, "Numerical analysis of journal bearings lubricated with micropolar fluids including thermal and cavitating effects". Trib. Int. 39 227-237 (2006).
- [15] S. Verma, V. Kumar, K.D. Gupta, "Analysis of multirecess hydrostatic journal bearings operating with micropolar lubricant". J. of Trib. 131 021103-1-9 (2009).
- Trans. 110 181-187 (1988).
- [16] J.R. Lin, T.L. Chou, L.J. Liang, T.C. Hung, "Non-Newtonian dynamics characteristics of parabolic-film slider bearings: Micropolar fluid model". Trib. Int. 48 226-231 (2012).
- [17] S.C. Sharma, A.K. Rajput, "Effect of geometric imperfections of journal on the performance of micropolar lubricated 4-pocket hybrid journal bearing". Trib. Int. 60 156-168 (2013).
- [18] S. Das, S.K. Guha, "On the Steady-State Performance Characteristics of Finite Hydrodynamic Journal Bearing under Micro-Polar Lubrication with Turbulent Effect". Int. J of Mech. and Mechatronics Engg. 7(4) 654-662 (2013).
- [19] P. Bansal, A.K. Chattopadhyay, V.P. Agrawal, "Linear Stability Analysis of Hydrodynamic Journal Bearings with a Flexible Liner and Micropolar Lubrication. Tribol". Transc. 58 316-326 (2015).
- [20] P. Bansal, A.K. Chattopadhyay, V.P. Agrawal, "Steady State Performance Characteristics of Micropolar Lubricated Hydrodynamic Journal Bearings with Flexible Liner". J. of inst. of engr. (India) Series C 97(2) 195-207 (2016).
- [21] K. Budheja, S. Verma, "A Study on the Influence of Combined Elastic and Micropolar Effects on Hole-Entry Hybrid Journal Bearing. Tribol." Online 13(2) 20-35 (2018).
- [22] O. Pinkus, B. Sternlicht, "Theory of Hydrodynamic Lubrication". McGraw Hill NY 1961.
- [23] V.G. Rekač, "Manual of theory of elasticity". MIR publisher Moscow, 1979.
- [24] L. Floberg, "Boundary Condition of Cavitation Regions in Journal Bearings". Trans. ASLE 4 282-286 (1961).