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Numerical investigation of pocketed slip slider bearing with non-Newtonian lubricant

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ABSTRACT – In this study, the modified Reynolds equation for lubrication with non-Newtonian power-law fluid was proposed. The equation was solved numerically using a finite difference equation obtained by means of the micro- control volume approach. Here, numerical computations for slider bearing with several power-law indexes were compared in the presence of the pocket and slip. The numerical results showed that the lowest index of the non-Newtonian lubrication model gives the best performance for lubricated pocket bearing considering boundary slip.

1. INTRODUCTION

In recent years, micro-electro-mechanical-systems (MEMS) devices have offered significant technological advancement and have played important roles in many significant areas such as information, electro-mechanical, chemical and biological applications. However, one main factor that limits the widespread development and reliability of MEMS is a high level of friction and wear [1]. The use of artificial surface texturing is becoming popular in oil lubricated devices because of its potential benefits in terms of load support and friction force both experimentally and theoretically. It was shown experimentally that such texturing enhances the load support and reduces friction force, for instance, systems with two parallel sliding surfaces [2], and in reciprocating (cylinder-liner) contacts [3]. Recently, in addition to surface texturing, the use of an artificial slip surface is also of great interest with respect to lubrication [4-5]. As mentioned above, the lubrication performance analysis uses Newtonian fluids as lubricants.

As a consequence of the development of modern machines and the requirement of severe operation conditions, the increasing use of non-Newtonian fluids as lubricants have received much attention. For slider bearings with non-Newtonian fluids investigation, Dien and Elrod [6] employed the regular perturbation technique to expand the pressure and the velocity into series of forms and then substituted them into the Navier-Stokes equation to derive a modified Reynolds equation for a power-law fluid model. Furthermore, the model was used to analyze the lubrication performance of journal bearings. Buckholz [7] used a power-law model as a non-Newtonian lubricant in a slider bearing. Li-Ming Chu at al. [8] proposed an analytical method approach for analysis of slider bearing with non-Newtonian lubricants. However, all of them still applied no-slip surface boundary condition.

Therefore, to improve this approach, it is necessary to include the boundary slip effect on the non-Newtonian lubricated contact. This paper aims at comparing the models for pocketed slip slider bearing with non-Newtonian lubricant. Moreover, power-law indexes affecting the pressure were examined.

2. METHODOLOGY

In this study, non-Newtonian fluid is modeled by power-law. It reads:

$$\tau = \eta \left| \frac{\partial u}{\partial z} \right|^{n-1} \frac{\partial u}{\partial z} \qquad (1)$$

With the assumption of Navier slip for modeling the boundary slip, the modified flow rate reads:

$$q_x = -\frac{\mathrm{h}^3}{12\eta'}\left(1+\frac{3\alpha\eta'}{h+\alpha\eta'}\right)\frac{\partial p}{\partial x}+\frac{\mathrm{u_w}h}{2}\left(1+\frac{\alpha\eta'}{h+\alpha\eta'}\right) \qquad (2)$$

The modified Reynolds equation is solved numerically using a finite difference equation obtained by means of the micro- control volume approach [9]. The entire computed domain is assumed as a full fluid lubrication. By employing the discretization scheme, the computed domain is divided into number of control volumes. The mesh number for all the situations obtained from a mesh refinement study are 1000 for model validation and 5000 nodes for pocketed slip slider bearing analysis, respectively. For all derivatives, the central difference is used except at the boundaries. Appropriate one-sided difference is used at the boundaries. The schematic of a lubricated slider bearing is presented in Figure 1.

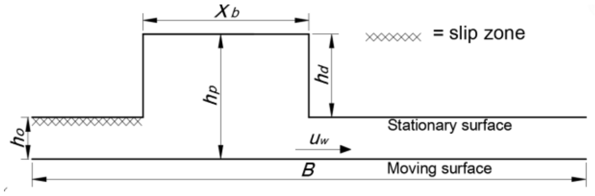

Figure 1 Schematic of a lubricated slider bearing. (Note: h_o = inlet film thickness, h_p = texture thickness, h_d = pocket height, X_b = pocket length, u_w = moving velocity).

3. RESULT AND DISCUSSION

Figure 2 shows the comparison of the dimensionless pressure distributions with various power-law exponent of pseudoplastics for classical (no-slip) bearing. For validation of the present numerical computation, the results were compared to the exact solution proposed by Dien & Elrod [6]. It can be seen in Figure 2, the simulation results match well with the theoretical prediction [6], especially with n=1. In the case of non-Newtonian fluid with n=1/3, n=1/2, the deviation is relatively small (< 3%). Therefore, the numerical algorithm can be extended for analyzing the pocketed bearing with boundary slip.

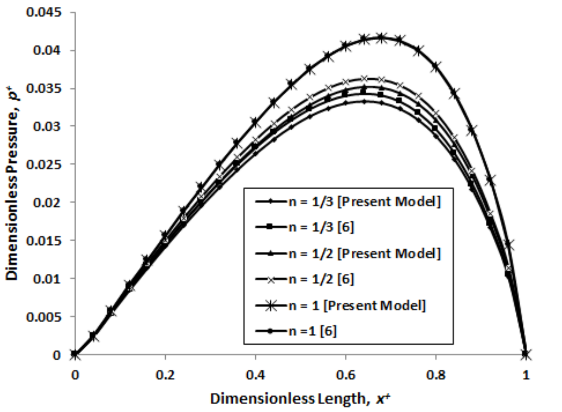

Figure 2 Pressure distribution for infinite width slider with various pseudoplastics (h_0/h_1 = 2, n = 1/3, 1/2 and 1). (Note: $p^+ = ph_o^2/(u_w \eta L)$ and $x^+ = x/L$).

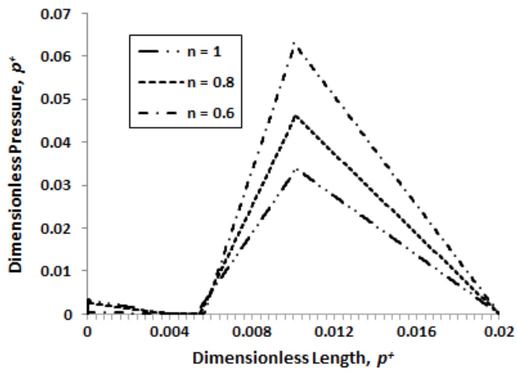

Figure 3 Pressure for pocketed slider bearing with various pseudoplastics (n = 0.6, 0.8 and 1).

Figure 3 shows the comparison of the dimensionless pressure distributions with various power-law exponent of pseudoplastics for pocketed slider bearing with boundary slip. As reflected in Figure 3, the peak of dimensionless pressure distribution is the highest for the lowest power-law index. Consequently, the bearing will have the highest load support. For Newtonian fluid (when n = 1), the generated load support has the lowest value.

4. SUMMARY

A numerical algorithm based on the finite volume method has been developed to deal with the slip pocketed bearing. The results showed that unlike Newtonian fluid, non-Newtonian model with the lowest index combined with boundary slip gives the best performance for lubricated pocket bearing. This finding seems to be a promising result to develop a pocketed non-Newtonian lubricated bearing with the highest performance.

5. REFERENCES

[1] M.P. de Boer, and T.M. Mayer, “Tribology of MEMS,” *MRS Bulletin*, vol. 26, pp. 302-304, 2001.

[2] I. Etsion, G. Halperin, V. Brizmer, and Y. Kligerman, “Experimental investigation of laser surface textured parallel thrust bearing,” *Tribology Letters*, vol. 17, pp. 295-300, 2004.

[3] G. Ryk, Y. Kligerman, and I. Etsion, “Experimental investigation of laser surface texturing for reciprocating automotive components,” *Tribology Transactions*, vol. 45, pp. 444 - 449, 2002.

[4] J.H. Choo, H.A. Spikes, M. Ratoi, Glovnea, and A. Forrest, “Friction reduction in low-load hydrodynamic lubrication with a hydrophobic surface,” *Tribology International*, vol. 40, pp. 154-159, 2007.

[5] M. Tauviqirrahman R. Ismail, Jamari, and D.J. Schipper, “ Combined effects of texturing and slippage in lubricated parallel sliding contact,” *Tribology International*, vol. 66, pp. 274 – 281, 2013.

[6] K. Dien, and H.G. Elrod, “A generalized steady-state Reynolds equation for non-Newtonian fluids, with application to journal bearings, ”*Journal of Lubrication Technology”*, vol. 105, pp. 385–390, 1983.

[7] R.H. Buckholz, “Effects of power-law non-Newtonian lubricants on load capacity and friction for plane slider bearing, ”*Journal of Tribology*,” vol. 108, pp. 86–91, 1986.

[8] L.M. Chu, H.C. Hsu, and J.L. Chen, “An Analytical Method Approach for Analysis of Slider Bearing with Non-Newtonian Lubricants”, *Advances in Mechanical Engineering*, vol. 2014, pp. 1-7, 2014.

[9] S.V. Patankar, *Numerical Heat Transfer and Fluid Flow*, Taylor & Francis, Levittown, 1980.