SQUEEZE FILM IN SPHERICAL BEARING WITH TWO LAYER FLUID CONSIDERING THERMAL EFFECT AND VISCOSITY VARIATION

M.Ganapathi[1], Prof. S.Vijayakumar Varma[2], Prof. K.R.K.Prasad[3], V.Bharath Kumar[4]
[1]Research Scholar, [2]Professor, [3]Emeritus Fellow, [4]Teaching Assistant
S.V.University, Tirupati, A.P., India.

ABSTRACT: In this paper the squeeze film lubrication of spherical bearing considering viscosity variation and thermal effects are analyzed. Expressions for load capacity and squeezing time are obtained and analyzed numerically, graphs are plotted. It is shown that the load capacity and time of squeezing increases due to high viscous layer near the periphery and decreases due to low viscous layer. A parameter 'q' is introduced to see the thermal effect in load capacity and squeezing time for spherical bearing and analyzed for different parameters.
Key Words: squeeze film, viscosity, eccentricity, thermal effect, film thickness, squeezing time etc.,

I. INTRODUCTION

The phenomenon of two lubricated surfaces approaching each other with a normal velocity is known as squeeze film lubrication. The thin film of lubricant present between the two surfaces acts as a cushion and it prevents the surfaces from making instantaneous contact. The time required to squeeze out the lubricant depends upon surface configuration, fluid properties and the load applied. In general, the relation between the load carrying capacity and the rate of approach is studied in the most squeeze film analysis. Much work is done in this line and the mathematical review on such process was done by various workers [1-47]. Although squeeze film lubrication has been generally understood for sometimes, the importance of applications lead to draw the attention of many workers in sixties. Pan et.al [30] studied the theory and experiments of squeeze film bearing parti-cylindrical journal bearings. Jacson.J.D [20]studied a study of squeezing flow. Gould.P [14] studied about parallel surface squeeze films: The effects of variation of viscosity with temperature and pressure. Beck et.al [4] studied flat disk squeeze film bearing including the effects of supported mass motion. Ramaiah.G and Dubey J.N [34] studied squeeze films and thrust bearing using Micro polar fluid. Murti.P.R.K [26] studied squeeze films in porous bearings. J.B.Shukla, K.R.Prasad and P.Chandra studied various squeeze films using power law fluid [21]. In this paper the squeeze film lubrication of spherical bearing considering viscosity variation and thermal effects are analyzed. Expressions for load capacity and squeezing time are obtained and analyzed numerically, graphs are plotted. A parameter 'q' is introduced to see the thermal effect in load capacity and squeezing time for analyzing due to it.

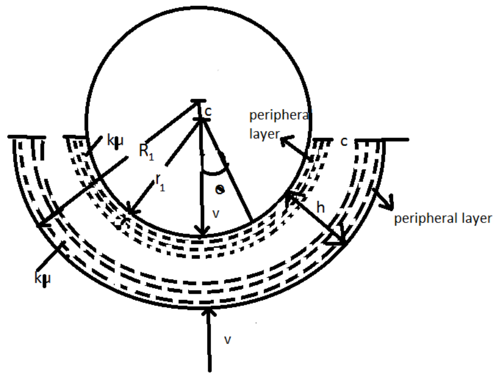

Fig (1.1): SQUEEZE FILM IN SPHERICAL BEARING

II. SQUEEZE FILM LUBRICATION IN SPHERICAL BEARING

Consider squeezing between two eccentric spherical surfaces of radii r_i and R_i which are approaching each other with a normal velocity V as shown in Fig (1.1).

The film thickness h is given by $h = c(1- \varepsilon\cos\theta)$. Where $c = R_1 - r_1$ is the clearance width and $\varepsilon = e/c$ is the eccentricity ratio.

The flow flux in this case is obtained by

$$Q = \left[\frac{F}{r} \frac{dp}{d\theta} \, 2\pi r_1 \sin\theta \right] \quad (1.1)$$

the flux Q obtained from the equation of continuity is

$$Q = 2\pi r_1 V \sin^2\theta \quad (1.2)$$

Where

$$F = \frac{1}{12\mu} \frac{\left(1-\frac{a}{h}\right)^3 (k-1)+1}{k} \quad (1.3)$$

From (1.1) and (1.2) $\frac{dp}{d\theta} = \frac{r_1 V \sin\theta}{F}$ (1.4)

Integrating (1.4) equation using the boundary condition $p = 0 \;\; at \;\; \theta = \frac{\pi}{2}$ We get the expression for pressure distribution as

$$p(\theta) = \int_0^\theta \left[\frac{r_1 V \sin\theta}{F}\right] d\theta \quad (1.5)$$

If $$\mu = \mu_0 \left(\frac{h}{h_0}\right)^q \qquad (1.6)$$

Then $$F = \frac{1}{12\mu_0\left(\frac{h}{h_0}\right)^q} \frac{\left[\left(1-\frac{a}{h}\right)^3(k-1)+1\right]}{k} \qquad (1.7)$$

The load capacity W is given by

$$W = 2\pi r_1^2 \int_0^{\pi/2} p \sin\theta \cos\theta \, d\theta \qquad (1.8)$$

Using (1.5) in (1.7) we get the load capacity W as

$$W = 2\pi r_1^3 V \int_0^{\pi/2} \left[\frac{\sin^2\theta\cos\theta}{F}\right] d\theta \qquad (1.9)$$

Where $$F = \frac{h_0{}^q h^{-q}}{12\mu_0} \frac{\left[\left(1-\frac{a}{h}\right)^3(k-1)+1\right]}{k} \qquad (1.10)$$

And squeeze time $\bar{t}$ for the surfaces to approach from the initial eccentric position (ε= 0) to a final eccentric position (ε = ε_1) we get

$$\bar{t} = \int_0^{\varepsilon_1} I_1 \, d\varepsilon \qquad (1.11)$$

Where $$I_1 = \int_0^{\frac{\pi}{2}} \left[\frac{\sin^2\theta\cos\theta}{F}\right] d\theta$$

The graphs are plotted for equations (1.9) and (1.11) are analyzed numerically.

III. RESULTS AND DISCUSSION

Figures (1.2) to (1.7) are drawn for load capacity and squeezing time are plotted with a, q for various parametersε, k and a.

Fig (1.2) is plotted for load capacity with'a' for different'k'. From this figure we can say with the increase of 'k' the load capacity increases and load capacity decreases with decrease of 'k' for increasing 'a'

Fig (1.3) is plotted for load capacity with'q' for different'ε'. From this figure we can say with the increase of 'q' the load capacity decreases for increasing of eccentricity 'ε'

Fig (1.4) is plotted for load capacity with'q'for different k. From this figure we can say with the increase of 'q'the load capacity decreases for decreasing values of 'k'.

Fig (1.5) is plotted for load capacity with'q'for different 'a'. From this figure we can say with the increase of 'q' the load capacity decreases for decreasing values of 'a'.

Fig (1.6) is plotted for squeezing time with'a' for different'k'. From this figure we can say the squeezing time decreases for decreasing 'k' and squeezing time increases for increasing 'k' for increasing values of a

Fig (1.7) is plotted for squeezing time with'q'for different'k'. From this figure we can say with the increase of 'q'the squeezing time decreases for decreasing 'k'.

IV. GRAPHS

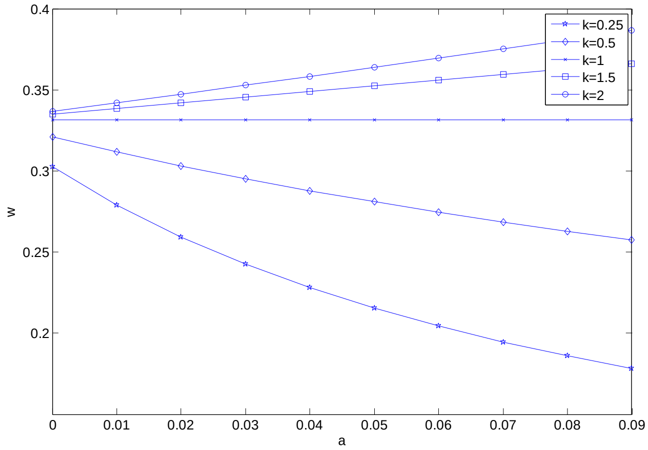

Fig (1.2): Load carrying capacity Vs a for various k, ε=0.1,q=0.1

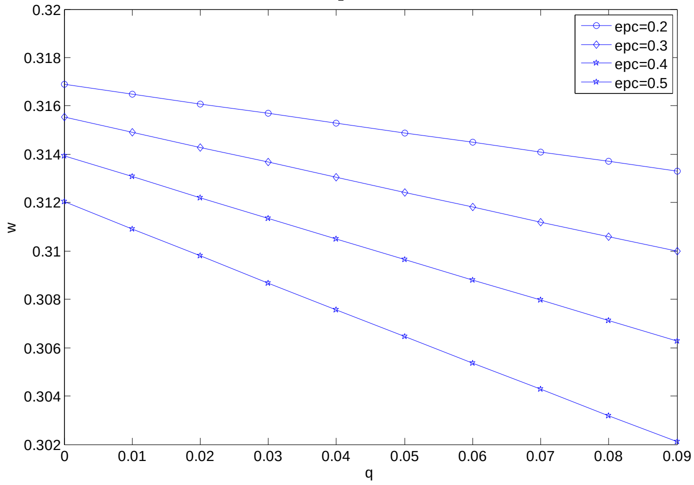

Fig (1.3): Load carrying capacity Vs q for variousε, at k=0.4 and a=0.01

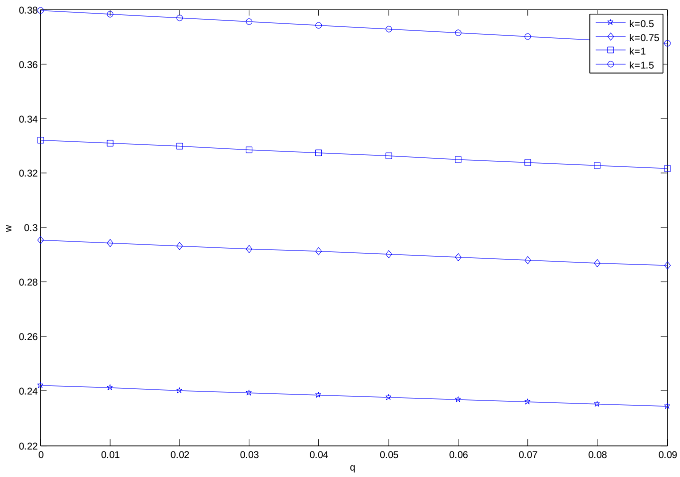

Fig (1.4): Load carrying capacity Vs q for various k, a=0.01 and ε=0.5

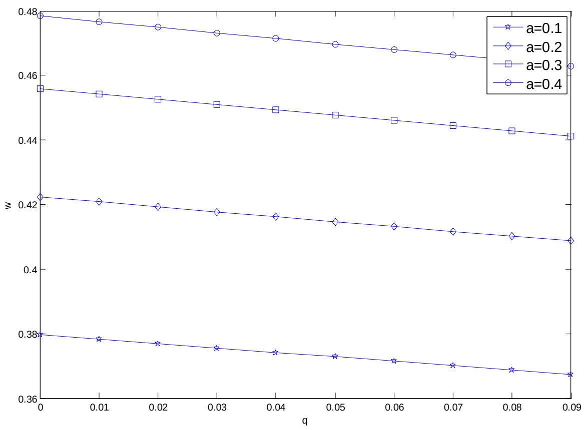

Fig (1.5): Load carrying capacity Vs q for various a, k=1.5 and ε=0.5

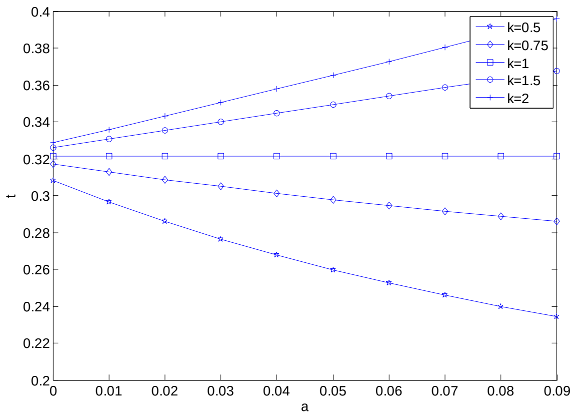

Fig (1.6): Squeezing time Vs a for various k, ε=0.2 to 0.3 and q=0.1

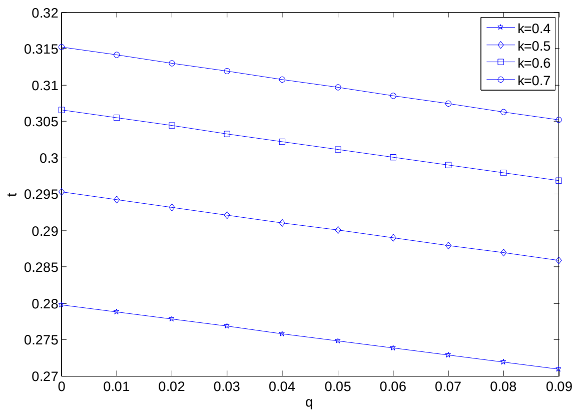

Fig (1.7): Squeezing time Vs q for various k, a=0.03 and ε=0.2 to 0.3

V. SUMMARY

It is observed that the load capacity increases for increasing values of k , a and the squeezing time is also increases for increasing values of k, a but when thermal factor increases the load capacity decreases. It is shown that the load capacity and time of squeezing increases due to high viscous layer near the periphery layer and decreases due to low viscous layer. It is also observed that the load capacity decreases as thermal factor increases for different parameters.

NOMENCLATURE

c Clearance width in journal bearing or spherical bearing
h Film thickness of hydrodynamic Zone
k Ratio of viscosities in different layers
p Hydrodynamic pressure
r_1 Radius of the journal or the radius of the spheres
R_1 Radius of the bearing
V Squeeze velocity
W Load capacity for stiff surfaces
X Cartesian coordinate in the direction of flow
μ Viscosity of the purely hydrodynamic zone
ε Eccentricity ratio
q Thermal factor
a peripheral layer thickness

REFERENCES

[1] Archibald, F.R., “Load capacity and time relations for squeeze films”, Trans. ASME, Vol.78, 1958, P.29.

[2] Ask with. T.C., Cameron, A. and Crouch, R.F., “Chain length of additive in relation to the lubricants in the film and boundary lubrication”, Proc. Roy.Soc., Vol. 291A, 1966, P.506.

[3] Barewell, F.T., “Lubrication of bearings”, Butterworths scientific publications, London, 1956.

[4] Beck, J.V., Holiday, W.G., and strodman, C.L., “Experiment and analysis of a flat disk squeeze film bearing including effects of supported mass motion”, Trans. ASME, F, Vol.91, 1969, P.138.

[5] Beltzener, M. and Jahanmir, S., “Role of dispersion interactions between hydrocarbon chains in boundary lubrication”, ASLE Trans, Vol.30, 1, 1980.

[6] Bird, R.B., Stewart, W.E., and Lightfoot, E.N., “Transport phenomena”, John Wiley and sons, Inc., 1960.

[7] Cameron, A. and Gohar, R., “Theoretical and experimental studies of the oil film in Lubricated point contacts “Proc. Roy. Soc., Vol. 291A, 1966, P.520.

[8] Chandra, “Mathematical Models for synovial joints”, Ph.D. Thesis, I.I.T. Kanpur, 1974.

[9] Christensen, H., “The oil film in a closing gap”, Proc. R. Soc., London, Ser, A., Vol.226, 1962, P.312.

[10] Christenson, H., “Elastohydrodynamic theory of spherical bodies in normal approach”, J. lub.Technol, F, 1970, P.145.

[11] Dine, I.K. and Elrod, H.G., “A generalized steady-state Reynolds Equation for non- Newtonian fluids, with application to journal bearings”, Jol. of. Lub.Tech. Trans., Trans.ASME, Vol.105, July, 1983, P.385.

[12] Fein, R.S., “Are synovial joints squeeze film lubricated”, Proc. Inst. Mech. Eng., London, Vol.181, 3J, 1967, P.152.

[13] Gaman, I.D.C., Higginson, G.R. and Norman,R., “Fluid entrapment by a soft surface layer”, Wear, Vol.28, 1974, P.345.

[14] Gould, P., “Parallel surface squeeze films: The effect of variation of viscosity with temperature and pressure, Trans. ASME, F, Vol.91, 1969, P.138.

[15] Har prashad, “The effects of viscosity variation and clearance on the performance of hydrodynamic journal bearings”, Tribology Transactions, Vol.31, 2, P.303.

[16] Hasegawa, E., “On squeeze film of a curved circular plate”, Bull. Of. JSME, Vol.28, No.239, 1985. P.951.

[17] Hayashi, W. Wada, S. and Nakari, N., “Hydrodynamic lubrication of journal bearings by non-Newtonian lubricants”, Bulletin of the JSME, Vol.20, No.140, 1977, P.224.

[18] Higginson, G.R., “Squeeze films between complaint solids”, Wear, Vp;.46, 1978, P.387.

[19] Hsu, Y.C., “Non-Newtonian flow in infinite length full journal bearing”, Trans. ASME, Paper, No. 66-lub-D, 1966.

[20] Jackson, J.D., “A study of squeezing flow”, Appl.Sci, res., Vol. II, 1963, P.148.

[21] J.B. Shukla and K.R. Prasad and Peeyush Chandra, “Effects of consistency variation of power law lubricants in squeeze films”, Wear, 1982, P.299.

[22] John, A.Tichy. “Effect of fluid inertia and viscoelasticity on the one-dimensional squeeze-film bearing”, ASLE Trans. Vol.27, 2, 1984. P.164.

[23] Mahanti, A.C. “A Theoretical study of the effect of solid particles in the lubricant of a partial journal bearing”, Wear, Vol.39, P.45.

[24] Malik, M. and Bhagwan Dass and Sinhasan, R., The Analysis of Hydrodynamic journal bearings using non-Newtonian lubricants by viscosity averaging across the film”, ASLE Trans., Vol.26, 1, 1983, P.385.

[25] Metzner, A.B., “Non-Newtonian fluids: Advances in Chemical Engineering”, Vol.1, 1956, P.103, Academic press, Newyork.

[26] Murti, P.R.K., “Squeeze film behavior in porous circular disks”, Trans. ASME, Vol.96, 1974, P.206.

[27] Najji. B., Bou-Said. B., and Berthe, D., “New formulation for lubricantion with non- Newtonian fluids”, Jol.of.Tribology, Trans.ASME, Vol.111, Jan, 1989, P.29.

[28] Nuri, K.A., “The contact behavior of surfaces of small nominal area”, Wear, Vol.57, 1979, P.255.

[29] Needs, S.J., “Boundary film investigation”, Trans, ASME, Vol.62, 1940, P.331.

[30] Pan, C.H.T. Malinowski, S.B., Broussard, Jr., P.H, and Burch, J.L, “Theory and Experiments of squeeze film bearings, Parti-cylindrical journal bearings”, Trans. ASME, D, Vol.88, 1966, P.191.

[31] Prajapati, B.L., “Squeeze film behavior between rotating porous circular plates with a Concentric circular pocket: surface roughness and elastic deformation effect”, Wear, Vol.152, 1992, P.301.

[32] Prakash, J and Vij, S.K., “Load capacity and Time-Height relations for squeeze films between porous plates”, Wear, Vol.24, 1973, P.309.

[33] Raj, A. and Sinha, P. “Transverse roughness in short journal bearings under dynamic loading, “Tribology international, Vol.16, No. 5, Oct, 1983, P.245.

[34] Roberts, A.D., “Squeeze films between rubber and glass”, J.Phys.D, Vol.4, 1971, P.423.

[35] Safar, Z.S., “Frictional behavior of non-Newtonian lubricants”, Tribology international, April, 1979, P.76.

[36] Safar, Z.S., “Journal bearing operating with non-Newtonian lubricant films”, Wear, Vol.53, 1979, P.95.

[37] Shukla, J.B., “Theory for the squeeze film for power law lubricants”, Trans. ASME,paper No.64-lub-4, 1964.

[38] Shukla, J.B., “Load capacity and time relation for squeeze films in conical bearings”, Wear, Vol.7, 1964, P.368.

[39] Shukla, J.B., Kumar, S., and Chandra, P., “Generalized Reynolds Equation with slip at bearing surfaces: Multilayer lubrication theory “, Wear, Vol.60, 1980, P.253.

[40] Sinha,P., Singh.C., and Prasad, K.R., “Effect of viscosity variation due to lubricant additives in journal bearings”, Wear, Vol.66, 1981, P.175

[41] Sinha, P., Singh, C., and Prasad, K.R., “Viscosity variation considering cavitation in a journal bearing lubricant containing additives”, Wear, Vol.86, 1983, P.43.

[42] Sinha, P., Kennedy, J.S., Rodkiewicz, C.M., Chandra, P., Sharma, R., and Prasad, K.R.,“ Effects of surface roughness and additives in lubrication: generalized Reynolds Equation and its application to elasto hydro dynamic film”, Proc. Instn. Mech. Engrs., Vol.201, No.C1, 1987.

[43] Tanner, R.I., “Non-Newtonian lubrication theory and its application to the short journal bearing”, Australian journal of Applied science, Vol.14, 1963, P.129.

[44] Tanner, R.I., “Study of an isothermal short journal bearings with non-Newtonian Lubricants”, J.AIP.157

[45] White, J.W., “Analytic solution of a finite width rough surface hydrodynamic bearing”, Jol.Appl.Mech., Trans ASME, Vol.53, June 1986

[46] Ye.A.Kuznetsov and G.A. Gorokhovsky, “Effect of roughness and poisson’s ratio on deformation conditions in the surface layers of contacting bodies”, Wear, Vol.53, 1979, P.43

[47] P.Suneetha, V.Bharath Kumar and Ramakrishna Prasad, “Lubrication of Journal bearing consider in thermal effect in two layer fluid considering cavitation”, International journal of advanced Engineering Technology, E-ISSN 0976-3945.

