Analysis of Slider Bearing with Partial Slip Surface

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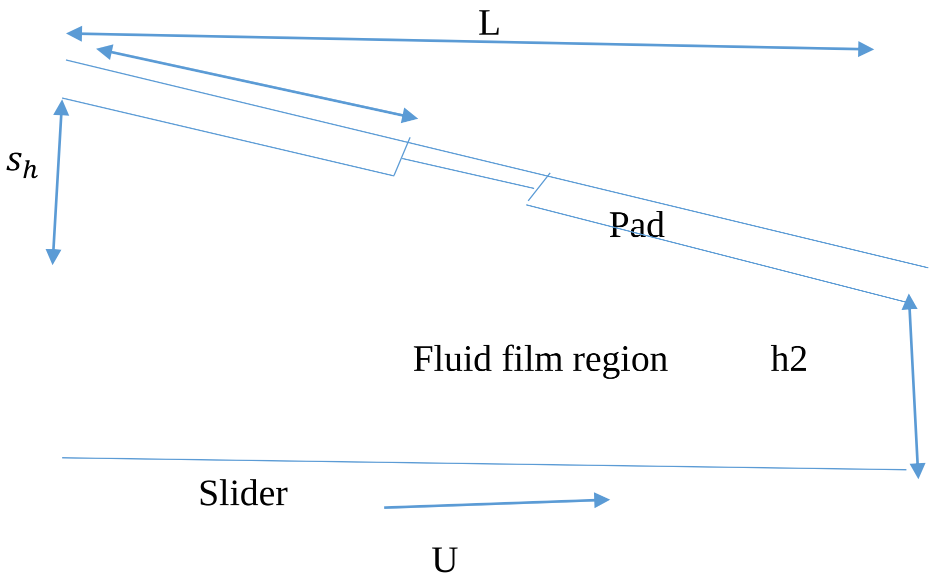
Abstract:

In this problem pressure and shear stress are derived under steady state using one-dimensional analysis of the single grooved slider bearing and journal bearing with partial slip on the stationary surface. The Reynolds boundary conditions are used in the analysis of journal bearing to predict the extent of the full film region. In the case of partial slip on both slider and journal bearing the single groove immediately followed by the partial slip region results in the increase in pressure distribution. The results also show that in comparison to the conventional bearing with no slip.

Introduction:

The classical Reynolds equation is based on the assumption of no slip of fluid over two surface with relative sliding motion .Recent studies showed that slip occurs on the specially prepared hydrophobic surface that utilized coated mica lubricated water ,Spikes[1] annualized the influence of wall slip on the hydrodynamic properties of half –wetted bearing. Wall slip is usually described by the slip length model at low shear rate or by limiting the shear stress model at high shear rate. In the half wetted bearing, where the fluid has no slip boundary condition against the moving surface ,but has a slip boundary condition against stationary surface results in high hydrodynamic pressure and low friction. However in case of bearing where in the case of bearing where in the fluid with zero critical shear stress that has slip boundary condition against the moving surface will no certain fluid and thus cannot support load. The high hydrodynamic pressure is due to fluid entrainment and low frication is due to very low coquette friction at the slip surface .Salant and Fortier [2,3] presented the numerical analysis of a slider and journal bearing using modified slip length model. Their results illustrated high load support and low friction using heterogeneous slip/no slip bearing surface. Wuet al. studied the behaviour of a slider bearing with mixed slip surface and their results indicated that convergent, parallel and divergent wedge can provide hydrodynamic load support .Fowl hydrodynamic bearings that has micro electro mechanical systems (MEMS), it is possible to design device with hydrodynamic lubrication of textured surface with partial slip.

In this paper pressure and shear stress in the single grooved slider and journal bearing under steady state are deduced from the governing equation using quadratic distribution of fluid velocity along the sliding direction .Partial slip is considered on the stationary surface of single grooved slider bearing .



Governing Equation:

A one dimensional analysis of single grooved partial slip slider bearing are considered in the analysis. Assuming that the pressure does not vary along the film thickness and considering that the pressure is a function of sliding direction(x) the momentum equations are simplified as

$$\frac{\partial p}{\partial x} = \eta \frac{\partial^2 u}{\partial y^2} \quad \text{---} \text{ --(1)}$$

The shear stress can be written as

$$\tau_{xy} = -\eta \frac{\partial u}{\partial y} \quad \text{--(2)}$$

The quadratic velocity distribution of the fluid in the x direction is of the form [4,5]

$$u = U\,(C_1 y^2 + C_2 y + C_3) - - - - - - - - - (3)$$

Considering the slip region on the nonrotating surface of the slider/journal bearing .the boundary condition for the steady flow at the sliding surface(y=0) and the stationary surface(y=h) are as follows [2,3]:

At y=0, u=U and at y=h, u=$-\alpha\eta \frac{\partial u}{\partial y}$ ----------------(4)

Substituting the boundary condition in eq.(4) in Eq.(3) yields the velocity distribution of the fluid in the x direction as

$$u = U\left[C_2\left(y - \frac{y^2(h+\alpha\eta)}{h(h+2\alpha\eta)}\right) + 1 - \frac{y^2}{h(h+2\alpha\eta)}\right] - - - - - - \quad - - - (5)$$

Three boundary conditions are required for u in Eq.(3) since the velocity distribution is quadratic .The third boundary condition or the steady flow is as follows .

$$\int_0^h u\,dy = q \quad \text{------------------------------------ ----} \qquad (6)$$

Substituting the value of u from Eq.(5) in the boundary condition of Eq.(6) and simplifying for constant ,result in

$$C_2 = \frac{6q(h+\alpha\eta)}{Uh(h+2\alpha\eta)} - \frac{4(h+3\alpha\eta)}{h(h+4\alpha\eta)} \quad \text{--------------------------------------} \quad \text{-(7)}$$

Substituting Eq. (5) and (7) in Eq.(1) results in the pressure gradient distribution in the slider/journal bearing as

$$\frac{\partial p}{\partial x} = \eta U\left(\frac{6q(h+\alpha\eta)}{h^2(h+2\alpha\eta)} - \frac{12q(h+\alpha\eta)}{Uh^3(h+4\alpha\eta)}\right) \text{------------------------------ --------} \quad (8)$$

The pressure distribution can be obtained from Eq.(8) as

$$P(x) = pIx{=}0 + \int_0^x \frac{dp}{dx}dx \quad - - - - - - - - - - - - - - - - - \quad - \quad (9)$$

Substituting Eq. (5) and (7) in Eq. (2) the shear stress in the slider bearing at y=0 is obtained as

$$\tau_{xy}|y = 0 \quad = -\eta U\left(\frac{6q(h+\alpha\eta)}{h^2(h+2\alpha\eta)} - \frac{4(h+3\alpha\eta)}{h(h+4\alpha\eta)}\right) \quad \text{-------------------------} \ (10)$$

Analysis of Slider Bearing:

The Film thickness expression of the plain slider bearing (ungrooved) for 0$\leq x \leq L$ is shown in Eq. (11) and the film thickness of the single grooved bearing is h+h_g

$$h = h_2 + s_h\left(1 - \frac{x}{L}\right) \quad \text{------------------------------------- ------------} \quad (11)$$

Equation (11) can be rewritten in non-dimensional form as

$$H = H_0 + (1-X) \text{ --------------------------------- -------} \quad -(12)$$

Using the no dimensional parameter for the slider bearing we will get pressure gradient distribution from eq.(8) is simplified as

$$\frac{dp}{dX} = \frac{h_1^2}{L}\left(\frac{6(1+2A)}{H^2 s_h^2(1+4A)} - \frac{12Q(1+A)}{H^3 {s_h}^3(1+4A)}\right) \text{------------------}(13)$$

The boundary condition for no dimensional pressure at the inlet(X=0) and outlet(X=1) of the slider bearing are

$$P|(X = 0) = P\,|(X = 1) \quad = \ 0 \quad \text{---------------------------------------}(14)$$

For 0$\leq X \leq 1$ the nondimensional pressure in the single –grooved partial slip slider bearing can be written as

$$P(0 \leq X \leq X_s) = \ P|(X = 0) + \int_0^X \frac{h_1^2}{L}\left(\frac{6(1+2A)}{H^2 s_h^2(1+4A)} - \int_0^X \frac{h_1^2}{L}\frac{12Q(1+A)}{H^3 {s_h}^3(1+4A)}\right) \text{---------}(15)$$

$$P(X_s \leq X \leq X_s + X_g) = P|(X = X_s) + \int_{X_s}^X \frac{h_1^2}{L}\left(\frac{6}{(H+H_g)^2 s_h^2(1+4A)} - \int_{X_s}^X \frac{h_1^2}{L}\frac{12Q}{(H+H_g)^3 {s_h}^3(1+4A)}\right) \text{----- --}(16)$$

$$P(X_s + X_g \le X \le 1) = P\big|(X = X_s + X_g) + \int_{X_s+X_g}^{X} \frac{h_1^2}{L}\frac{6}{(H)^2 s_h^2} - \int_{X_s+X_g}^{X} \frac{h_1^2}{L}\frac{12Q}{(H)^3 {s_h}^3} \text{ --(17)}$$

Where H= h/s_h , $H_1 = h_2/s_h$, X= x/L , A= $\frac{\alpha\eta}{s_h}$ $\alpha = Slip\ Coificient\ \eta = fluid\ viscocity$

Substituting the boundary condition from eq.(14) in equations 15,16,&17 we get

$$Q = \frac{\int_0^{X_s}\left(\frac{(1+2A)}{H^2 s_h^2(1+4A)}dX + \int_{X_s}^{X_s+X_g}\frac{1}{(H+H_g)^2 s_h^2}dX + \int_{X_s+X_g}^{1}\frac{1}{(H)^2 s_h^2}dX\right.}{2\int_0^{X_s}\left(\frac{(1+2A)}{H^3 s_h^3(1+4A)}dX + 2\int_{X_s}^{X_s+X_g}\frac{1}{(H+H_g)^3 s_h^3}dX + \int_{X_s+X_g}^{1}\frac{1}{(H)^3 s_h^3}dX\right.} \text{ -------------------------(18)}$$

We consider uniform film thickness for the slider bearing (H=1) for 0≤ X ≤1,the value of Q will be obtained from Eq.(18)

Hence

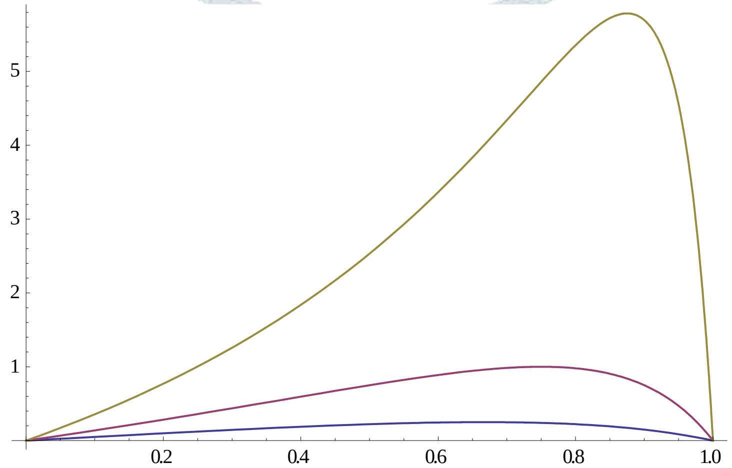
$$Q = \frac{\frac{(1+2A)}{s_h^2(1+4A)}(X_s) + \frac{1}{(1+H_g)^2 s_h^2}(X_g) + \frac{1}{s_h^2}(1-X_s-X_g)}{2\{\frac{(1+2A)}{s_h^3(1+4A)}(X_s) + \frac{1}{(1+H_g)^3 s_h^3}(X_g) + \frac{1}{s_h^3}(1-X_s-X_g)\}} \text{ --------------------------------(19)}$$

In the case of partial slip slider bearing with uniform film thickness for 0≤ X ≤1

Results:

The nondimensional slip length A is zero in no slip regions we assume the value of A are in slip regions are A=1,10(Watanable).The parameters used in the analysis of slider bearing are s_h=0.3 and 0.2 the value of $X_s = 0.6$ *and* $X_g = 0.3$.

From Eq.10 we will find the value of P in terms of X and other non dimensional parameter then by using the the value of Q we will find the different pressure distribution.



X

In above figure Y axis stands for Nondimensional pressure hence the above figure shows the pressure distribution of slider bearing.

The Non dimensional pressure is higher than conventional bearings. For a grooved slider bearing the pressure distribution profile is some little different and if we compaired with conventional bearing without grooved slider bearing we find that pressure are different.

Nomenclature:

H_g = depth of groove

L= length of slider bearing

τ_{xy} = shear stress

P = pressure distribution

References:

[1] spikes ,H.A.,2003 "The half –wetted Bearing .Part1:Extended Reynolds Equation "Proc.Inst.Mech.Eng.Tribol.,217(1)pp.1-14

[2] Salant R.F.and Fortier A.E.2004 ' Numerical Analysis of a slider bearing with a heterogeneous Slip/No –Slip Surface ,'STLE Tribo.Trans.,47(3) PP-328-334.

[3] Salant R.F.and Fortier A.E.2005 ' Numerical Analysis of a Journal bearing with a heterogeneous Slip/No –Slip Surface', ASME J.Tribol.127(4) pp,820-825.

[4] C.M. Rodkiewicz, P. Sinha, on the lubrication theory: a mechanism responsible for generation of the parallel bearing load capacity, Trans. ASME 105 (1993) 584}590.

[5] M.R. Schumack, Application of the pseudo spectral method to thermohydrodynamic lubrication, Int. J. Numer.Methods. Fluids 23 (1996) 1145}1161.

[6] J. Young, The thermal wedge in hydrodynamic lubrication, Eng. J. 45 (3) (1962) 46}54.

[7] A.O. Lebeck, Parallel sliding load support in the mixed friction regime, Part 1 } The experimental data, ASME J. Tribol. 109 (1987a) 189}195.

[8] A.O. Lebeck, Parallel sliding load support in the mixed friction regime, ASME J. Tribol. 109 (1987b) 196}205.

[9] W. Hunter, O.C. Zienkiewicz, E!ects of temperature variation across the lubricant "lm in the theory of hydro- dynamic lubrication, J. Mech. Eng. Sci. 2

[10]T.V.V.L.N.Rao ,Analysis of Single-Grooved Slider and Journal Bearing With Partial Slip Surface ,J.Tribology (2010)

[11] M.R. Schumack, Application of the pseudo spectral method to thermohydrodynamic lubrication, Int. J. Numer.Methods. Fluids 23 (1996) 1145}1161.

[12] B.V. Rathish Kumar et al., A SUPG/FEM analysis of thermal effects on load carrying capacity in slider bearing lubrication, Numer. Heat Transfer Part A 38 (3) (2000) 305}328.