Motion of MR-fluid via Plane Inclined Slider Bearing

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Abstract

At presently the technological state of affairs, machines rotating at excessive velocity and carrying heavy rotor load capacity are used. As a end result, slider bearings with a fixed inclination are used. They're designed for excessive axial loads, when the bearing rotates at high speed, the lot amount of heat generated because of high shear in the lubricant film will increase its temperature, which reduces the viscosity of the lubricant and consequently influences the performance traits of the bearing. Consequently, a hydrodynamic evaluation need to be done to achieve sensible overall performance characteristics of the bearing.

In most of the analysis, the two-dimensional equation for energy is used to locate the temperature distribution inside the fluid film by using neglecting temperature adjustments inside the axial route. In this research, a second order lubrication theory is used with MR-fluid instead of normal classical fluid. A magnetic field is applied for the MR-fluid to get much better performance of the slider. Numerical outcomes acquired for strain, temperature and velocity can be analyzed, mentioned and graphically represented. The coefficient of friction and other various factors of the bearing will also be determined, analyzed and graphically represented. The outcomes acquired right here may be beneficial inside the layout and modification of fluid dynamic bearings.

Keywords: Film thickness, Hartmann number, Magnetic field, MR-fluid, Reynolds equation, Rotation number, Taylor's number, Viscosity.

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1. Introduction

For all geometrically shaped sliding bearings, wedge runners provide the only aid for fluid lubrication and are therefore normally used as a part of axial sliding bearings. With the development of contemporary equipment, polymer lubrication fluid is usually introduced to the lubricating oil, mainly motor oil for vehicles, including multi-grade crankcase oil, to correctly reduce the friction lack of machinery components. But, such polymer lubricants belong to the non-Newtonian form of fluid. Consequently, the non-Newtonian groups of lubricants have become crucial. In recent years, a large range of polymer lubricants have been used to explain non-Newtonian fluids. Amongst them, the pressure model is the most effective and most widely used. Safar and Shawki [17] divided fluids into 3 distinctive categories:

(1) Newtonian fluid, n =1, that is taken into consideration a type of regular natural fluid and gas;

(2) Dilatant or shear-thickening fluids, $n > 1$, which show an increase in apparent viscosity with increasing shear charge;

(3) Pseudo plastic fluids, $n < 1$, which are characterized by means of linearity at extraordinarily low and extremely excessive shear rates.

With regard to the research of plane slider bearings, many researchers [10, 16, and 19] have derived closed form of the Newtonian fluid solutions for various type of plane bearings.

Hamrock [8] analyzed the pressure and velocity distribution, film thickness, load capacity with respect to width of the bearings, and coefficient of friction of fixed inclination sliding bearings with Newtonian fluid. As already explained, closed-form solutions recognition on a simple geometric shape and a Newtonian fluid. However, many experiments have shown that a base oil mixed with lengthy-chain components right into a Newtonian fluid provides the maximum favorable lubrication consequences and may enhance the bearing capacity and decrease the friction parameter [15, 18]. Therefore, the usage of non-Newtonian fluids as lubricants has come to be a extra crucial issue with in the industries. For non-Newtonian fluids, it's miles tough to achieve a closed solution, such a lot of researchers have used a numerical technique to remedy the bearing overall performance, along with pressure distribution and film thickness consideration. But, closed-form formulas can in reality find the consequences of working parameters in preference to numerical methods. it is able to be effortlessly used for engineers.

For sliding bearings, investigating non-Newtonian fluids, Dien and Elrod [6] used the normal perturbation method to enlarge the pressure and velocity into collective form after which analyzed them with the Navier-Stokes equation to derive the generalized Reynolds equation for the power equation fluid model. Furthermore, the model was used to analyze the lubrication overall performance of radial bearings. Buckholz [4] used the power-law fluid analysis model to research the bearing load capacity and coefficient of friction of the sliding bearings. Das [5] evolved a set of algebraic equations to gain the implemented inclined and parabolic countless-width undeniable sliding bearings to interpret this mathematical improvement and analyzed the changes within the ideal bearing load capacity, coefficient of friction, etc., considering the simultaneous modifications inside the input and output film ratio and other various exponents of the lubricant.

Naduvinamani et al. [14] analyzed the lubrication performance of simple bearings with one-of-a-kind shapes the use of a seize strain fluid model. In addition they discussed the results of coupling pressure and surface roughness parameters on bearing capability and coefficient of friction, and the effect of temperature on sliding bearings of different shapes. Lin [9] proposed an approximate closed-form answer for MHD power-law bearings with film thickness, which can also include the special characteristics of willing aircraft and parabolic foil profile bearings. As noted above, evaluation of the lubrication performance of the power fluid on simple bearings is nearly always obtained with the help of numerical methods. Closed hydrodynamic lubrication solutions with energy fluids had been lacking. Consequently, this paper proposes a few analytical solutions for the overall performance fluid model of sliding bearings by using the MR-fluid and applying the magnetic field. Eventually, we will use these proposed answers to analyze the lubrication overall performance of a sliding bearing with MR-fluids.

2. Mathematical Equation and Boundary Conditions

The generalized form of slider bearing is Plane Inclined slider bearing. The geometry of plane inclined slider is demonstrated by figure (1).

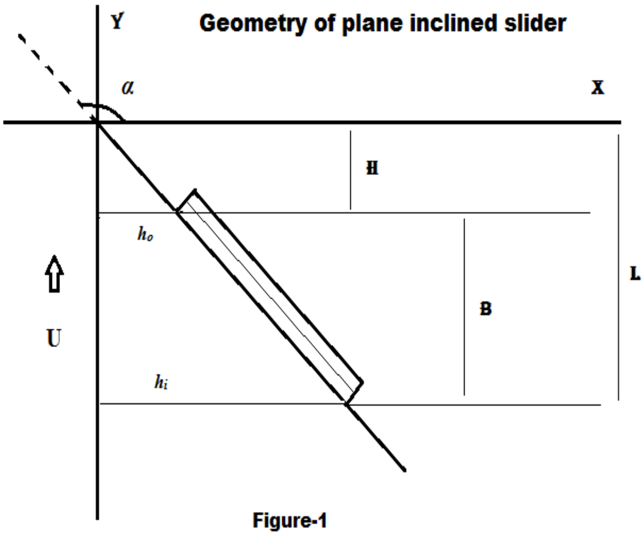

Figure-1 (Plane inclined slider bearing)

That represents that the gap H decreases on increasing y, hence the runner is moving towards origin in y-direction with velocity U. The minimum and maximum film thicknesses are h_o and h_i .The position h_o is distant H apart from origin and h_i is distant L apart from origin. On considering n as [1, 2, 3 and 7]:

$$n = \frac{h_i - h_o}{h_o} \tag{2.1}$$

The film thickness h can be written at any arbitrary point as:

$$h = h_o\left(1 + \frac{ny}{L}\right) \tag{2.2}$$

$$h = y \cot \alpha, \tag{2.3}$$

α = angle of inclination of the slider.

$$\cot \alpha = \frac{h_o}{H} = \frac{h_i}{L} = \frac{dh}{dy} \tag{2.4}$$

$$\frac{dh}{dy} = \frac{nh_o}{L} = \frac{h_i - h_o}{L} \tag{2.5}$$

$$\frac{h_o}{H} = \frac{h_i}{L} = \frac{h_i - h_o}{L-H} = \frac{L\frac{dh}{dy}}{L-H} \tag{2.6}$$

The new version of the Extended Generalized Reynolds Equation is written by

$$\frac{\partial}{\partial x}\left[-\frac{h^3}{12\mu}\left(1-\frac{17M^2\rho^2h^4}{1680\mu^2}\right)\rho\frac{\partial P}{\partial x}\right]+\frac{\partial}{\partial y}\left[-\frac{h^3}{12\mu}\left(1-\frac{17M^2\rho^2h^4}{1680\mu^2}\right)\rho\frac{\partial P}{\partial y}\right]$$
$$+\frac{\partial}{\partial x}\left[-\frac{M\rho^2h^5}{120\mu^2}\left(1-\frac{31M^2\rho^2h^4}{3024\mu^2}\right)\frac{\partial P}{\partial y}\right]-\frac{\partial}{\partial y}\left[-\frac{M\rho^2h^5}{120\mu^2}\left(1-\frac{31M^2\rho^2h^4}{3024\mu^2}\right)\frac{\partial P}{\partial x}\right]$$
$$=-\frac{\partial}{\partial x}\left[\frac{\rho U}{2}\{h-\frac{M^2\rho^2h^5}{120\mu^2}\left(1-\frac{31M^2\rho^2h^4}{3024\mu^2}\right)\}\right]$$
$$-\frac{\partial}{\partial y}\left[\frac{M\rho^2U}{2}\{-\frac{h^3}{12\mu}\left(1-\frac{17M^2\rho^2h^4}{1680\mu^2}\right)\}\right]-\rho W^* \tag{2.7}$$

The symbols have the meaning as follows:

x, y, z=coordinate system, μ=dynamic viscosity of the fluid, *U*=sliding velocity, *P*=pressure, ρ=density of fluid, W^*=fluid velocity in *z*-direction.

.On neglecting the term *∂p/∂x* w. r. t. *∂p/∂y* in the final differential equation, and taking *h=h(y), U=-U, P=P(y)*; we have

$$\frac{\partial}{\partial y}\left[-\frac{h^3}{12\mu}\left(1-\frac{17M^2\rho^2h^4}{1680\mu^2}\right)\rho\frac{\partial P}{\partial y}\right]+\frac{\partial}{\partial x}\left[-\frac{M\rho^2h^5}{120\mu^2}\left(1-\frac{31M^2\rho^2h^4}{3024\mu^2}\right)\frac{\partial P}{\partial y}\right]$$
$$=\frac{\partial}{\partial x}\left[\frac{\rho U}{2}\left\{h-\frac{M^2\rho^2h^5}{120\mu^2}\left(1-\frac{31M^2\rho^2h^4}{3024\mu^2}\right)\right\}\right]$$
$$+\frac{\partial}{\partial y}\left[\frac{M\rho^2U}{2}\left\{-\frac{h^3}{12\mu}\left(1-\frac{17M^2\rho^2h^4}{1680\mu^2}\right)\right\}\right] \quad (2.8)$$

We also have

$$M^2=T_a=\frac{4\Omega^2L^2}{\mu^2} \quad (2.9)$$

$$H_a=LB\sqrt{\frac{\sigma}{\mu\rho}} \quad (2.10)$$

Where,

T_a =Taylor's number

H_a=Hartmann number

Ω =Characteristic angular velocity

L =Characteristic length scale perpendicular to the direction of rotation

B=Magnetic flux density

σ =Electric cunductivity

Hence the differential equation for the motion of system in the fluid can be expressed as [11, 12 and 13]:

$$\frac{d}{dy}\left[-\frac{h^3}{12\mu}\left(1-\frac{17\,\Omega^2H_a^4\rho^2h^4}{420\mu^2B^4\sigma^2}\right)\rho\frac{\partial P}{\partial y}\right]=\frac{d}{dy}\left[\frac{\Omega B^2\rho^2U}{\sigma H_a^2}L^3\left\{-\frac{h^3}{12\mu}\left(1-\frac{17\,\Omega^2H_a^4\rho^2h^4}{420\mu^2B^4\sigma^2}\right)\right\}\right] \quad (2.11)$$

The used boundary conditions for the plane inclined slider are as given [17-19]:

P=0 at $h=h_o$ and *P=0* at $h=h_o\,(1+n)$

On solving, we get the dimensionless pressure

$$P=\frac{\Omega UH_a\rho^{3/2}}{B(\sigma\mu)^{1/2}}\left[-\left\{\left(\frac{n(n+1)^2-1}{n(n+1)^2}\right)L-y+\frac{L^3}{n(ny+L)^2}\right\}\right.$$
$$\left.+\frac{17\Omega^2U^2{H_a}^2\rho^5{h_0}^4}{1680\mu^3B^2\sigma}\left\{\frac{L^3}{n(ny+L)^2}-\left(y+\frac{ny^2}{2L}\right)-\left(\frac{2-n(n+1)^2(n+2)}{2n(n+1)^2}\right)L\right\}\right]$$

(2.12)

The load capacity for plane inclined slider bearing is given by

$$W = \int_L^0 P\, dy \tag{2.13}$$

$$W = \frac{\Omega U H_a \rho^{3/2} L^2}{6B(\sigma\mu)^{1/2}(n+1)^2}\left[-3(n^2+2n+3) + \frac{17\Omega^2 U^2 {H_a}^2 \rho^5 {h_0}^4}{1680\mu^3 B^2 \sigma}(2n^3+7n^2+8n+9)\right] \tag{2.14}$$

3. Boundary Conditions and Derivative Analysis

3.1 Numerical Simulation-1

Table-1 Calculated values of pressure and load capacity by taking the values of different mathematical terms in C.G.S. system as: $\mu = 0.0002, U = 500,$

$L = 15, n = 1, y = 7.5, h = 0.015, h_i = 0.02, h_o = 0.01, U = 80,\ \rho = 1.0,\ R = 3.35,\ h_o = 0.0167,\ \mu = 0.0002, \Omega = 23.88059,\ M = 0.1,\ \sigma = 1, B = 5$

S. No.	H_a	$P \times 10^6$	$W \times 10^6$
1.	10	40.750	61.929
2.	20	163.027	247.718
3.	30	366.812	557.366
4.	40	652.110	990.872
5.	50	1018.922	1548.238
6.	60	1467.248	2229.463
7.	70	1997.087	3034.547
8.	80	2608.440	3963.491
9.	90	3301.307	5016.293
10.	100	4075.687	6192.954

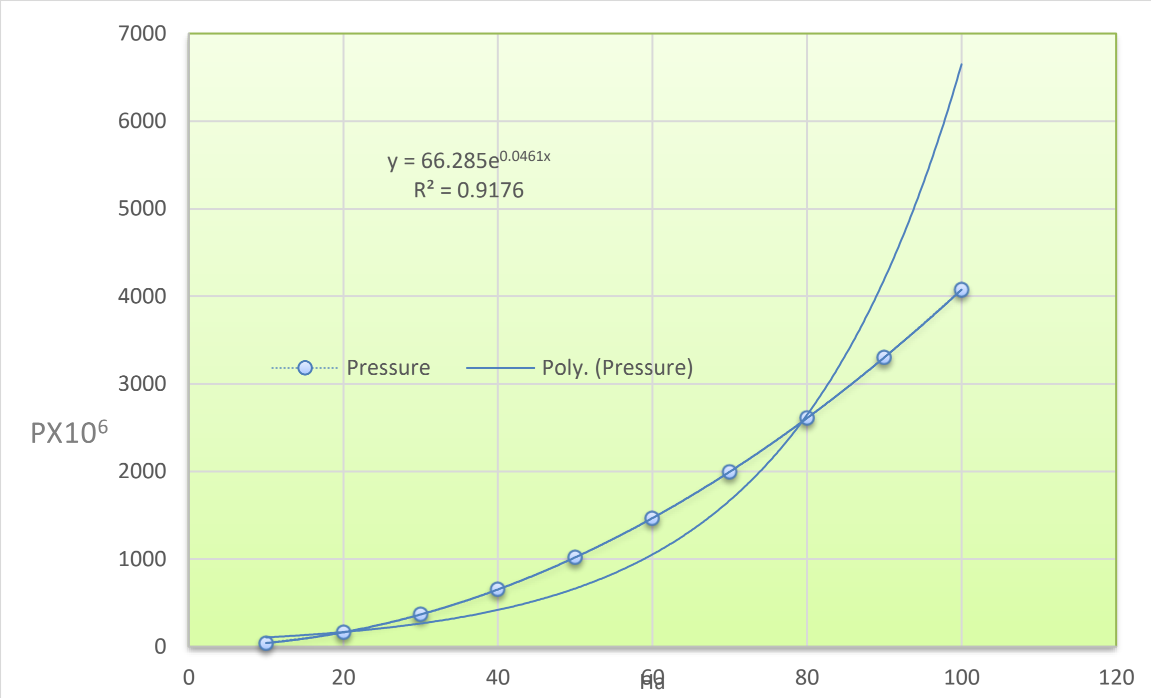

Figure-4.2 (Pressure Variation against Hartmann number H_a)

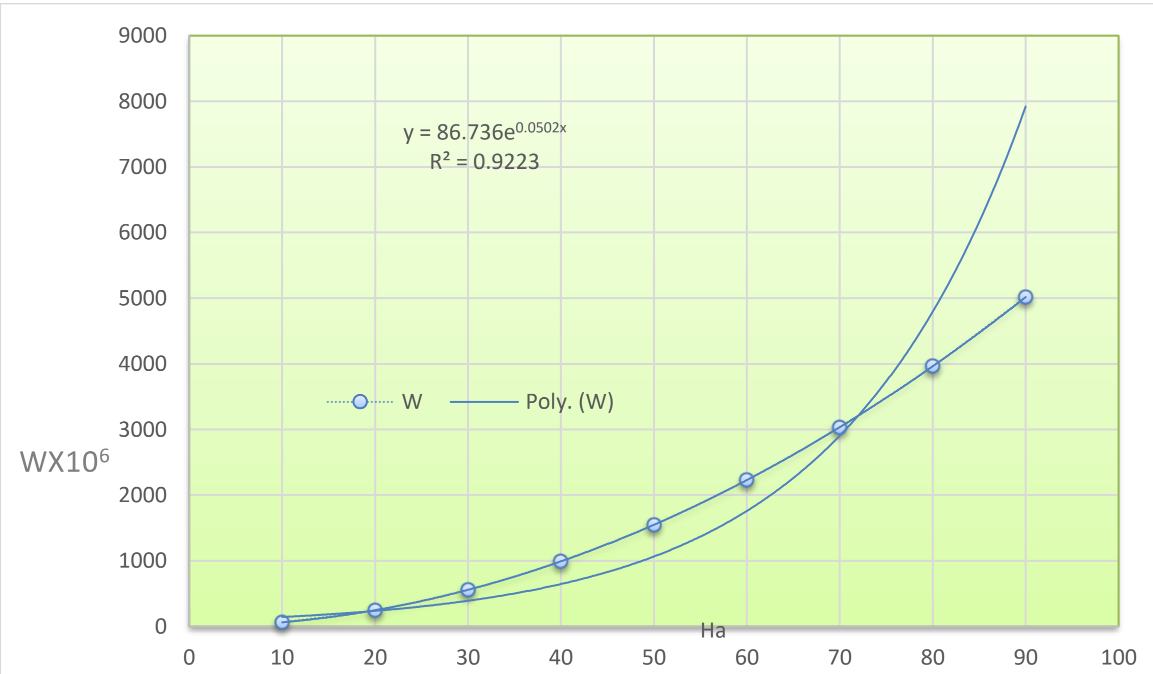

Figure-4.2 (Variation of ***W*** against Hartmann number $\boldsymbol{H_a}$)

4. Conclusion

The variation of pressure and load capacity for plane inclined slider bearings with respect to Hartmann number H_a, are shown by table-1 and graphs-2, 3. Hence in the second order rotatory theory of hydrodynamic lubrication, the pressure and load capacity for plane inclined slider bearings both increase with increasing values Hartmann number H_a.

The exponential equation of pressure and load capacity are also calculated by using the graphs. These are:

$$P = 66.285\, X10^6\, e^{0.0461 H_a}, R^2 = 0.9056 \quad (4.1)$$

$$W = 86.736 X10^6\, e^{0.0502 H_a}, R^2 = 0.9119 \quad (4.2)$$

But we know that:

$$H_a \propto B \quad (4.3)$$

Hence the dimensionless pressure and load carrying capacity of the slider both varies with intensity of magnetic field B.

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