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PERFORMANCE OF HYDROMAGNETIC POROUS LONG BEARINGS

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ABSTRACT: This study aims to analyze the performance of a hydromagnetic infinitely long bearing. The results suggest that the bearing system registers a relatively better performance as compared to that of a bearing system dealing with a conventional lubricant. It is noticed that the load carrying capacity rises sharply with increasing values of magnetization parameter. It is established that negative effect induced by the porosity can be neutralized up to a large extent by the positive effect of the magnetization with a suitable combination of conductivity and aspect ratio. This investigation suggests ample measures to reduce the friction.
KEYWORDS: Long bearing, Hydromagnetic lubricant, Reynolds' equation, Pressure, Load carrying capacity, Friction

INTRODUCTION

The infinitely long slider bearing is in fact, the idealization of a single sector shaped pad of a hydrodynamic thrust bearing. Such a bearing comprises of a fixed or pivoted pad and a moving pad which may be plane, stepped, curved or composite shaped (such bearings are widely used in hydrodynamic generators and turbines). In Cameron (1966), Basu et. al. (2005) and Hamrock (1994) one can come across the analytic exact solutions of Reynolds' equation for thrust bearing with various simple geometries. Prakash and Vij (1973) investigated the performance of a plane inclined slider bearing and found that porosity decreased the friction. However, the already decreased load carrying capacity due to porosity got further decreased by slip velocity as investigated by Patel and Gupta (1983).

The effect of electric and magnetic fields on the flow of electrically conducting lubricants has been studied. These studies have shown that MHD bearings have several theoretical advantages over ordinary bearings. Different kinds of MHD bearings have been analyzed. The most common type is the slider bearing and two general configurations have been considered. One configuration uses a transverse magnetic field with a tangential electric field while other makes use of a tangential magnetic field with a tangential electric field. Each of these configurations has been investigated with various geometrical shapes of the bearing surfaces (Snyder (1962), Elco and Huges (1962), Huges (1963.a, 1963.b)). A number of theoretical and experimental studies (Maki et. al. (1966), Shukla (1965), Sinha and Gupta (1973, 1974)) have been devoted to magnetohydrodynamic lubrication. Patel and Hingu (1978) considered the hydromagnetic effect on the squeeze film performance between circular disks. Patel and Gupta (1979) used Morgan Cameron approximation and investigated the behavior of hydromagnetic squeeze film between parallel plates for a number of geometrical shapes. Gupta and Bhat (1979) studied the effect of transverse magnetic field on the performance of a plane inclined slider bearing. Bhat and Gupta (1985) analyzed the behavior of porous inclined slider with variable porous wall thickness and azimuthal magnetic field. Bhat and Deheri (1994) discussed the problem of finding the optimum profile involving a non-uniform magnetic field for a parallel plate porous slider bearing taking tangential velocity slip into account.

Vadher et. al. (2008) made an attempt to analyze the effect of transverse surface roughness on the behavior of a hydromagnetic squeeze film between conducting porous infinitely long rectangular plates. Recently, Patel et. al. (2010) discussed the lubrication of an infinitely long bearing by a magnetic fluid. The above two studies established that the magnetization induced an enhanced performance of the bearing system.

Thus, here it is proposed to study and analyze the performance of a hydromagnetic porous infinitely long bearing.

ANALYSIS

The plates are considered electrically conducting and clearance space between them is filled by an electrically conducting lubricant. An external transverse uniform magnetic field is applied in between. The flow in the porous medium obeys the modified form of Darcy's law (Ene (1969)) while, for the film region the equations of hydromagnetic lubrication theory hold. The lubricant film is considered to be isoviscous, incompressible and the flow is laminar.

Figure: (1) consists of the configuration of the bearing system which is infinite in Z - direction. The slider moves with the uniform velocity u in X – direction. The length of the bearing is L and breadth B is in Z – direction.

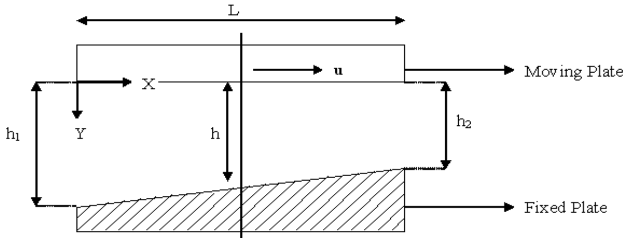

Figure: 1 Geometrical configuration of the bearing system

Following the usual assumptions of hydromagnetic lubrication one arrives at the governing Reynolds' equation (Vadher et. al. (2008), Patel et. al. (2010))

$$\frac{dp}{dx}=\frac{6u\left[h_2\left(1+m\left(1-\frac{x}{L}\right)\right)-\lambda h_2\right]}{h_2^3\left(1+m\left(1-\frac{x}{L}\right)\right)^3\left[\frac{\psi}{\mu c^2}-\frac{2}{\mu M^3}\{\tanh(M/2)-(M/2)\}\right]\left[\frac{\phi_0+\phi_1+1}{\phi_0+\phi_1+\frac{\tanh(M/2)}{(M/2)}}\right]} \tag{1}$$

The associated boundary conditions are

$$p = 0 \text{ at } x = 0 \text{ and } x = L \tag{2}$$

Introducing the dimensionless quantities $m=\frac{h_1-h_2}{h_2}$, $X=\frac{x}{L}$, $P=\frac{h_2^3 p}{\mu u B^2}$ *and integrating Equation (1) under boundary conditions (2) one obtains the pressure in non-dimensional form as*

$$P=\frac{6h_2\left[\frac{1}{(1+m(1-X))}-\frac{(m+1)}{(m+2)(1+m(1-X))^2}-\frac{1}{(m+2)}\right]}{mL\left[\frac{2}{M^3}\{\tanh(M/2)-(M/2)\}-\frac{\psi}{c^2}\right]\left[\frac{\phi_0+\phi_1+1}{\phi_0+\phi_1+\frac{\tanh(M/2)}{(M/2)}}\right]} \tag{3}$$

The dimensionless load carrying capacity then, is given by $W=\frac{h_2^3 w}{\mu u B^4}=\int_0^1 P\,dX$

$$=\frac{\frac{6h_2}{L}\left[\frac{\ln(m+1)}{m^2}-\frac{2}{m(m+2)}\right]}{\left[\frac{\psi}{c^2}-\frac{2}{M^3}\{\tanh(M/2)-(M/2)\}\right]\left[\frac{\phi_0+\phi_1+1}{\phi_0+\phi_1+\frac{\tanh(M/2)}{(M/2)}}\right]} \tag{4}$$

The frictional force $\bar{F}$ *on the lower plane of the moving plate is found to be*

$$\bar{F}=\int_0^1 \bar{\tau}\,dX$$

wherein, $\bar{\tau}=\left(\frac{h_2}{\mu u}\right)\tau$ *is non-dimensional shearing stress, while* $\tau=\frac{dp}{dx}\left(y-\frac{h}{2}\right)+\frac{\mu u}{h}$

Now one can find that

$$\bar{\tau}=\frac{dP}{dX}\frac{L}{h_2}\{1+m(1-X)\}\left(Y-\frac{1}{2}\right)+\frac{1}{\{1+m(1-X)\}} \tag{5}$$

At the moving plate (Y = 0) one observes that

$$\bar{F}_0=\frac{3\left[\frac{2}{(m+2)}-\frac{\ln(m+1)}{m}\right]}{\left[\frac{\psi}{c^2}-\frac{2}{M^3}\{\tanh(M/2)-(M/2)\}\right]\left[\frac{\phi_0+\phi_1+1}{\phi_0+\phi_1+\frac{\tanh(M/2)}{(M/2)}}\right]}+\frac{\ln(m+1)}{m} \tag{6}$$

while, at the stationery plate (Y = 1) the dimensionless frictional force is calculated as

$$\bar{F}_1 = \frac{3\left[\frac{\ln(m+1)}{m} - \frac{2}{(m+2)}\right]}{\left[\frac{\psi}{c^2} - \frac{2}{M^3}\{\tanh(M/2)-(M/2)\}\right]\left[\frac{\phi_0+\phi_1+1}{\phi_0+\phi_1+\frac{\tanh(M/2)}{(M/2)}}\right]} + \frac{\ln(m+1)}{m} \tag{7}$$

RESULTS AND DISCUSSION

Equations (3) and (4) determine the dimensionless pressure and load carrying capacity respectively. Further, Equations (6) and (7) present the variation of dimensionless friction. It is seen that while the pressure and load carrying capacity depend on the ratio L/h_2, the friction is independent of this ratio particularly, in this type of bearing system. Setting the conductivities to be zero this investigation reduces to the study of Prakash and Vij (1973) in the absence of magnetization. In addition, taking the porosity to be zero this discussion leads to the performance of squeeze film between non-porous infinitely long plates. Besides, the effect of conductivity is determined via the factor $\left[\frac{\phi_0+\phi_1+\frac{\tanh(M/2)}{(M/2)}}{\phi_0+\phi_1+1}\right]$.

A close glance at this factor reveals that the load carrying capacity increases with increasing values of conductivity $\phi_0 + \phi_1$ and which becomes more sharp for larger values of magnetization. A comparison of the present study with the discussion of Patel et. al. (2010) indicates that the overall performance is little bit improved here.

The variation of load carrying capacity presented in Figures (2) – (5) conveys that the load carrying capacity increases sharply due to magnetization parameter M. Also, the combined effect of conductivity $\phi_0 + \phi_1$ and magnetization M is significantly positive. Of course, the load carrying capacity decreases owing to the combined effect of the ratio L/h_2 and porosity ψ.

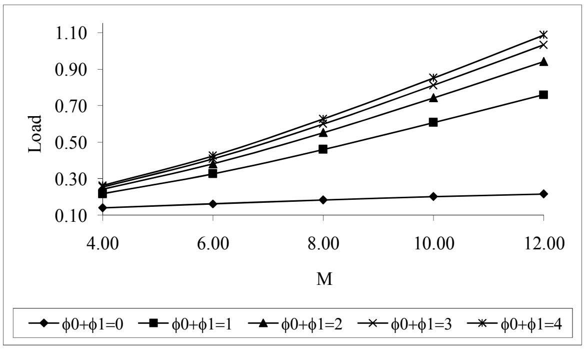

Figure: 2 Variation of load carrying capacity with respect to M and $\phi_0+\phi_1$

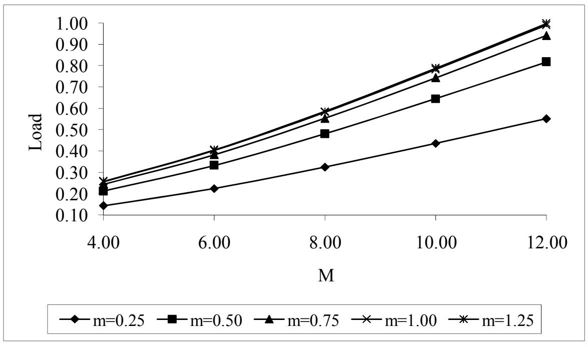

Figure: 3 Variation of load carrying capacity with respect to M and m

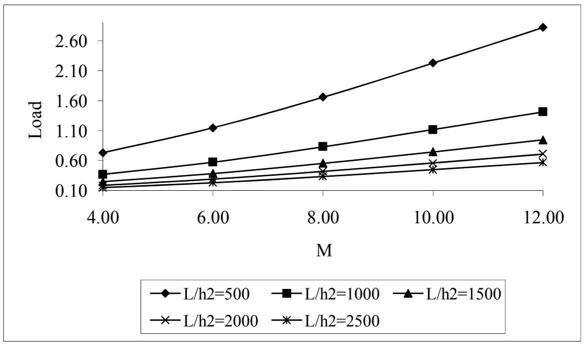

Figure: 4 Variation of load carrying capacity with respect to M and L/h_2

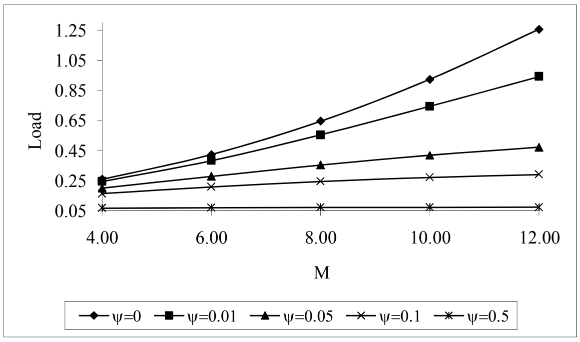

Figure: 5 Variation of load carrying capacity with respect to M and ψ

Figures (6) – (8) deal with the distribution of load carrying capacity with respect to conductivity $\phi_0 + \phi_1$. It is clearly observed that conductivity increases the load carrying capacity. The load carrying capacity is more increased in the case of the aspect ratio m. Besides, the load carrying capacity is observed to be more increased for smaller values of conductivity ($0 \le \phi_0 + \phi_1 \le 1$). Of course, porosity ψ induces the usual negative effect, in the sense that it decreases the load carrying capacity. The fact that the aspect ratio m plays a significant role in increasing the load carrying capacity, can be seen from Figures (9) and (10). In addition, the adverse effect introduced by porosity ψ is more as compared to the adverse effect of ratio L/h_2. Lastly, Figure (11) reveals that the already decreased *load carrying capacity due to ratio L/h_2 gets further decreased due to porosity ψ and this effect is more for smaller values of ratio L/h_2 and porosity ψ.*

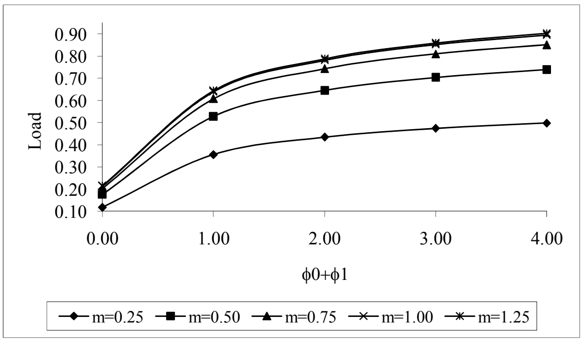

Figure: 6 Variation of load carrying capacity with respect to $\phi_0+\phi_1$ and m

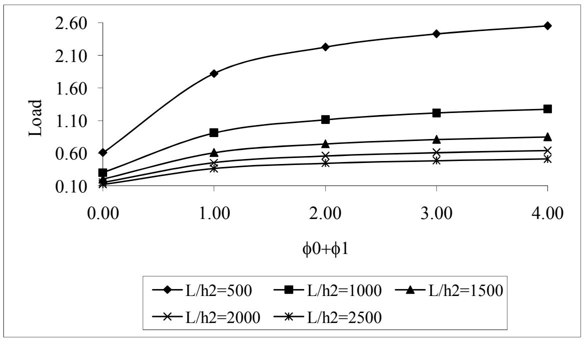

Figure: 7 Variation of load carrying capacity with respect to $\phi_0+\phi_1$ and L/h_2

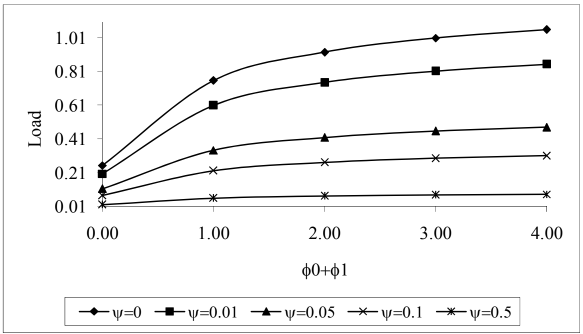

Figure: 8 Variation of load carrying capacity with respect to $\phi_0+\phi_1$ and ψ

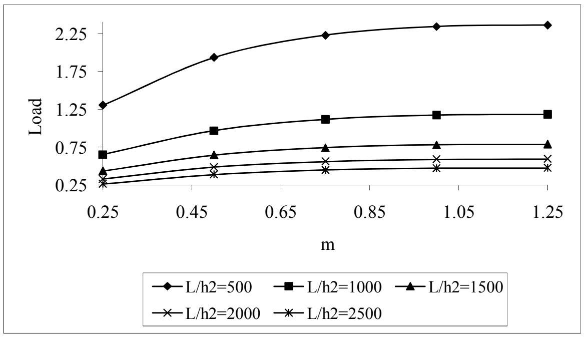

Figure: 9 Variation of load carrying capacity with respect to m and L/h_2

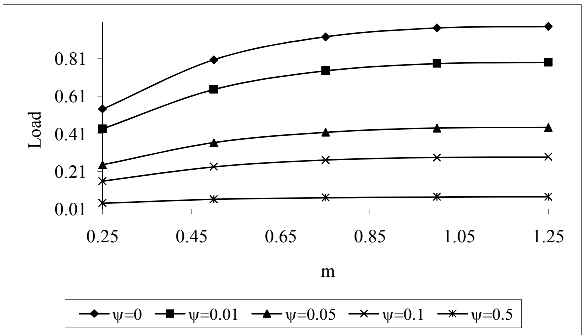

Figure: 10 Variation of load carrying capacity with respect to m and ψ

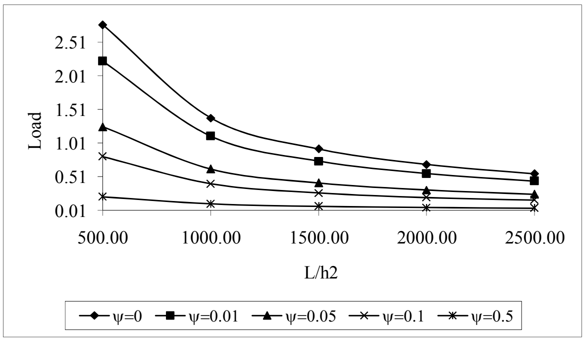

Figure: 11 Variation of load carrying capacity with respect to L/h_2 and ψ

Figures (12) - (17) depict the variation of friction with respect to various parameters at the moving plate. It is observed that the combined effect of magnetization and conductivity reduces the friction considerably. This decreased friction gets further decreased due to the aspect ratio m. However, porosity increases the friction. But the decrease in friction due to conductivity is more for smaller values of the conductivity when either smaller values of porosity or smaller values of aspect ratio are involved. The reverses of these trends of friction at the fixed plate with respect to various parameters are visible in Figure (18) - (23). Furthermore, this discussion offers some measures for the reduction of friction thereby, leading to an extension for the life period of the bearing system.

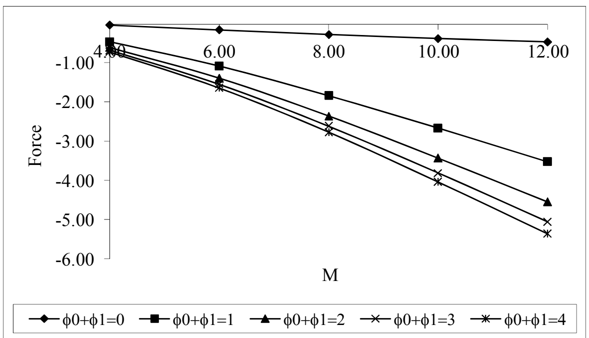

Figure: 12 Variation of frictional force (moving plate) with respect to M and $\phi_0+\phi_1$

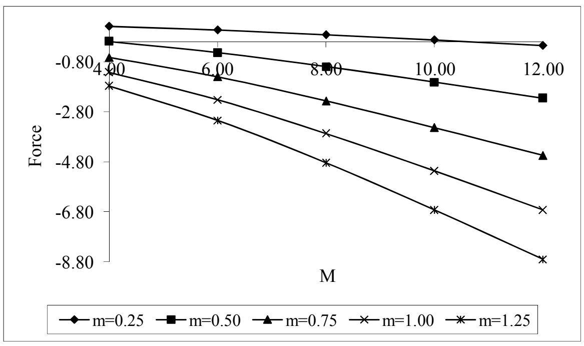

Figure: 13 Variation of frictional force (moving plate) with respect to M and m

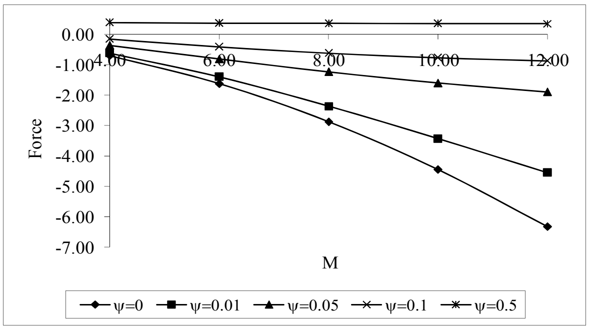

Figure: 14 Variation of frictional force (moving plate) with respect to M and □

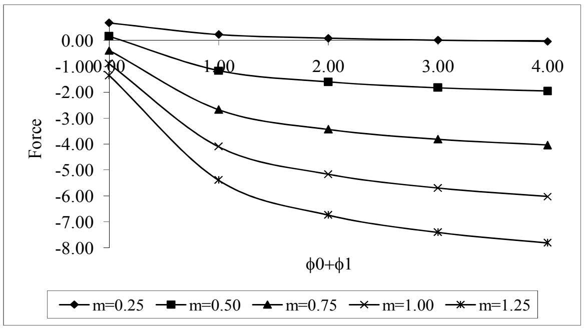

Figure: 15 Variation of frictional force (moving plate) with respect to $\phi_0+\phi_1$ and m

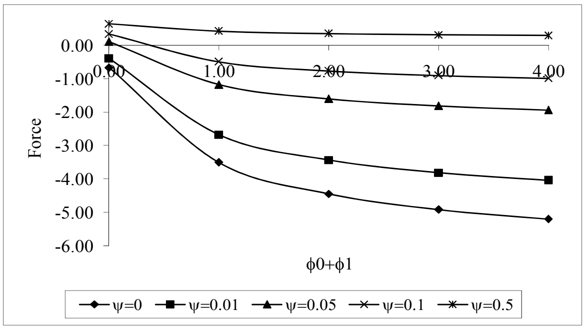

Figure: 16 Variation of frictional force (moving plate) with respect to $\phi_0+\phi_1$ and ψ

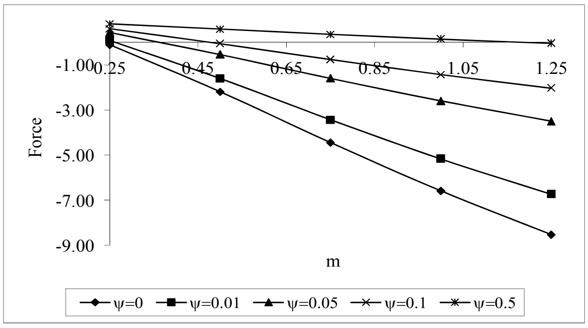

Figure: 17 Variation of frictional force (moving plate) with respect to m and ψ

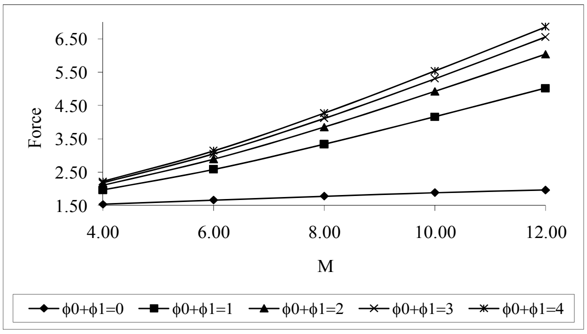

Figure: 18 Variation of frictional force (fixed plate) with respect to M and $\phi_0+\phi_1$

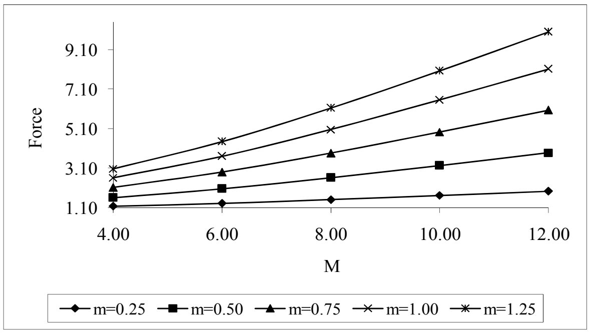

Figure: 19 Variation of frictional force (fixed plate) with respect to M and m

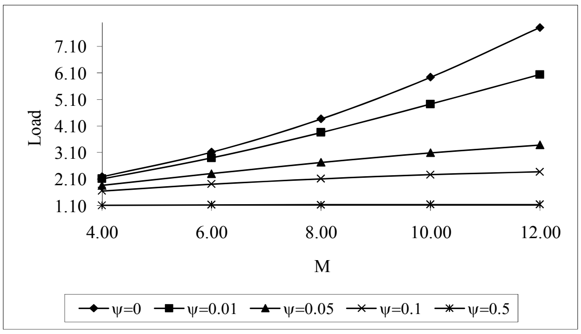

Figure: 20 Variation of frictional force (fixed plate) with respect to M and □

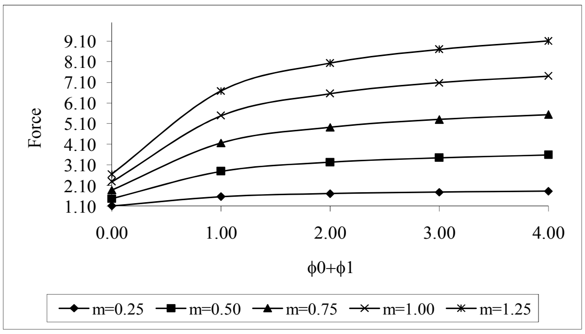

Figure: 21 Variation of frictional force (fixed plate) with respect to $\phi_0+\phi_1$ and m

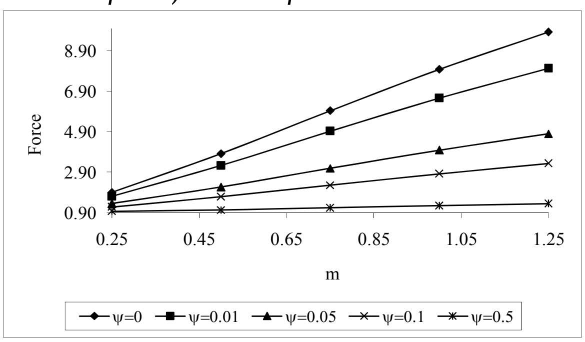

Figure: 22 Variation of frictional force (fixed plate) with respect to $\phi_0+\phi_1$ and ψ

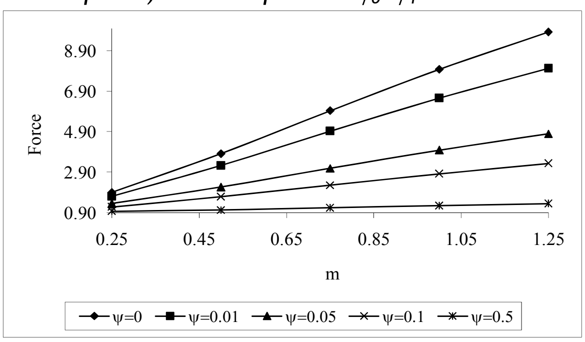

Figure: 23 Variation of frictional force (fixed plate) with respect to m and ψ.

CONCLUSIONS

This article makes it clear that the performance of the bearing system is significantly improved here due to the magnetization. Of course, the conductivity also contributes substantially to this improvement. A close glance at the results reveals that the negative effect of porosity and the ratio L/h_2 can be overcome to a large extent by the combined effect of magnetization and conductivity by suitably choosing the aspect ratio. Lastly, while designing this type of bearing system the aspect ratio must be duly considered for an overall improved performance of the bearing system. Measures have been suggested to reduce the friction, thereby, extending the life period of the bearing system.

Nomenclature

h	Fluid film thickness at any point (mm)	B	Breadth of the bearing (mm)
h_1	Maximum film thickness (mm)	L	Length of the bearing (mm)
h_2	Minimum film thickness (mm)	m	Aspect ratio
u	Uniform velocity in X - direction	w	Load carrying capacity (N)
p	Lubricant pressure (N/mm^2)	W	Non-dimensional load carrying capacity
P	Dimensionless pressure	μ	Lubricant viscosity ($N.s/mm^2$)
τ	Shear stress (N/mm^2)	F	Frictional force (N/mm^2)
$\bar{\tau}$	Dimensionless shear stress	$\bar{F}$	Dimensionless frictional force
F_0	Frictional force (at moving plate)	F_1	Frictional force (at fixed plate)
s	Electrical conductivity of the lubricant	K	Permeability ($col^2 kgm/s^2$)
M	$= B_0 h\left(\frac{s}{\mu}\right)^{1/2}$ = Hartmann number	ψ	$= \frac{m^* H_0}{h^3}$ = Porosity
H_0	Thickness of porous facing	m^*	Porosity of the porous matrix
B_0	Uniform transverse magnetic field applied between the plates.	c^2	$= 1+\frac{KM^2}{h^2 m^*}$
h_0'	Surface width of the lower plate (m)	s_0	Electrical conductivity of lower surface (mho)
h_1'	Surface width of the upper plate (m)	s_1	Electrical conductivity of upper surface (mho)
$\phi_0(h)$	$= \frac{s_0 h_0'}{sh}$ =Electrical permeability of lower surface	$\phi_1(h)$	$= \frac{s_1 h_1'}{sh}$ =Electrical permeability of the upper surface

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