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Abstract

Purpose – The purpose of this paper is to consider magnetohydrodynamic (MHD) squeeze film characteristics between finite porous parallel rectangular plates with surface roughness.
Design/methodology/approach – Based upon the MHD theory, this paper analyzes the surface roughness effect squeeze film characteristics between finite porous parallel rectangular plates lubricated with an electrically conducting fluid in the presence of a transverse magnetic field.
Findings – It is found that the magnetic field effects characterized by the Hartmann number produce an increased value of the load carrying capacity and the response time as compared to the classical Newtonian lubricant case. The modified averaged stochastic Reynolds equation governing the squeeze film pressure is derived.
Research limitations/implications – The present study has considered both Newtonian fluids and non-Newtonian liquids.
Practical implications – The work represents a very useful source of information for researchers on the subject of MHD squeeze film with finite porous parallel rectangular plates lubricated with an electrically conducting fluid.
Originality/value – This paper is relatively original and illustrates the squeeze film characteristics between finite porous parallel rectangular plates with MHD effects.

Keywords Surface roughness, Squeeze film, MHD
Paper type Research paper

Nomenclature

B_o	applied magnetic field	m	porosity
E	expectancy operator	M	Hartmann number
H	film thickness $(h+h_s)$	p	squeeze film pressure
h	mean film thickness at $t=0$	$\overline{p*}$	pressure in the porous region
h_o	film thickness at $t=0$	x,y,z	Cartesian coordinates
k	permeability of the porous material	t	squeeze time
L_1	length of the plate	u,v,w	velocity components
L_2	width of the plate	w	load carrying capacity

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α	mean of the stochastic film thickness	σ^2	variance
β	aspect ratio	μ	lubricant velocity
σ	standard deviation of the film thickness	$\bar{\sigma}$	electrical conductivity
		ε	measure of symmetry of the stochastic random variable

1. Introduction

Studies of squeezing-film characteristics play an important role in engineering science and industrial application. The study of the effect of surface roughness on the lubrication of various bearing surfaces has attracted many researchers in recent years. Patir and Cheng (1978, 1979) proposed an average flow model of a randomly generated rough surface with known statistical properties for the bearing surfaces. Christensen (1969-1970) developed a stochastic model for the study of hydrodynamic lubrication of rough surfaces. Ramanaiah and Sundarammal (1982a, b), Sundarammal and Ramanaiah (1982) studied the effect of bearing deformation on the characteristics of squeeze film between circular and rectangular plates and slider bearing. Sundarammal and Santhana Krishnan (2012), Santhana Krishnan and Sundarammal (2012) studied surface roughness effects and pressure distribution on squeeze film behavior in porous transversely triangular plates with couple stress fluid. Traditionally, the analysis of porous squeeze film bearings was based on the Darcy's model, where the fluid flow in the porous matrix obeys Darcy's law and at the case of two approaching surfaces which attempt to displace a viscous fluid between them. If one (or) both of the approaching surfaces are porous, the lubricant not only get squeezed out from the sides but also bleeds into the pores of the porous matrix, thus reducing the time of approach of the surfaces considerably. Despite this advantage, porous bearing have proved to be useful because of their design simplicity and self-lubricating characteristics.

The study of magnetohydrodynamic (MHD) lubrication has attracted the attention of several investigators in the field, because of its importance in many industrial applications. Lin (2003) studied the squeeze film behaviors in parallel finite rectangular plates lubricated with an electrically conducting fluid in the presence of a transverse magnetic field. Hamza (1988) studied the effect of MHD squeeze film lubrication between two parallel disks and showed that electromagnetic forces increase the load carrying capacity. Representative researches concerning with MHD squeeze film characteristics have been presented for the annular disks and finite slider bearings by Lin (2001, 2002). Further Tsu-Liang *et al.* (2003) studied the MHD squeeze film characteristics between a sphere and a plane surface. Recently, Rajashekar and Biradar (2012) studied the effect of surface roughness on MHD between a sphere and a porous plane surface and Bujurke *et al.* (2011) studied the effect of surface roughness on MHD squeeze film characteristics between finite rectangular plates.

In the present study, we are mainly concerned with the effects of externally applied magnetic fields on the squeeze film characteristics between finite porous parallel rectangular plates with an electrically conducting fluid. Using the continuity equation and the MHD equation, the MHD Reynolds type equation is derived and applied to predict the squeezing motion behavior. Comparing with the classical non-conducting-lubricant case, the results of squeeze film characteristics such as load carrying capacity are presented for various values of Hartmann numbers.

2. Mathematical formulation

Figure 1 shows the squeeze film geometry between finite porous parallel rectangular plates of length L_1 and width L_2. The lower plate with a porous facing of thickness H is fixed and the upper plate has a squeezing velocity *dH/dt* is approaching the lower plate under a constant load. It is assumed that:

- the surfaces of the rectangular plates are rough;
- the lubricant in the film region is taken to be an isothermal, incompressible electrically conducting fluid; and
- an externally uniform transverse magnetic fluid B_o is applied in the z-direction.

Under the usual thin-film lubrication theory, it is assumed that the fluid inertial except for the Lorentz force, and the induced magnetic fluid is small compared to the applied magnetic field.

Following Christensen and Tonder (1969a, b, 1970), Bujurke *et al.* (2011), the film thickness of the lubricant film is taken as $H = \bar{h} + h_s$ where $\bar{h}$ is the mean film thickness and h_s is the deviation from the mean film thickness characterizing the random roughness of the bearing surfaces, h_s is considered to be stochastic in nature and governed by the probability density function:

$$f(h_s) = \begin{cases} \left(\frac{35}{32}\right) & \left(1 - \frac{h_s^2}{c^2}\right), \quad -c \leqslant h_s \leqslant c \\ 0, & otherwise \end{cases}$$

where c is the maximum deviation from the mean film thickness. The mean α, the standard deviation σ and the parameter $\in$, which is the measure of symmetry of random variable h_s are defined by the relationships:

$$\alpha = E(h_s)$$
$$\sigma^2 = E\left[(h_s - \alpha)^2\right]$$
$$\in = E\left[(h_s - \alpha)^3\right]$$

where E denotes the expected value defined by:

$$E[R] = \int_{-c}^{c} R f(h_s) ds$$

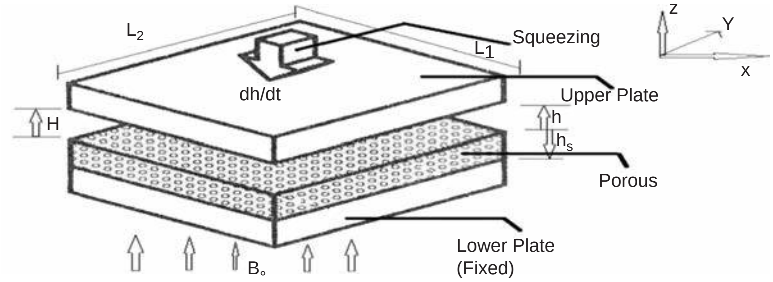

Figure 1. Squeeze film action between parallel rectangular plates in the presence of transverse magnetic field

Based upon these assumptions, the continuing equation and the MHD momentum equations governing the motion of the lubricant system in Cartesian coordinates are:

$$\frac{\partial p}{\partial x} = \mu \frac{\partial^2 u}{\partial z^2} - \overline{\sigma} B_0^2 u$$
$$\frac{\partial p}{\partial y} = \mu \frac{\partial^2 v}{\partial z^2} - \overline{\sigma} B_0^2 v$$
$$\frac{\partial p}{\partial z} = 0$$
$$\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} + \frac{\partial w}{\partial z} = 0$$

In the above equations, u and v denote the velocity components in the x and y directions, respectively, p is the film pressure, μ is the lubricant viscosity and σ is the electrical conductivity.

The boundary conditions for the velocity components are:

$$\mathrm{u(x, y, 0) = 0, \quad v(x, y, 0) = 0, \quad w(x, y, 0) = 0}$$
$$\mathrm{u(x, y, H) = 0, \quad v(x, y, H) = 0, \quad w(x, y, H) =} \frac{dH}{dt}$$

Solutions of above equations subject to the above boundary conditions is obtained as:

$$\mathrm{u(x, y, z)} = \frac{1}{\overline{\sigma} B_0^2}\left(\frac{\partial p}{\partial x}\right)\left[cos\left(B_0\sqrt{\frac{\overline{\sigma}}{\mu}}z\right) - 1 - \left\{cosh\left(B_0\sqrt{\frac{\overline{\sigma}}{\mu}}H\right) - 1\right\}\left\{\frac{sinh\left(B_0\sqrt{\frac{\overline{\sigma}}{\mu}}z\right)}{sinh\left(B_0\sqrt{\frac{\overline{\sigma}}{\mu}}H\right)}\right\}\right]$$
$$\mathrm{v(x, y, z)} = \frac{1}{\overline{\sigma} B_0^2}\left(\frac{\partial p}{\partial y}\right)\left[cos\left(B_0\sqrt{\frac{\overline{\sigma}}{\mu}}z\right) - 1 - \left\{cosh\left(B_0\sqrt{\frac{\overline{\sigma}}{\mu}}H\right) - 1\right\}\left\{\frac{sinh\left(B_0\sqrt{\frac{\overline{\sigma}}{\mu}}z\right)}{sinh\left(B_0\sqrt{\frac{\overline{\sigma}}{\mu}}H\right)}\right\}\right]$$

Introducing the Hartmann number M, defined by:

$$M = B_0 h_0 \sqrt{\frac{\overline{\sigma}}{\mu}}$$

where h_O is the film thickness at t = 0, then:

$$\mathrm{u(x, y, z)} = \frac{h_0^2}{\mu M^2}\left(\frac{\partial p}{\partial x}\right)\left[cos\left(\frac{Mz}{h_0}\right) - 1 - \left\{cosh\left(\frac{Mz}{h_0}\right) - 1\right\}\left\{\frac{sinh\left(\frac{Mz}{h_0}\right)}{sinh\left(\frac{MH}{h_0}\right)}\right\}\right]$$
$$\mathrm{v(x, y, z)} = \frac{h_0^2}{\mu M^2}\left(\frac{\partial p}{\partial y}\right)\left[cos\left(\frac{Mz}{h_0}\right) - 1 - \left\{cosh\left(\frac{Mz}{h_0}\right) - 1\right\}\left\{\frac{sinh\left(\frac{Mz}{h_0}\right)}{sinh\left(\frac{MH}{h_0}\right)}\right\}\right]$$

Integrating the continuity equation with respect to z using the boundary conditions on w(x, y, z) by substituting the velocity components u and v, the following modified Reynolds equation governing the film pressure is obtained:

$$\frac{h_0^3}{\mu M^3}\left[\frac{\partial}{\partial x}\left[\frac{MH}{h_0}-2tanh\left(\frac{MH}{2h_0}\right)sinh^2\left(\frac{MH}{2h_0}\right)\right]\frac{\partial p}{\partial x}+\frac{\partial}{\partial y}\left[\frac{MH}{h_0}-2tanh\left(\frac{MH}{2h_0}\right)sinh^2\left(\frac{MH}{2h_0}\right)\right]\frac{\partial p}{\partial y}\right]$$
$$=-\frac{dH}{dt}$$

The probability density function $f(h_s)$ is multiplied on both sides of above equation and integrating with respect to h_s from $-$c to c, we get:

$$\frac{h_0^3}{\mu M^3}E\left[\frac{\partial}{\partial x}\left[\frac{MH}{h_0}-2tanh\left(\frac{MH}{2h_0}\right)sinh^2\left(\frac{MH}{2h_0}\right)\right]\frac{\partial p}{\partial x}+\frac{\partial}{\partial y}\left[\frac{MH}{h_0}-2tanh\left(\frac{MH}{2h_0}\right)sinh^2\left(\frac{MH}{2h_0}\right)\right]\frac{\partial p}{\partial y}\right]$$
$$=-E\frac{dH}{dt}$$

Considering $sinh^2$ $(MH/2h_0)$ as a unit quantity and the flow of conducting lubricant in the porous region is governed by the modified Darcy's law (Bhat, 1978):

$$\overline{u}=-\frac{k}{\mu}\frac{\partial\overline{p*}}{\partial x}\left\{1+\frac{k}{m}\frac{M^2}{h_0^2}\right\}^{-1}$$

where $\overline{p*}$ is the pressure in the porous matrix, we have:

$$\frac{h_0^3}{\mu M^3}E\left[\frac{\partial}{\partial x}\left[\frac{MH}{h_0}-2tanh\left(\frac{MH}{2h_0}\right)\right]\frac{\partial\overline{p*}}{\partial x}+\frac{\partial}{\partial y}\left[\frac{MH}{h_0}-2tanh\left(\frac{MH}{2h_0}\right)\right]\frac{\partial\overline{p*}}{\partial y}\right]$$
$$=-E\left(\frac{dH}{dt}\right)$$

Introducing the dimensionless variables and parameters:

$$\alpha=\frac{\alpha^*}{h_0},\ \sigma=\frac{\sigma^*}{h_0^2},\ \in=\frac{\varepsilon^*}{h_0^3},\ \overline{H}=\frac{H}{h_0}=\frac{h+h_s}{h_0}=\overline{h}+h_s$$

$\overline{p}=(E(\overline{p*})h_0^3)/(\mu L_1^2(d\overline{h}/dt))$, $\overline{x}=x/L_1$ and $\overline{y}=x/L_1$ where $\overline{p}$ is the non-dimensional mean value of the film pressure p, yields:

$$\frac{h_0^3}{\mu M^3}E\left[\left[M\overline{H}-2tanh\left(\frac{M\overline{H}}{2}\right)\right]\frac{\partial^2E(\overline{p})}{\partial x^2}+E\left[M\overline{H}-2tanh\left(\frac{M\overline{H}}{2}\right)\right]\frac{\partial^2E(\overline{p})}{\partial y^2}\right]=-E\left(\frac{d\overline{h}}{dt}\right)$$

$$\frac{\partial^2}{\partial\overline{x}^2}\left[\frac{E(\overline{p})h_0^3}{\mu L_1^2\left(\frac{d\overline{h}}{dt}\right)}\right]+\frac{\partial^2}{\partial\overline{y}^2}\left[\frac{E(\overline{p})h_0^3}{\mu L_1^2\left(\frac{d\overline{h}}{dt}\right)}\right]=-\frac{M^3}{E\left[M\overline{H}-2tanh\left(\frac{M\overline{H}}{2}\right)\right]}$$

The modified Reynolds equation in non-dimensional form is:

$$\frac{\partial^2 \bar{p}}{\partial \bar{x}^2} + \frac{\partial^2 \bar{p}}{\partial \bar{y}^2} = -\frac{M^3}{E\left[M\bar{H} - 2tanh\left(\frac{M\bar{H}}{2}\right)\right]}$$

and:

$$\begin{aligned} E\left[M\bar{H} - 2tanh\left(\frac{M\bar{H}}{2}\right)\right] &= M\left(\bar{h} + \alpha\right) \\ &\quad - 2E\left[\left(tanh\left(\frac{M\bar{h}}{2}\right) + tanh\left(\frac{Mh_s}{2}\right)\right)\left(1 + tanh\left(\frac{M\bar{h}}{2}\right) + tanh\left(\frac{Mh_s}{2}\right)\right)^{-1}\right] \\ &= M\left(\bar{h} + \alpha\right) - 2tanh\left(\frac{M\bar{h}}{2}\right) - \frac{1}{12}E\left(12Mh_s - M^3h_s^3\right)\left(1 - tanh^2\left(\frac{M\bar{h}}{2}\right)\right) \\ &= M\left(\bar{h} + \alpha\right) - 2tanh\left(\frac{M\bar{h}}{2}\right) - \frac{1}{12}\left(12M\alpha - M^3\left(\varepsilon^* + 3\alpha\sigma^{*^2} + \alpha^3\right)\right)\left(1 - tanh^2\left(\frac{M\bar{h}}{2}\right)\right) \end{aligned}$$

where $E(h_s^2) = \sigma^{*2} + \alpha^2$ and $E(h_s^3) = \epsilon^* + 3\alpha\sigma^{*2} + \alpha^3$.

The suitable solution for the pressure distribution is defined by:

$$\bar{p}(\bar{x}, \bar{y}) = (c_1 \sin k\bar{x} + c_2 \cos k\bar{x})(c_3 \sin k\bar{y} + c_4 \cos k\bar{y})$$

with the relevant boundary conditions for the pressure field are:

$$\begin{aligned} \bar{p} &= 0 \ at \ \bar{x} = 0 \\ \bar{p} &= 0 \ at \ \bar{x} = 1 \\ \bar{p} &= 0 \ at \ \bar{y} = 0 \\ \bar{p} &= 0 \ at \ \bar{y} = \beta \end{aligned}$$

where $\beta = L_2/L_1$ is the aspect ratio.

Upon solving for $\bar{p}$, we get the general solution:

$$\begin{aligned} \bar{p}(\bar{x}, \bar{y}) &= \sum_{m=1}^{\infty}\sum_{n=1}^{\infty} B_{mn} \sin(m\pi\bar{x}) \sin\left(\frac{n\pi\bar{y}}{\beta}\right) \\ &= \sum_{m=1}^{\infty}\sum_{n=1}^{\infty} B_{mn}\left\{\frac{\cos\left(m\pi\bar{x} - \frac{n\pi\bar{y}}{\beta}\right) - \cos\left(m\pi\bar{x} - \frac{n\pi\bar{y}}{\beta}\right)}{2}\right\} \end{aligned}$$

Substituting into the non-dimensional mean Reynolds type equation, it becomes:

$$\sum_{m=1}^{\infty}\sum_{n=1}^{\infty}B_{mn}\left\{\frac{\cos\left(m\pi\bar{x}-\frac{n\pi\bar{y}}{\beta}\right)-\cos\left(m\pi\bar{x}-\frac{n\pi\bar{y}}{\beta}\right)}{2}\right\}=\frac{\mathrm{M}^3\beta^2}{\pi^2\left(\beta^2m^2+n^2\right)E\left[M\overline{H}-2tanh\left(\frac{M\overline{H}}{2}\right)\right]}$$

The coefficient B_{mn} can be determined by using the orthogonal conditions of eigenfunctions as:

$$B_{mn}=\begin{cases}\dfrac{16\beta^2M^3}{mn\pi^4\left(\beta^2m^2+n^2\right)E\left[M\overline{H}-2tanh\left(\frac{M\overline{H}}{2}\right)\right]} & m,n\,odd\\ 0 & m,n\,even\end{cases}$$

The mean pressure can be evaluated as:

$$\bar{p}(\bar{x},\bar{y})=\sum_{m=1}^{\infty}\sum_{n=1}^{\infty}$$
$$\left\{\begin{cases}\dfrac{16\beta^2M^3}{mn\pi^4\left(\beta^2m^2+n^2\right)E\left[M\overline{H}-2tanh\left(\frac{M\overline{H}}{2}\right)\right]} & m,n\,odd\\ 0 & m,n\,even\end{cases}\right\}\left\{\frac{cos\left(m\pi\bar{x}-\frac{n\pi\bar{y}}{\beta}\right)-cos\left(m\pi\bar{x}-\frac{n\pi\bar{y}}{\beta}\right)}{2}\right\}$$

By integrating the mean film pressure over the film region, the MHD mean load carrying capacity is obtained as:

$$E(W)=\int_{x=0}^{L_1}\int_{y=0}^{L_2}E(p)dx\,dy$$

The dimensionless quantity of load carrying capacity $\overline{W}$ and dimensionless response time T is given by:

$$\overline{W}=\frac{E(W)h_0^3}{\mu L_1^3L_2\left(\frac{d\bar{h}}{dt}\right)}$$

$$T=\frac{E(W)h_0^2}{\mu L_1^3L_2}$$

The dimensionless load carrying capacity is given by:

$$\overline{W}=\sum_{m=1,3}^{\infty}\sum_{n=1,3}^{\infty}\frac{16\beta^2M^3}{m^2n^2\pi^6\left(\beta^2m^2+n^2\right)E\left[M\overline{H}-2tanh\left(\frac{M\overline{H}}{2}\right)\right]}$$

The time-height relationship can be obtained as:

$$\frac{d\overline{h}}{dt} = \frac{-\pi^6 E\left[M\overline{H} - 2tanh\left(\frac{M\overline{H}}{2}\right)\right]}{64\beta^2 M^3} \sum_{m=1,3}^{\infty} \sum_{n=1,3}^{\infty} m^2 n^2 \left(\beta^2 m^2 + n^2\right)$$

Using the fourth-order Runge-Kutta method, the non-linear ordinary differential equation is solved with an initial condition $\overline{h} = 1 \; at \; T = 0$ and a step size of $\Delta T = 0.01$.

3. Results and discussion

In this study, the effect of surface roughness on the squeeze film characteristics between finite porous parallel rectangular plates with an electrically conducting fluid in the presence of a transverse magnetic field is studied. The effect of magnetic field signifies with the dimensionless parameters α, σ and € characterize the nature of surface roughness patterns and the Hartmann number M. The squeeze film characteristics are presented for different values of M, α, σ, β and €.

Figures 2(a-f) show the variation of non-dimensional mean squeeze film pressure $\overline{p}$ as a function of dimensionless coordinates $\overline{x}$ and $\overline{y}$ for different values of Hartman number M for other fixed parameters. It is observed from these figures that, as Hartmann number increases, the pressure built-up in fluid region also increases.

Figures 3(a-e) show the contour variation of non-dimensional mean squeeze film pressure $\overline{p}$ as a function of dimensionless coordinates $\overline{x}$ and $\overline{y}$ for different values of Hartman number M for other fixed parameters. It is observed from these figures that, as Hartmann number increases, the pressure built-up in fluid region also increases. Table I shows the dimensionless B_{mn} values for different values of Hartmann number M with aspect ratio $\beta = 1$, $\overline{h} = 0.4$, $\alpha = 0.1$, $€ = 0.1$ and $\sigma = 0.1$ used for surfing and contouring mean squeeze film pressure $\overline{p}$ as a function of dimensionless coordinates $\overline{x}$ and $\overline{y}$.

It is observed that, the pressure built-up in fluid film region increases as Hartmann number increases as shown in Figure 4(a). This is so because the effect of magnetic field is to reduce the lubricant velocity (flowing out) of the plates and also the surface asperities present on the bearing surface reduce the sidewise leakage of the fluid, hence large amount of fluid is retained in the region. This generates additional pressure distribution in the lower boundary layers as shown in Figure 4(b) and upper boundary layers in Figure 4(c).

The pressure $\overline{p}$ as a function of dimensionless co-ordinate $\overline{x}$ at $\overline{y} = 0.5$ with aspect ratio $\beta = 1$ and $\overline{h} = 0.4$, $\alpha = 0.1$, $€ = 0.1$, $\sigma = 0.1$ for different values of M are shown in Figure 5. The line curve in the graph corresponds to the non-conducting lubricant case for $M = 0$. As Hartmann number increases, the pressure distribution in the fluid film region increases and in reverse direction, as Hartmann number increases, the pressure distribution in the fluid film region decreases. These predictions are useful in finding suitable design parameters of bearings in general.

The variation of non-dimensional mean squeeze film pressure $\overline{p}$ as a function of dimensionless coordinate $\overline{x}$ at $\overline{y} = 0.5$ with aspect ratio $\beta = 1$, $\overline{h} = 0.4$, $\alpha = 0.1$, $\sigma = 0.1$ and $M = 1$ for different values of $\in$ are shown in Figure 6. It is found that smaller value of $€ = 0$ increase $\overline{p}$ whereas positively increasing values of € decrease $\overline{p}$.

The variation of non-dimensional mean squeeze film pressure $\overline{p}$ as a function of dimensionless coordinate $\overline{x}$ at $\overline{y} = 0.5$ with aspect ratio $\beta = 1$, $\overline{h} = 0.4$, $€ = 0.1$, $\sigma = 0.1$

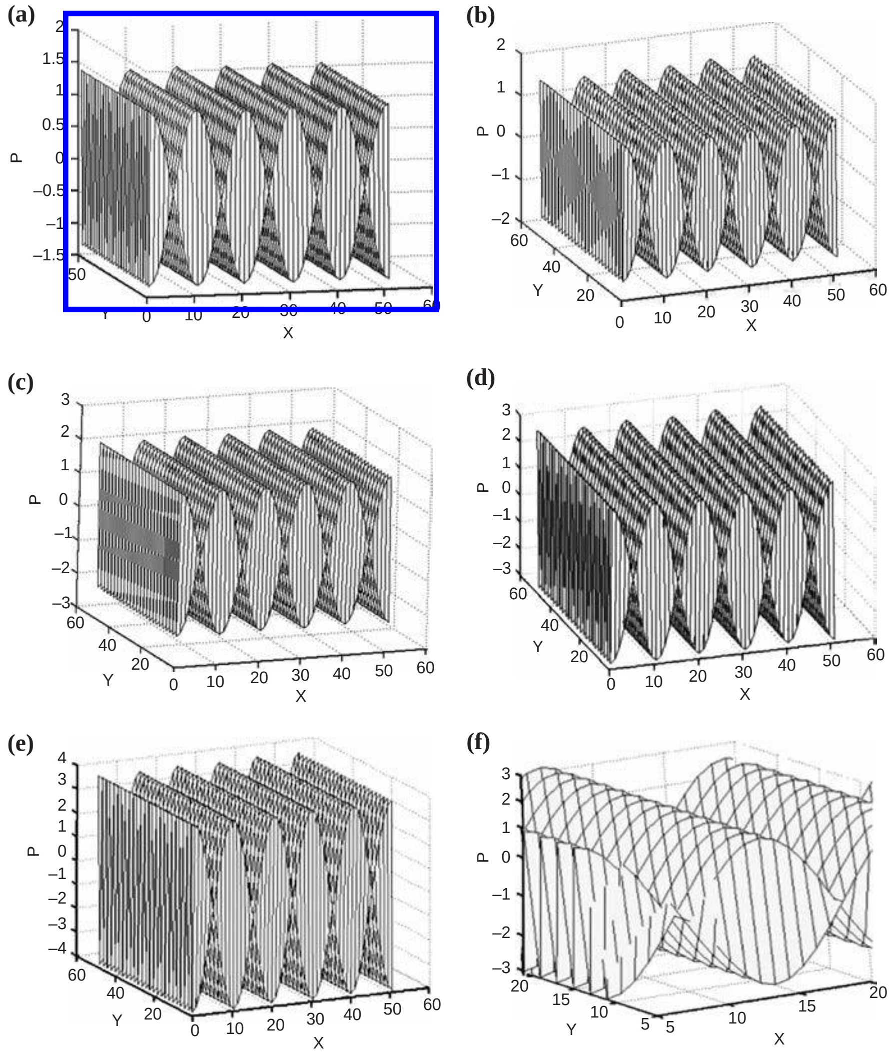

Figure 2.
(a) Variation of distribution of pressure $\bar{p}$ for M = 1; (b) variation of distribution of pressure $\bar{p}$ for M = 3; (c) variation of distribution of pressure $\bar{p}$ for M = 5; (d) variation of distribution of pressure $\bar{p}$ for M = 7; (e) variation of distribution of pressure $\bar{p}$ for M = 9; (f) inner variation of distribution of pressure $\bar{p}$ for M = 5

and M = 1 for different values of α are shown in Figure 7. It is found that smaller value of $\alpha = 0$ increase $\bar{p}$ whereas positively increasing values of α decrease $\bar{p}$. Therefore, squeeze film pressure increases for negatively skewed surface roughness pattern whereas $\bar{p}$ decreases for positively skewed surface roughness pattern.

The variation of non-dimensional mean squeeze film pressure $\bar{p}$ as a function of dimensionless coordinate $\bar{x}$ at $\bar{y} = 0.5$ with aspect ratio $\beta = 1$, $\bar{h} = 0.4$, $\epsilon = 0.1$, $\alpha = 0.1$ and M = 1 for different values of α are shown in Figure 8. It is observed that smaller value of $\sigma = 0$ marginally increase $\bar{p}$ whereas positively increasing values of σ marginally decrease $\bar{p}$. Therefore, squeeze film pressure increases for negatively skewed surface roughness pattern whereas $\bar{p}$ decreases for positively skewed surface roughness pattern.

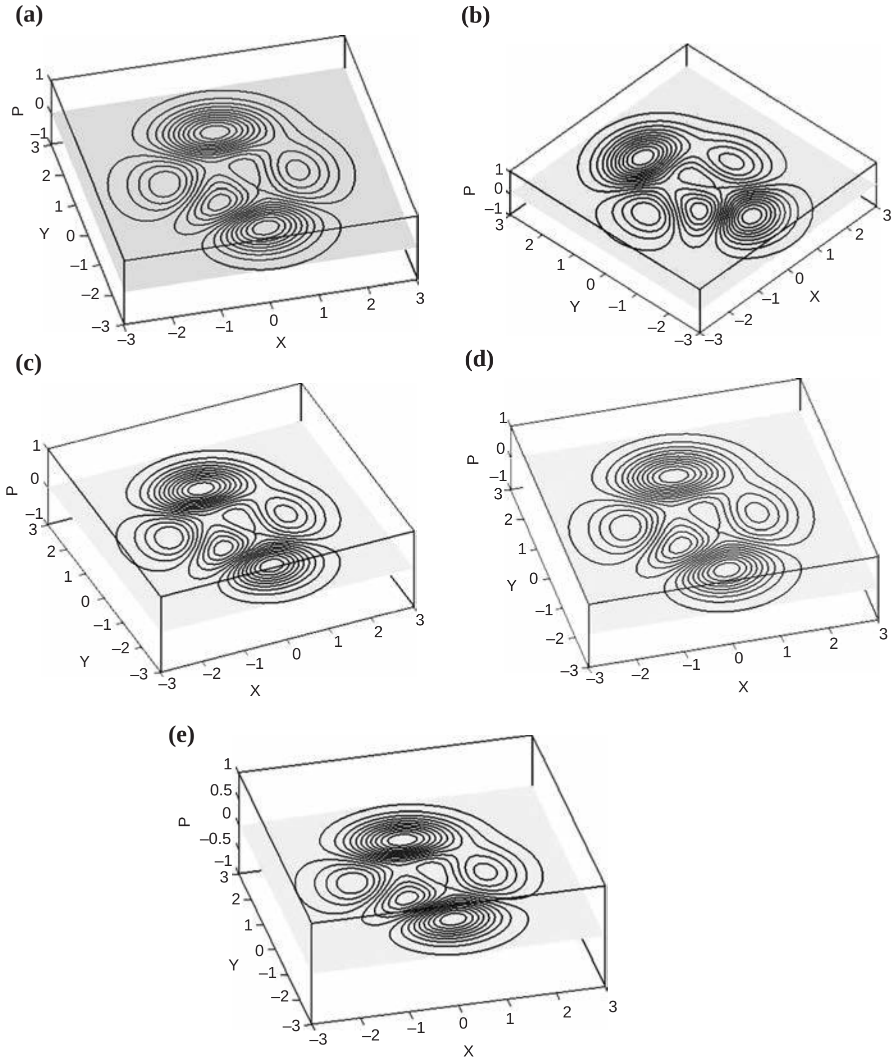

Figure 3.
(a) Contour variation of distribution of pressure $\bar{p}$ for M = 1; (b) contour variation of distribution of pressure $\bar{p}$ for M = 3; (c) contour variation of distribution of pressure $\bar{p}$ for M = 5; (d) contour variation of distribution of pressure $\bar{p}$ for M = 7; (e) contour variation of distribution of pressure $\bar{p}$ for M = 9

Table I.
Dimensionless B_{mn} for different values of Hartmann number M with aspect ratio $\beta = 1$, $\bar{h} = 0.4$, $\alpha = 0.1$, $\epsilon = 0.1$ and $\sigma = 0.1$

Hartmann number M	B_{mn}
1	1.35664948
3	1.620595041
5	2.145043958
7	2.924104893
9	3.950890887

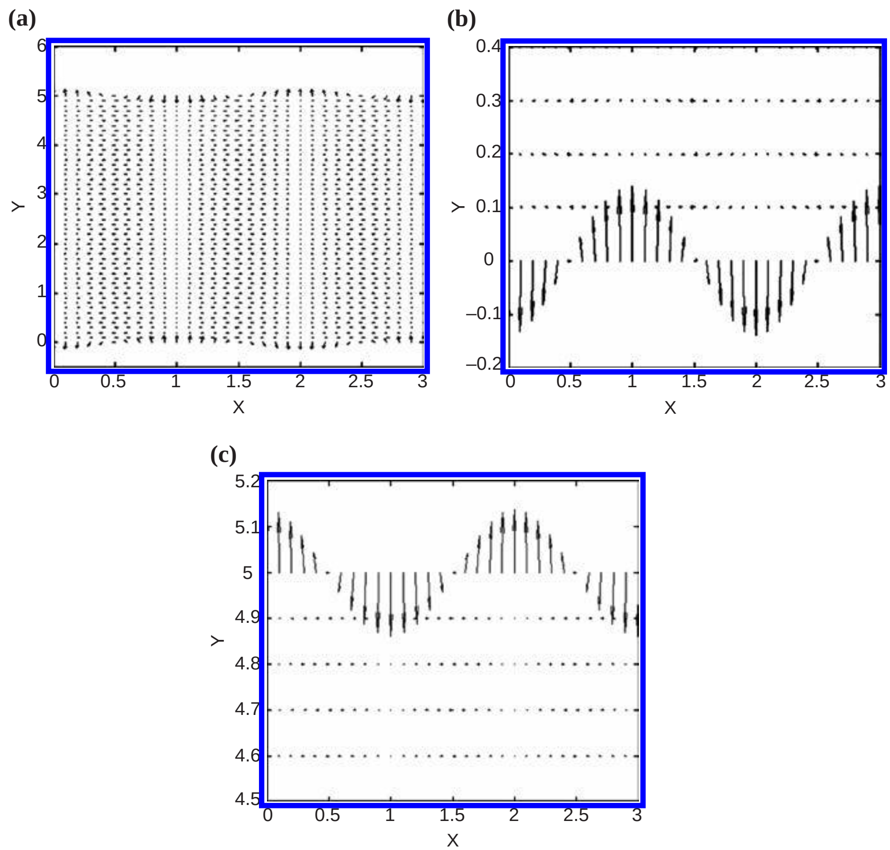

Figure 4. (a) Quiver variation of distribution of pressure $\bar{p}$ for M = 7; (b) Quiver variation of distribution of pressure $\bar{p}$ at lower boundary layers for M = 7; (c) Quiver variation of distribution of pressure $\bar{p}$ at upper boundary layers for M = 7

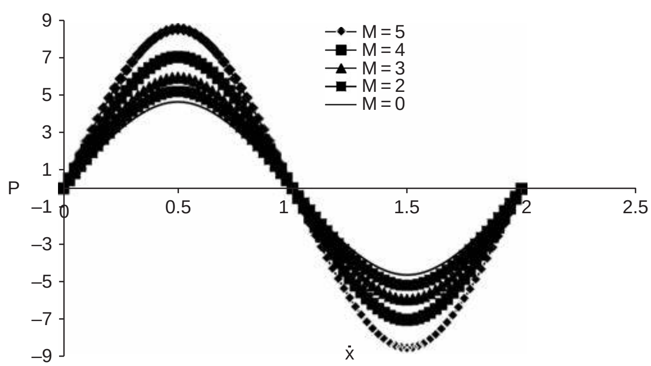

Figure 5. Dimensionless mean film pressure $\bar{p}$ for different values of Hartmann number M

Figure 9 shows the variation of the dimensionless maximum pressure $\bar{p}$ with aspect ratio β for different values of M with $\bar{h} = 0.4$, € = 0.1, α = 0.1 and σ = 0.1. It is observed that, the effect of magnetic field is to increase pressure for increasing values of β.

The variation of non-dimensional mean load carrying capacity $\overline{W}$ with the Hartmann number M for various values of $\bar{h}$ with aspect ratio β = 1, α = 0.1, $\sigma = 0.1$

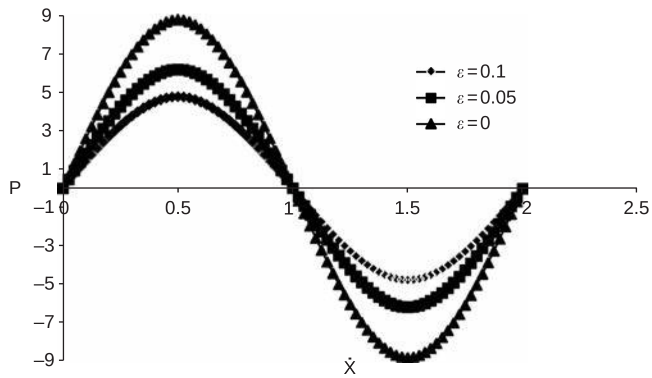

Figure 6.
Dimensionless mean film pressure $\bar{p}$ for different values of €

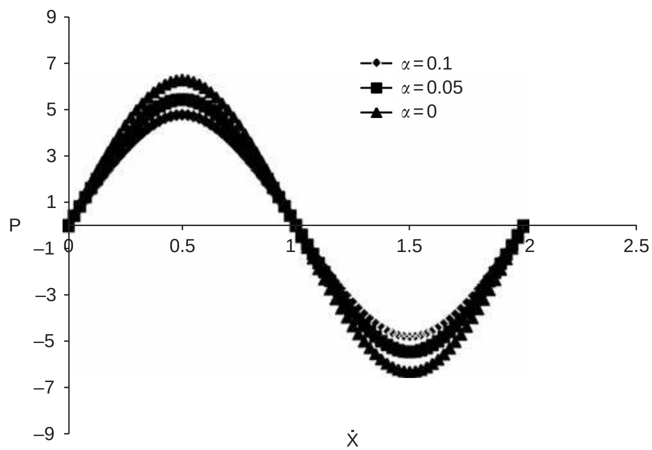

Figure 7.
Dimensionless mean film pressure $\bar{p}$ for different values of α

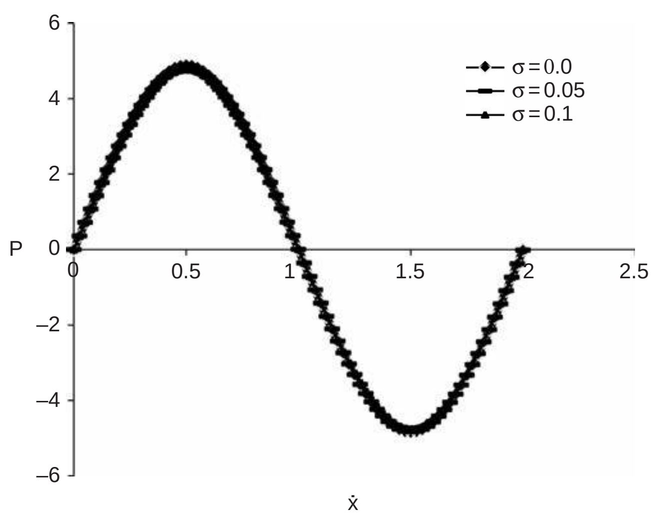

Figure 8.
Dimensionless mean film pressure $\bar{p}$ for different values of σ

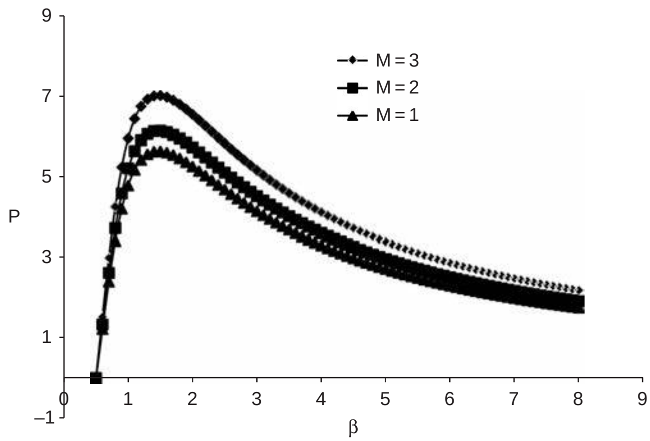

Figure 9. Dimensionless mean film pressure $\bar{p}$ as function of aspect ratio β for different values of M

and $\varepsilon = 0.1$ is shown in Figure 10. It is observed that $\overline{W}$ increases for increasing values of M, decreasing values of $\bar{h}$.

4. Conclusions

This work studied the effect surface roughness effect on MHD squeeze film characteristics between finite porous parallel rectangular plates lubricated with an electrically conducting fluid in the presence of a transverse magnetic field. A generalized form of surface roughness pattern was considered. The main salient predictions of the present work were observed as follows:

- the presence of magnetic field enhanced the load carrying capacity and increased the response time for both positively and negatively skewed surface roughness patterns;
- the negatively skewed surface roughness pattern increased the load carrying capacity and the squeeze film time; and

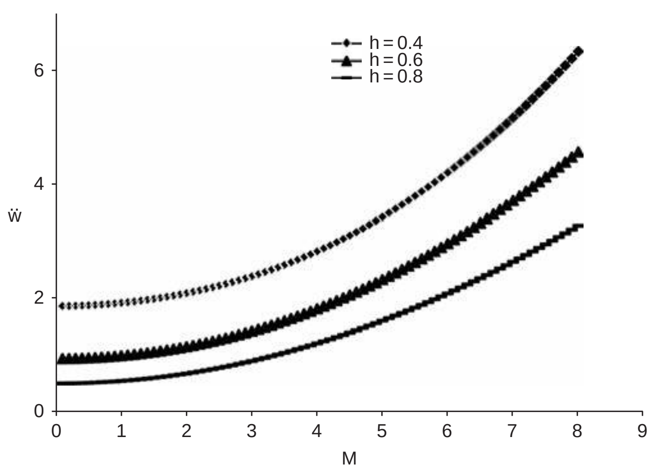

Figure 10. Dimensionless mean load carrying capacity $\overline{W}$ as a function of Hartmann number M for different values of $\bar{h}$

- the positively skewed surface roughness pattern decreased the load carrying capacity and the response time.

Hence, the performance of the squeeze film can be improved by the presence of negatively skewed surface roughness pattern on the lubricating surface. In general, these predictions are useful in finding suitable design parameters of bearings in engineering applications.

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