Shliomis model-based magnetic squeeze film in rotating rough curved circular plates: a comparison of two different porous structures

Jimit R. Patel* and Gunamani Deheri

Department of Mathematics,
Sardar Patel University,
Vallabh Vidyanagar,
Anand, Gujarat, 388120, India
E-mail: patel.jimitphdmarch2013@gmail.com
E-mail: gm.deheri@rediffmail.com
*Corresponding author

Abstract: This study aims to analyse the effect of different porous structures on the performance of a Shliomis model-based magnetic squeeze film in rotating rough porous curved circular plates. For porous structures Kozeny-Carman’s formulation and Irmay’s model have been adopted. A Shliomis model-based magnetic fluid flow is considered. The stochastically averaging models of Christensen and Tonder have been used for characterising the effect of transverse roughness. The associated stochastically averaged Reynolds type equation is solved to obtain the pressure distribution leading to the calculation of the load carrying capacity. The results presented in graphical form show that the adverse effect of transverse roughness can be compensated by the positive effect of magnetisation in the case of negatively skewed roughness, suitably choosing the rotation ratio and the curvature parameters. Further, this compensation appears to be more in the case of Kozeny-Carman’s formulation as compared to that of Irmay’s model, which makes the Kozeny-Carman’s model a superior choice.

Keywords: porous structures; magnetic fluid; curved circular plates; squeeze film; roughness; rotation.


Biographical notes: Jimit R. Patel is currently at Department of Mathematics pursuing his PhD programme, Sardar Patel University. His research area is related to tribology. He has published six research papers in national and international journals. To his credit, he has a teaching experience of around three years.

Gunamani Deheri is currently at the Department of Mathematics, Sardar Patel University. He has a teaching and research experience of around 28 years. He has published more than 180 research papers in various international and national journals. Besides he has received various awards including Hari Ohm Ashram Award and Excellence in Research Award.
1 Introduction

Magnetic fluids, also known as ferrofluids, are a class of non-conducting suspensions of nano sized magnetic particles covered with a surfactant dispersed in liquid carriers like diester and polyphenyl ether. Under the application of a magnetic field, the magnetic moments of particles are oriented along the field lines. Consequently, magnetic fluids can be controlled and located at some preferred places in the presence of an external magnetic field. Because of these prominent characters, magnetic fluids are widely applied in different fields of engineering sciences, for instance, the heat transfer, rotating shaft, seals, damping of hybrid stepping motors, loudspeakers and coating systems.

In the last few years, the fact that the magnetic fluid when used as a lubricant turns in an enhanced performance has drawn considerable attentions all over the world. On the other hand Shliomis (1972) found a ferrofluid flow model, in which the effects of rotation of magnetic particles, their magnetic moments and the volume concentration are included. Kumar et al. (1992) dealt with a ferrofluid squeeze film for spherical and conical bearings with a constant external magnetic field applied in the direction transverse to that of fluid flow. Shah and Bhat (2005) studied the effects of ferrofluid on the curved squeeze film between two annular plates, when the upper plate approached the lower one normally, including the rotation of magnetic particles and their magnetic moments. Singh and Gupta (2012) presented theoretically, the effect of ferrofluid on the dynamic characteristics of curved slider bearings using Shliomis model. On the ground of the ferrohydrodynamic model proposed by Shliomis (1972), Lin (2013) investigated the influence of fluid inertia forces on the ferrofluid squeeze film between a sphere and a plate in the presence of external magnetic fields. It was found from the above studies that the volume concentration and the intensity of magnetic field provided an increase in the load carrying capacity and the time of approach. All these researchers have observed the steady state characteristics of the bearings lubricated with magnetic fluids, resorting to the model proposed by Shliomis (1972).

By now, it is well established that porous materials are used in a wide variety of applications which includes catalyses, chemical separation and tissue engineering. Porous structures are very important in biomedical applications where there are strict limits on the amount of residual organic solvent that may remain in the materials and this provides a strong driving force to seek non-toxic solvent alternatives. Of course, one needs to remember that surface modification or templating of nano porous material presents some special problem because organic solvents are often too viscous to fill such small pores. In view of their wide range of applications, numerous theoretical and experimental studies have been conducted by Liu (2009), Shah and Patel (2012) and Patel and Deheri (2013).

In all the above investigations bearing surfaces were taken to be smooth. After receiving some run-in and wear the bearing surfaces develop roughness, which appears to be random in character, hardly following any particular structural pattern. Also, the contamination of the lubricant and chemical degradation of surfaces contribute to the roughness. Various methods have been proposed to study and analyse the effect of surface roughness on the performance of the squeeze film bearing system. Several
investigators (Tzeng and Saibel, 1967; Christensen and Tonder, 1969a, 1969b, 1970) dealt with a stochastic approach to mathematically model the random nature of surface roughness. On the basis of the Christenson and Tonder’s stochastic model of roughness, Ting (1972), Prakash and Tiwari (1983), Prajapati (1991), Guha (1993), Gupta and Deheri (1996) and Abhangi and Deheri (2012) studied the effect of surface roughness on the performance of different bearing systems. Bujurke et al. (2008) analysed the effect of surface roughness on squeeze film behaviour between two circular disks with couple stress lubricant when the upper disk was porous facing, which approached the lower disk with uniform velocity. The effect of surface roughness was observed to be quite significant.

Patel et al. (2009) analysed the effect of roughness and magnetic fluid lubricant on the performance of the squeeze film in circular plates when the upper plate with a porous facing approached an impermeable and flat lower plate by considering the rotation of the plates. Shimpi and Deheri (2012) dealt with the combined effect of surface roughness and deformation on the behaviour of a squeeze film in rotating curved porous circular plates under the presence of a magnetic fluid. It was found that with suitable values of curvature parameters the negatively skewed roughness tried to mitigate the adverse effect of porosity and deformation, even for lower values of magnetisation parameter. Shimpi and Deheri (2013) modified the approach of Abhangi and Deheri (2012) and Patel et al. (2009) to analyse the performance of a magnetic fluid-based squeeze film between a curved rough circular plate and the flat rough porous circular plate. Abhangi et al. (2014) considered the magnetic fluid lubrication of a squeeze film in rotating curved rough circular plates. This study suggested that the negative variance induced a better performance of the bearing system particularly, when negatively skewed roughness was involved. All these above studies established that increasing values of porosity caused reduced load carrying capacity and friction. The combination of magnetisation and negatively skewed roughness reduced the friction. Moreover, porosity played a seminal role in improving the overall performance of a bearing system by choosing a suitable range of roughness parameters with proper selection of rotation ratio.

Here it has been proposed to embark on a comparative study of the porous structures mooted by Kozeny-Carman’s formulation and Irmay’s porous structures on the performance of a Shliomis model-based magnetic squeeze film in rotating rough curved porous circular plates.

2 Analysis

The configuration and geometry of the curved circular plates are displayed in Figure 1. The bearing comprises of two circular plates, each of radius $a$. The upper and lower plates rotate with angular velocities $\Omega_u$ and $\Omega_l$ respectively, about the $z$-axis. The upper disk moves normally towards the lower disk with uniform velocity $h_0 = \frac{dh_0}{dt}$. 
According to the discussions of Christensen and Tonder (1969a, 1969b, 1970) for the stochastic modelling of transverse roughness, the expression for the film thickness $h(x)$ of the lubricant film is considered to be:

$$h(x) = \bar{h}(x) + h_s$$

where $\bar{h}(x)$ is the mean film thickness and $h_s$ is the deviation from the mean film thickness characterising the random roughness of the bearing surfaces. The deviation $h_s$ is obtained by a generalised probability density function. The details of the mean $\alpha$, the standard deviation $\sigma$ and the parameter $\varepsilon$ which is the measure of symmetry of the random variable $h_s$ are considered from the deliberation of Christensen and Tonder (1969a, 1969b, 1970).

It is considered that the rotating upper disk lying along the surface determined by the relation:

$$Z_u = h_0 \exp(-\beta r^2); 0 \leq r \leq a$$

approaches with normal velocity $\dot{h}_0$ to the rotating lower plate, lying along the surface given by,

$$z_l = h_0 \left[\sec \gamma r^2 - 1\right]; 0 \leq r \leq a$$

where $\beta$ and $\gamma$ are the curvature parameters of the corresponding plates and $h_0$ is the central film thickness. The film thickness $h(r)$ then is defined by Bhat (2003) and Abhangi and Deheri (2012).

$$h(r) = h_0 \left[\exp(-\beta r^2) - \sec \gamma r^2 + 1\right]; 0 \leq r \leq a.$$
particles in the fluid and the other one by rotation of the magnetic moment with in the particles. Brownian relaxation time parameter $\tau_B$ gives particle rotation while the relaxation time parameter $\tau_S$ describe the intrinsic rotational process. Assuming steady flow, neglecting inertial and second derivatives of $\vec{S}$, the equations governing the flow become,

$$-\nabla p + \mu \nabla^2 \vec{q} + \mu_0 (\vec{M} \cdot \nabla) \vec{H} + \frac{1}{2\tau_S} \nabla \times (\vec{S} - \vec{I}) = 0$$  \hspace{1cm} (2)$$

$$\vec{S} = I_{\vec{I}} + \mu_0 \tau_S (\vec{S} \times \vec{H})$$  \hspace{1cm} (3)$$

$$\vec{M} = M_0 \frac{\vec{H}}{H} + \frac{\tau_B}{I} (\vec{S} \times \vec{M})$$  \hspace{1cm} (4)$$

where $\vec{S}$ is the internal angular momentum, $I$ is the sum of moment of inertia of the particles per unit volume, $I_{\vec{I}} = \frac{1}{2} \nabla \times \vec{q}$, together with;

$$\nabla \vec{q} = 0, \nabla \times \vec{H} = 0, \nabla \times (\vec{H} + \vec{M}) = 0$$

(Bhat, 2003), $\vec{q}$ is the fluid viscosity in the film region, $\vec{H}$ is external magnetic field, $\overrightarrow{\mu}$ is magnetic susceptibility of the magnetic field, $p$ is the film pressure, $\eta$ is the fluid viscosity and $\mu_0$ is the permeability of the free space. By making use of equation (3), in equation (2) and (4), one finds that;

$$-\nabla p + \eta \nabla^2 \vec{q} + \mu_0 (\vec{M} \cdot \nabla) \vec{H} + \frac{1}{2} \mu_0 \nabla \times (\vec{M} \times \vec{H}) = 0$$  \hspace{1cm} (5)$$

and

$$\vec{M} = M_0 \frac{\vec{H}}{H} + \frac{\tau_B}{I} (\vec{S} \times \vec{M})$$  \hspace{1cm} (6)$$

Neglecting $\tau_B \tau_S$ terms, substitution of $\vec{M}$ in above equation, leads to;

$$-\nabla p + \left( \eta + \frac{\mu_0}{4} \tau_B \vec{I} \cdot \vec{H} \right) \nabla^2 \vec{q} + \mu_0 (\vec{M} \cdot \nabla) \vec{H}$$

$$+ \frac{1}{2} \mu_0 \tau_B \left[ \nabla (\vec{I} \cdot \vec{H}) \times \vec{M} + (\vec{I} \vec{H}) \cdot \nabla \times \vec{M} - \nabla \times (\vec{M} \cdot \vec{H}) \times \vec{I} \right] = 0$$  \hspace{1cm} (7)$$

From equation (6), it is easily observed that an initial approximation to $\vec{M}$ is $\vec{M} = M_0 \frac{\vec{H}}{H}$. Substituting the value of $\vec{M}$ on the right side of equation (6), a second approximation to $\vec{M}$ is easily seen to be;

$$\vec{M} = M_0 \frac{\vec{H}}{H} + \frac{M_0}{H} \tau_B (\vec{S} \times \vec{H})$$

Again, substituting this value of $\vec{M}$ on the right side of equation (6), third approximation to $\vec{M}$ is found to be;
In view of the equations of Shliomis model with uniform magnetic field, when both surfaces are solid and upper one rotates, the governing equation for the film pressure is obtained from Bhat (2003):

\[
\tilde{M} \tilde{H} = M_0 H + \frac{M_0 H}{H} \tau_\alpha^2 \left( (\tilde{\Omega} \tilde{H})^2 - \Omega^2 H^2 \right)
\]

with \( \tau_\alpha \) being layer thickness.

Neglecting \( \tau_\beta \) term and considering the discussions of Christensen and Tonder (1969a, 1969b, 1970) regarding the modelling of roughness and under the usual assumptions of hydro-magnetic lubrication (Bhat, 2003; Prajapati, 1995; Deheri et al, 2005), the modified Reynolds equation when both plates rotate, takes the form;

\[
\frac{1}{r} \frac{d}{dr} \left( h^3 + 12 \rho \eta l \right) r \frac{d}{dr} = 12 \eta \eta_0 + 24 \rho \eta \Omega_0^2 + \frac{3}{10} \rho \Omega_0^2 - \frac{1}{r} \frac{d}{dr} \left( r^2 h^3 \right)
\]

\[
+ \frac{3 N r^2 l d}{320 \eta_0 \rho d r} \left[ h^3 r \left( \frac{d p}{dr} \right)^3 + \frac{27}{616} \rho^3 r^3 \Omega_0^6 + \frac{13}{14} \left( \frac{d p}{dr} \right)^2 \rho r \Omega_0^2 - \frac{251 d p}{756 d r} \rho^3 r^3 \Omega_0^4 \right]
\]

with \( \eta_0 \) being layer thickness.

Neglecting \( \tau_\beta \) term and considering the discussions of Christensen and Tonder (1969a, 1969b, 1970) regarding the modelling of roughness and under the usual assumptions of hydro-magnetic lubrication (Bhat, 2003; Prajapati, 1995; Deheri et al, 2005), the modified Reynolds equation when both plates rotate, takes the form;

\[
\frac{1}{r} \frac{d}{dr} \left( g(h) + 12 \rho \eta l \right) r \frac{d}{dr} = 12 \eta (1 + r) h_0 + 24 \rho \eta \Omega_0^2
\]

\[
+ \rho \left( \frac{3}{10} \Omega_0^2 + \Omega \Omega_0 + \Omega_0^2 \right) \frac{1}{r^2} \frac{d}{dr} \left( r^2 g(h) \right)
\]

where

\[
g(h) = h^3 + 3 h^2 \alpha + 3 (\sigma^2 + \alpha^2) h + 3 \sigma^2 \alpha + \alpha^3 + \epsilon.
\]

The following non-dimensional quantities are introduced;

\[
\bar{h} = \frac{h}{h_0}, \quad \bar{R} = \frac{R}{a}, \quad P = - \frac{h_0}{\rho a^2}, \quad B = \beta a^2, \quad C = \gamma a^2,
\]

\[
\bar{\sigma} = \frac{\sigma}{h_0}, \quad \bar{\alpha} = \frac{\alpha}{h_0}, \quad \bar{\eta} = \eta (1 + \tau), \quad \bar{\Omega} = \Omega - \Omega_0, \quad S = - \frac{\rho \Omega_0^2 h_0^3}{\eta h_0}, \quad \bar{\Omega}_0 = \frac{\Omega}{\Omega_0},
\]

\[
\bar{\psi} = \frac{\Omega_0^2 h_0^3}{h_0^3}, \quad \bar{\psi}^* = \frac{\Omega_0^2 h_0^3}{h_0^3}, \quad A = \frac{\bar{\psi} e^3}{15(1 - e)^2}, \quad D = \frac{\bar{\psi} e^3}{15(1 - e)^2}, \quad \bar{\psi}^* = \left( 1 - (1 - e)^3 \right) \left( 1 + (1 - e)^3 \right)
\]

The boundary conditions associated are;

\[
P(1) = 0, \quad \left( \frac{d P}{d R} \right)_{R=0} = 0
\]

to obtain the pressure distribution.

Two different porous structures are described below;

2.1 Case 1: a globular sphere model as shown in Figure 2

In this model, a porous material is filled by globular spherical particles, with a mean particle size \( D_c \).
Figure 2  Configuration of a globular sphere model

The Kozeny-Carman equation is well known in fluid dynamics. Relatively better results for pressure drop are obtained when this model is applied to laminar flow. The hydraulic radius theory of Kozeny-Carman formulation resulted in the relationship (Liu, 2009; Patel and Deheri, 2013);

\[
\psi = \frac{D_s^2 e^3}{180(1-e)^2}
\]

where \( e \) is the porosity parameter. From experimental investigation, usually 180 is set for the permeability structure by Kozeny-Carman. The Kozeny-Carman equation yields satisfactory results for media that consists of particles of approximately spherical shape and whose diameter fills with a narrow range. Many investigators worked on this permeability structures and they also modified this model.

Using the boundary conditions (12) and non-dimensional quantities (11), the non-dimensional pressure distribution for globular sphere model is derived as;

\[
P = (-6 - 6 \tau + SA) \int_0^h \frac{R}{g(h) + A} dR + S \int_0^h \left(3 \Omega f + 4 \Omega f + 3\right) \frac{R g(h)}{g(h) + A} dR
\]

where

\[
g(h) = h^4 + 3h^2 \alpha + 3(\sigma^2 + \alpha^3)h + 3\sigma^2 \alpha + \alpha^3 + \varepsilon
\]

and the dimensionless load carrying capacity of the bearing system is obtained from;

\[
W = -\frac{\eta}{2 \pi \eta d h} \int_0^h R P dR
\]

Therefore, the non-dimensional load carrying capacity for Kozeny-Carman is calculated as;

\[
W = \left(3 + 3 \tau - \frac{1}{2} SA\right) \int_0^1 \frac{R^3}{g(h)} dR - \frac{S}{20} \left(3 \Omega f + 4 \Omega f + 3\right) \int_0^1 \frac{R^3 g(h)}{g(h) + A} dR
\]

2.2 Case 2: a capillary fissures model as displayed in Figure 3

This model of porous sheets consists of three sets of mutually orthogonal fissures with a mean solid size \( D_s \).
Considering no loss of hydraulic gradient at the junctions, Irmay (1955) derived the following expression for the permeability of the grid of cubes, valid for $e \ll 1$;

$$\psi = \frac{D_i^2 \left(1 - m^2\right)^{\frac{1}{3}} \left(1 + m^2\right)}{12(1 - e)}$$

where $m = 1 - e$ and $e$ is the porosity.

By making use of the boundary conditions (12) and non-dimensional quantities (11), the expression for non-dimensional pressure distribution for Irmay’s model turns out to be:

$$P = (-6 - 6\tau + SD) \int_0^R \frac{R}{g(h) + D} dR + \frac{S}{10} \left(3\Omega_f^2 + 4\Omega_f + 3\right) \int_0^R \frac{Rg(h)}{g(h) + D} dR$$  \hspace{0.5cm} (16)

Using equation (14), the expression for the dimensionless form of load carrying capacity is found to be;

$$W = \left(3 + 3\tau - \frac{1}{2} SD\right) \int_0^R \frac{R^3}{g(h) + D} dR - \frac{S}{20} \left(3\Omega_f^2 + 4\Omega_f + 3\right) \int_0^R \frac{R^3g(h)}{g(h) + D} dR$$  \hspace{0.5cm} (17)

Bear et al. (1968) informs that for porosity in between 0.25 and 0.65 the Kozeny-Carman’s formulation and Irmay’s model jell well in the sense that the performance differs by at the best eight to nine percentage.

3. Results and discussion

It is easily seen that non-dimensional pressure distribution in the bearing system is obtained by equation (13) and equation (16) while the load carrying capacity of the bearing system in dimensionless form is determined from the equation (15) and equation (17). It is clearly noticed that while the pressure increases by:

$$(6\tau) \int_0^R \frac{R}{g(h) + D} dR.$$
and

$$(6\tau) \int_{r}^{1} \frac{R}{g(h) + D} dR.$$  

the increase in load carrying capacity appears to be;

$$(3\tau) \int_{0}^{R} \frac{R^3}{g(h) + A} dR$$

and

$$(3\tau) \int_{0}^{R} \frac{R^3}{g(h) + D} dR$$
as compared to the case of conventional lubricants.

Probably, this is due to the fact that the magnetisation increases the effective viscosity of the lubricant thereby, increasing the pressure and hence the load carrying capacity. Setting the magnetisation parameter to be zero for a porous bearing with smooth surfaces, the current investigation reduces to the study of Prakash and Vij (1973) in the absence of rotation.

**Figure 4** Variation of load carrying capacity with respect to $r$ and $\bar{\sigma}$

**Figure 5** Variation of load carrying capacity with respect to $r$ and $e$
Figure 6  Variation of load carrying capacity with respect to $\tau$ and $B$

Figure 7  Variation of load carrying capacity with respect to $\tau$ and $C$

Figure 8  Variation of load carrying capacity with respect to $\psi$ and $e$
Figure 9  Variation of load carrying capacity with respect to $\varphi$ and $B$

Figure 10  Variation of load carrying capacity with respect to $\varphi$ and $C$

Figure 11  Variation of load carrying capacity with respect to $\varphi$ and $\tau$
Figure 12  Variation of load carrying capacity with respect to $e$ and $B$

![Graph showing variation of load carrying capacity with respect to $e$ and $B$.]

Figure 13  Variation of load carrying capacity with respect to $e$ and $C$

![Graph showing variation of load carrying capacity with respect to $e$ and $C$.]

Figure 14  Variation of load carrying capacity with respect to $e$ and $\tau$

![Graph showing variation of load carrying capacity with respect to $e$ and $\tau$.]
Figure 15  Variation of load carrying capacity with respect to $B$ and $C$

Figure 16  Variation of load carrying capacity with respect to $B$ and $\bar{\tau}$

Figure 17  Variation of load carrying capacity with respect to $\bar{\tau}$ and $S$
Figure 18  Variation of load carrying capacity with respect to $\varepsilon$ and $\overline{\varepsilon}$

The graphical representations of Figures 4 to 18 relate to the Kozeny-Carman’s formulation, while the results for Irmay’s model-based porous structure case, are given in Figures 19 to 33.

Figure 19  Variation of load carrying capacity with respect to $\tau$ and $\psi^*$

Figure 20  Variation of load carrying capacity with respect to $\tau$ and $e$
Figure 21  Variation of load carrying capacity with respect to $\tau$ and $B$

Figure 22  Variation of load carrying capacity with respect to $\tau$ and $C$

Figure 23  Variation of load carrying capacity with respect to $\psi^*$ and $e$
Figure 24  Variation of load carrying capacity with respect to $\psi^*$ and $B$

Figure 25  Variation of load carrying capacity with respect to $\psi^*$ and $C$

Figure 26  Variation of load carrying capacity with respect to $\psi^*$ and $\epsilon$
Figure 27  Variation of load carrying capacity with respect to $e$ and $B$

Figure 28  Variation of load carrying capacity with respect to $e$ and $C$

Figure 29  Variation of load carrying capacity with respect to $e$ and $\bar{e}$
Figure 30  Variation of load carrying capacity with respect to $B$ and $C$

Figure 31  Variation of load carrying capacity with respect to $B$ and $\overline{\epsilon}$

Figure 32  Variation of load carrying capacity with respect to $\overline{\sigma}$ and $S$
The variation of load carrying capacity presented in Figures 4–7 and 19–22 makes it clear that the magnetisation sharply increases the load carrying capacity. However, the load carrying capacity appears to be more in the case of Irmay’s model.

The effect of porous structures parameter is presented in Figures 8–11 and 23–26. It is noticed that the load carrying capacity decreases due to the porous structure but the rate of decrease in the load carrying capacity is more in the case of Kozeny-Carman’s model.

Figures 12–14 and 27–29 depict the variation of load carrying capacity with respect to porosity parameter. It is observed that the load carrying capacity decreases sharply due to the porosity parameter. Here also, the rate of decrease in load carrying capacity is more in the case of Kozeny-Carman’s model.

The effect of upper plate’s curvature parameter is presented in Figures 15–16 and 30–31. It is found that the effect of $B$ is to increase the load carrying capacity. The Kozeny-Carman’s model records enhanced load as compared to the Irmay’s model. The nature of the effect of the lower plate’s curvature parameter is almost opposite to that of the upper plate’s curvature parameter, which can be seen from Figures 15 and 30.

The fact that the combined effect of standard deviation and rotation parameter is relatively adverse is reflected in Figures 17 and 32.

From Figures 18 and 33 one can infer that the positive skewness decreases the load carrying capacity while the load carrying capacity gets increased owing to negatively skewed roughness. Further, the effect of variance is quite similar to that of skewness so far as the trends of load carrying capacity are concerned. This means the combined effect of variance (-ve) and negatively skewed roughness is significantly favourable to the bearing system.

It is revealed from the graphical representations that the adverse effect of porosity, rotation and roughness can be minimised by the positive effect of magnetisation, choosing suitably the curvature parameters at least in the case of negatively skewed roughness.

4 Conclusions

This study makes it clear that roughness aspect must be addressed at the time of designing the bearing system, even if Shliomis model-based magnetic strength is in place.
A close scrutiny of the graphs suggests that the performance remains relatively better in the case of Kozeny-Carman’s model as compared to Irmay’s model. However, if one considers only the magnetisation aspect then Irmay’s model may be preferred over Kozeny-Carman’s model in the case of a bearing with smooth surfaces. In addition, it is found that this type of bearing system can support certain amount of load even in the absence of flow which does not happen in the case of conventional lubricants.

Acknowledgements

The authors gratefully acknowledge the comments and suggestions of reviewers and editor leading to an improvement in the presentation of the paper.

References


Shliomis model-based magnetic squeeze film


