

# Effect of Surface Roughness on Characteristics of Magnetic Fluid Based Squeeze Film between Porous Annular Discs

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**Abstract-** An endeavor has been made to check and investigate the impact of surface roughness on the characteristics of squeeze film between porous annular discs is bestowed in presence of magnetic fluid. The involved Reynolds equation is solved with suitable boundary conditions and expressions for pressure and load carrying capacity are obtained. The expressions are obtained numerically and results are bestowed graphically. It is found that the load carrying capacity increase with increasing magnetization. The impact becomes more sharp when mean (-ve) is involved. In addition, standard deviation and aspect ratio decrease the load carrying capacity this negative effect is going to be minimized by the magnetic fluid lubricant in the case of negatively skewed roughness. Moreover, the investigation makes it clear that a performance of a bearing system is going to be enhanced by choosing suitable values of magnetization parameter and aspect ratio.

**Keywords-** Magnetic fluid, squeeze film, Surface roughness, Porosity, Reynolds equation, Pressure distribution, Load carrying capacity.

## I. INTRODUCTION

The squeeze film occurs when one in all the lubricating surfaces advances towards the opposite with an ostensible velocity. As a result of the pressure built up during the squeezing action because of viscous resistance to extrusion of the lubricant, it takes specific period of time for two surfaces to into contact. The magnetic fluid could be a stable colloid solution supported nanoparticles in a basic fluid. The magnetic fluid is also called ferromagnetic fluid, magnetic nanofluid, magnetic liquid or ferrofluid. Magnetic fluids have a unique combination of fluidity and ability to interact with the magnetic field; therefore, they are of a good interest for practical applications. Magnetic fluids are widely utilized in the energy sector, for information storage and processing, in ecology, in medicine, mineral concentration.

Agrawal [1] considered a porous inclined slider bearing, lubricated with a magnetic fluid. It had been discovered that the load carrying capacity to be greater than that of a viscous porous inclined slider bearing. Bhat and Deheri [2] examined hypothetically the squeeze film behaviour between two annular discs, when the upper disc with porous facing approached the parallel lower disc. It had been reasoned that the performance

of the bearing with magnetic fluid better than the traditional lubricant. Shukla and Deheri [3] examined the performance of transversely rough porous circular convex pad slider bearing having magnetic fluid lubricant. It had been seen that the bearing with magnetic fluid gives better performance compare to identical bearing with conventional fluid. Shimpi et al. [7] introduced an examination of the conduct of a magnetic fluid based squeeze film between rotating transversely rough porous annular plates with elastic deformation. It was seen that the roughness of the bearing surfaces affects the system adversely and improved the performance of bearing because of magnetic fluid. Patel et al. [8] made an eamination on the effect of transverse surface roughness on the performance of a squeeze film between rotating porous circular plates having concentric circular pocket with velocity slip under the presence of a magnetic fluid lubricant. It had been seen that the load carrying capacity decreases because of porosity and slip velocity and also concluded that magnetic fluid improves the bearing performance.

Deheri and Patel [9] applied examination of the performance of a magnetic fluid based squeeze film for a sphere in a rough spherical seat with slip velocity. Here, it had been declared that for lower values of slip velocity enhances the performance of

bearing system. Patel and Deheri [10] investigated the performance of a squeeze film in an infinitely long rough journal bearing using the ferrofluid flow model of Jenkins. It had been evaluated that eccentricity and negatively skewed roughness increase the load carrying capacity and Jenkins material constant decreases the load carrying capacity. Patel and Deheri [11] did examination of the performance of a ferrofluid-based infinitely long rough porous slider bearing which makes use of thin film lubrication at nanoscale. The outcome showed that consideration of thin film lubrication at a nano scale improves the performance of bearing even for lower strength of the magnetic intensity. Naduvinamani et al. [12] led a theoretical examination of study on consequences of magneto hydrodynamic and surface roughness on the couple stresses squeeze film lubrication between circular stepped plates. It had been obtained that the effect of applied magnetic field on the squeeze film lubrication between circular stepped plates with couple stress fluids increases the load carrying capacity as compared to the corresponding non-magnetic case. Here, an attempt is made to study the effect of surface roughness on characteristics of magnetic fluid based squeeze film between porous annular discs.

**Analysis**

The bearing configuration is presented below

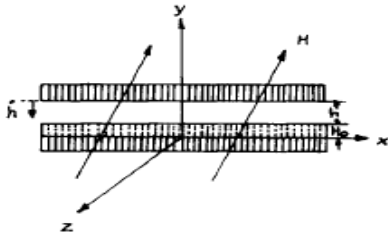


Fig. 1 Configuration of the bearing

The method of Christensen and Tonder [4-6] the thickness  $h(x)$  is considered as

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

The associated probability density function  $f(h_s)$ , is given by

$$f(h_s) = \begin{cases} \frac{32}{35b} \left(1 - \frac{h_s^2}{b^2}\right)^3 & -b \leq h_s \leq b \\ 0 & \text{elsewhere} \end{cases}$$

The random vaivable  $h_s$  is determined by the relations

$$\alpha = E(h_s)$$

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

and

$$\varepsilon = E \left[ (h_s - \alpha)^3 \right]$$

where E denotes the expected value defined by

$$E(R) = \int_{-c}^c Rf(h_s)dh_s$$

The details of charecterization of the roughness aspects can be taken from Christensen and Tonder [4-6]

In view of Agrawal [1] and Bhat and Deheri [2], the associated Reynolds equation for film pressure P, for normal approach of non rotating porous plates is given by

$$\frac{\partial^2 p'}{\partial x^2} + \frac{\partial^2 p'}{\partial z^2} = \frac{12\mu(dh/dt)}{h^3 + 12\phi H_0} \tag{1}$$

With  $p' = p - \frac{1}{2}\mu_0 \bar{\mu} H^2$

As the plates are annular, the flow becomes axisymmetric and equation (1) reduces to

$$\frac{1}{r} \frac{d}{dr} \left( r \frac{dp'}{dr} \right) = \frac{12\mu(dh/dt)}{h^3 + 12\phi H_0} ; b \leq r \leq a$$

With the aid of the stochastical avereging method of Christensen and Tonder[4-6], equation (1) is transformed to

$$\frac{1}{r} \frac{d}{dr} \left( r \frac{dp'}{dr} \right) = \frac{12\mu(dh/dt)}{g(h) + 12\phi H_0} \tag{2}$$

Where

$$g(h) = h^3 + 3\sigma^2 h + 3\alpha^2 h + 3h^2 \alpha + 3\sigma^2 \alpha + \varepsilon + \alpha^3 + 12\phi H_0$$

Using following boundary conditions solving equation (2)

$$p(a) = 0, \quad p(b) = 0$$

So the non dimensional pressure distribution comes out to be

$$P = \frac{ph^3}{\mu \frac{dh}{dt} (a^2 - b^2)} = 3 \left( \frac{1}{G} + \frac{\mu^*}{6} \right) \times \left[ \frac{\ln r^*}{\ln \beta} - \frac{r^{*2} - 1}{\beta^2 - 1} \right] \tag{3}$$

Where a and b are the outer and inner raddi of the discs and

$$\sigma^* = \frac{\sigma}{h} \quad \alpha^* = \frac{\alpha}{h} \quad \varepsilon^* = \frac{\varepsilon}{h^3} \quad r^* = \frac{r}{b}$$

$$\beta = \frac{a}{b} \quad \mu^* = -\frac{\mu_0 \bar{\mu} h^3}{\mu \frac{dh}{dt}} \quad \psi = \frac{\phi H_0}{h^3}$$

$$G = \frac{g(h)}{h^3}$$

$$= 1 + 3\sigma^{*2} + 3\alpha^{*2} + 3\sigma^* \alpha^* + 3\sigma^{*2} \alpha^* + \alpha^{*3} + \varepsilon^* + 12\psi$$

From equation of pressure distribution, the non-dimensional load carrying capacity turns out to be

$$W = -\frac{h^3 w}{\mu \frac{dh}{dt} (a^2 - b^2)^2}$$

$$= \frac{3}{2} \times \left[ \frac{\beta^2 + 1}{\beta^2 - 1} - \frac{1}{\ln \beta} \right] \times \left( \frac{1}{G} + \frac{\mu^*}{6} \right)$$

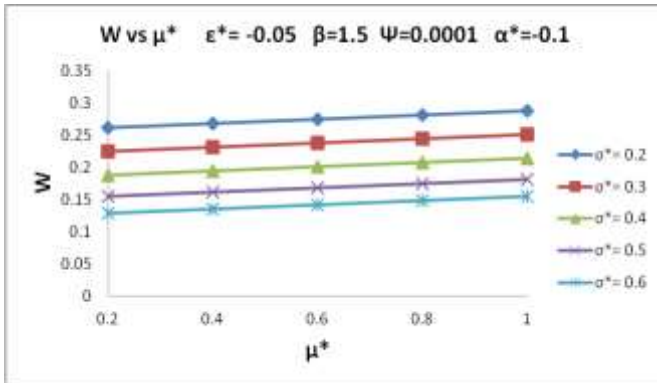


Fig. 2 W versus  $\mu^*$  for distinct values of  $\sigma^*$

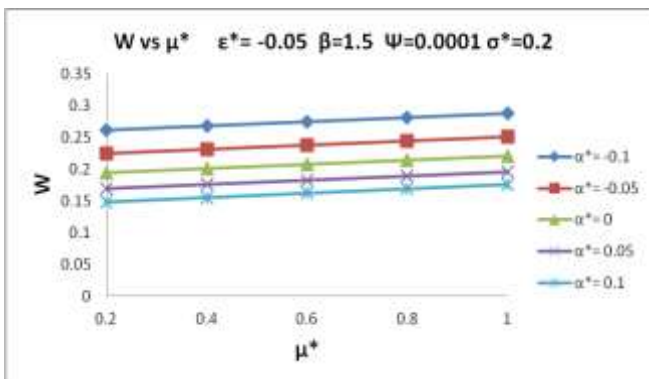


Fig. 3 W versus  $\mu^*$  for distinct values of  $\alpha^*$

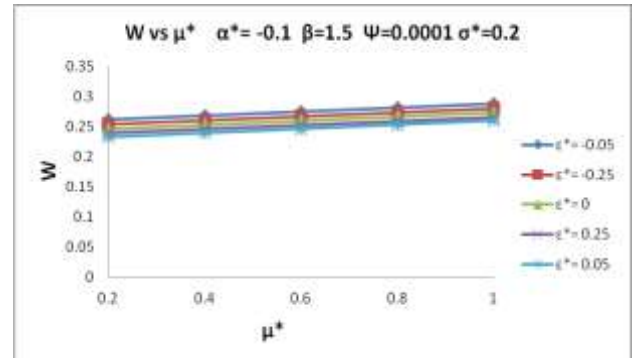


Fig. 4 W versus  $\mu^*$  for distinct values of  $\varepsilon^*$

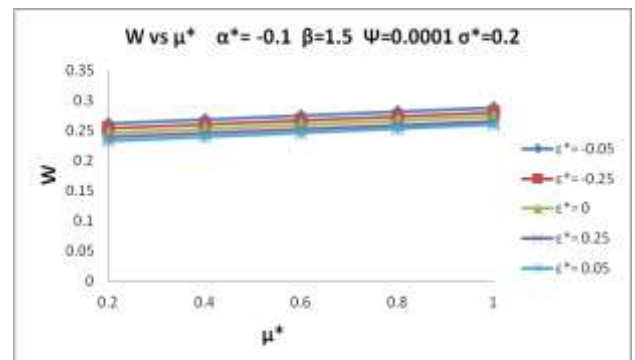


Fig. 5 W versus  $\mu^*$  for distinct values of  $\Psi$

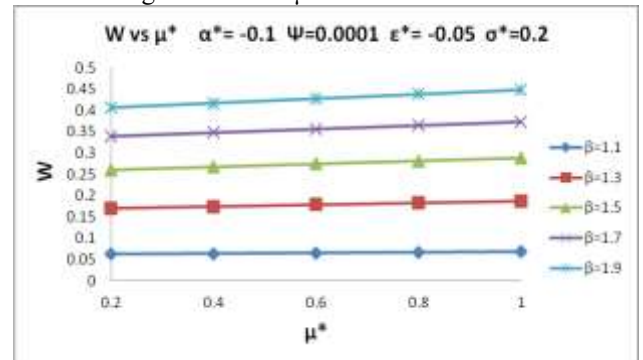


Fig.6 W versus  $\mu^*$  for distinct values of  $\beta$

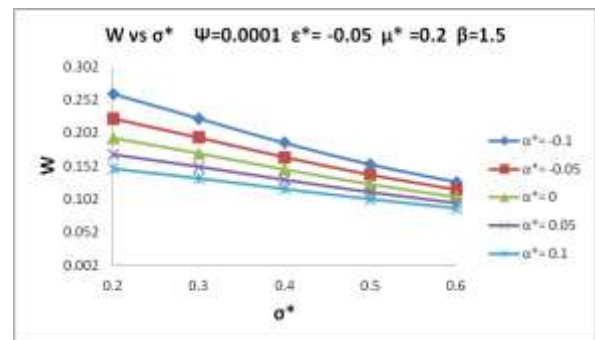


Fig. 7 W versus  $\sigma^*$  for distinct values of  $\alpha^*$

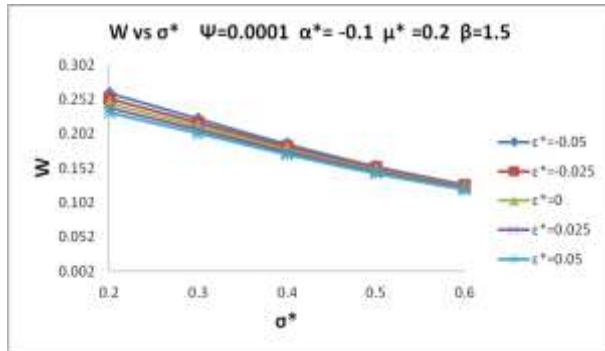


Fig. 8 W versus  $\sigma^*$  for distinct values of  $\epsilon^*$

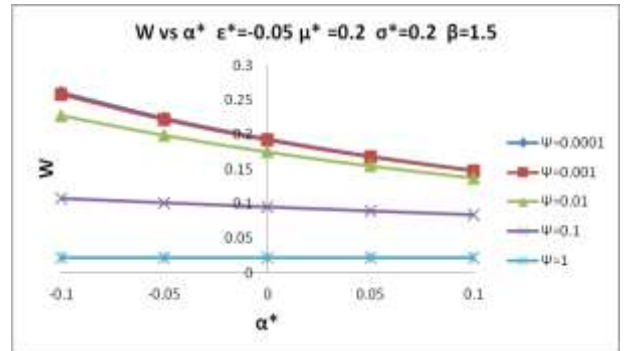


Fig. 12 W versus  $\alpha^*$  for distinct values of  $\Psi$

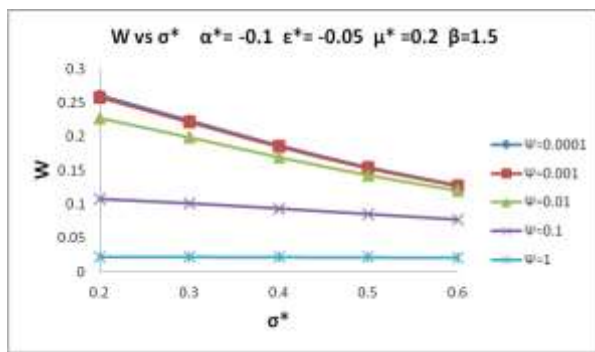


Fig. 9 W versus  $\sigma^*$  for distinct values of  $\Psi$

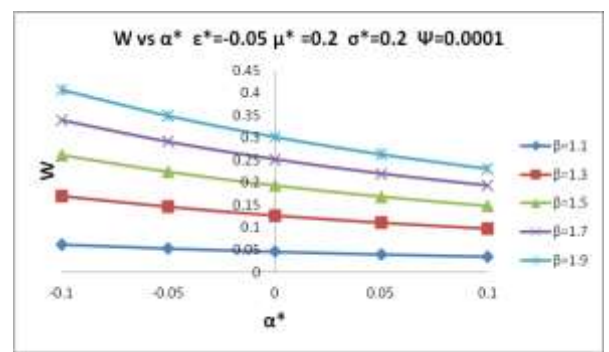


Fig. 13 W versus  $\alpha^*$  for distinct values of  $\beta$

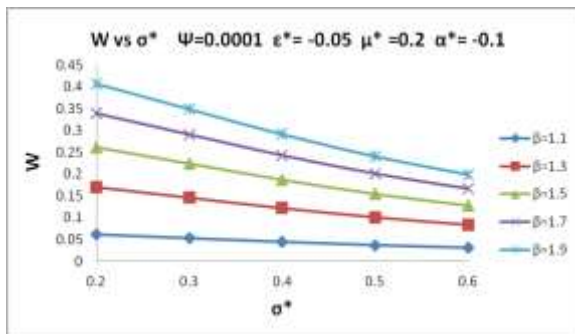


Fig. 10 W versus  $\sigma^*$  for distinct values of  $\beta$

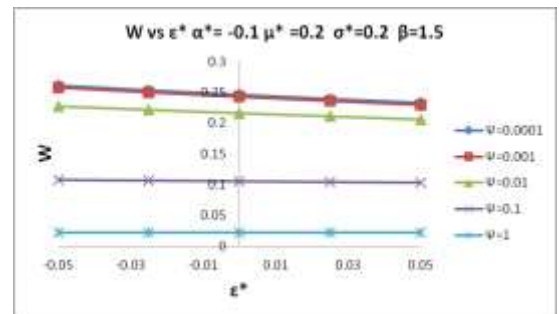


Fig. 14 W versus  $\epsilon^*$  for distinct values of  $\Psi$

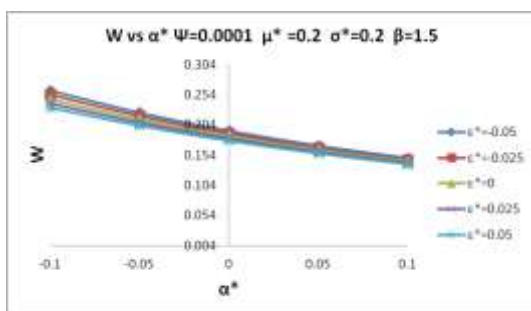


Fig. 11 W versus  $\alpha^*$  for distinct values of  $\epsilon^*$

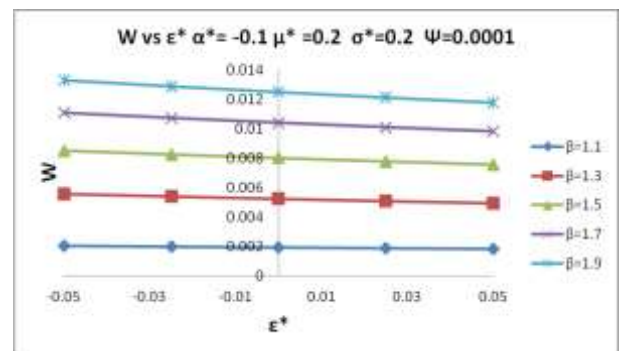


Fig. 15 W versus  $\epsilon^*$  for distinct values of  $\beta$

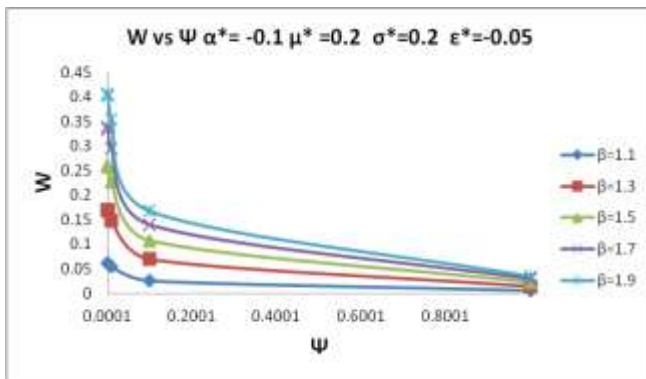


Fig. 16 W versus  $\Psi$  for distinct values of  $\beta$

## II. RESULT AND DISCUSSION

It is clearly seen that the dimensionless pressure distribution is decided from equation (3) while equation (4) gives the distribution of dimensionless load carrying capacity. In the absence of roughness, the result reduces to Bhat and Deheri [2]. Figures (2-6) present the variation of load carrying capacity with respect to magnetization parameter  $\mu^*$  for various values of roughness parameter standard deviation, mean, skewness, porosity and aspect ratio. It is clearly observe form these figures that the load carrying capacity increases sharply because of the magnetization parameter. Additionally from the figure (4) one can observe that the effect of skewness on load carrying capacity with respect to  $\mu^*$  is negligible. The profile for the distribution of non dimensional load carrying capacity with respect to standard deviation is presented in figures (7-10) different values of  $\alpha^*$ ,  $\epsilon^*$ ,  $\Psi$  and  $\beta$ .

It is seen that the standard deviation unfavourably affects the bearing system in the sense that the load carrying capacity decreases considerably significantly due to the standard deviation. However, this decrease is comparatively less in the case of meanwhile this rate of decrease is more due to aspect ratio. One can avail the distribution of non dimensional load carrying capacity with respect to  $\alpha^*$  from figures (11-13). It is found that mean (+ve) decreases the load carrying capacity while mean (-ve) increase the load carrying capacity. The variation of non dimensional load carrying capacity with respect to the skewness depicted in figures (14-15). It is clearly observed that negatively skewed roughness increases load carrying capacity. Figure (16) indicates the variation of non dimensional load carrying capacity with respect to  $\Psi$  for different values of aspect ratio. It is observed that the value of load carrying capacity increases as porosity increases.

## III. CONCLUSION

The outcomes recommend that roughness must be thought of while planning the bearing system regardless of whether proper values of magnetization parameter is chosen. It is acquired that the bearing can support a load even when there is no flow, despite the fact that there are several factors influencing the system antagonistically standard deviation, positive skewness and positive mean. Moreover, the outcomes affirm that the performance of bearing improves by selection of proper values of magnetization parameter and aspect ratio.

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### Nomenclature

$\alpha$  : Mean

$\sigma$  : Standard deviation

$\varepsilon$  : Skewness

$\alpha^*$  : Non dimensional mean

$\sigma^*$  : Non dimensional standard deviation

$\varepsilon^*$  : Non dimensional skewness

$p$  : Lubricant Pressure (N/mm<sup>2</sup>)

$P$  : Non dimensional Pressure

$w$  : Load carrying capacity (N)

$W$  : Non dimensional load carrying capacity

$H$  : External magnetic field

$\mu$  : Coefficient of viscosity

$\bar{\mu}$  : The magnetic susceptibility

$\mu_0$  : Free space magnetic permeability

$\phi$  : Permeability of porous matrix

$\frac{dh}{dt}$  : Normal velocity of approach

$\mu^*$  : Magnetization parameter

$\beta$  : Aspect ratio

$\bar{h}$  : Mean film thickness

$h_s$  : Deviation from the mean film thickness