Magnetic Fluid Lubrication Of A Double Layered Porous Squeeze Film In Longitudinally Rough Truncated Conical Plates Considering Slip Velocity

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Abstract: In this paper investigation we analyze the impact of slip velocity for a double layered porous magnetic squeeze film in longitudinally rough truncated conical plates. The stochastic modeling of Christensen-Tonder has been invoked for the effect of surface roughness Nuringer-Rosenwing model takes care of magnetic fluid flow while Beavers-Joseph slip model is employed. The graphical results are presented after solving the associated stochastically averaged Reynolds type equation. It is noticed that the magnetic fluid lubrication causes a relatively better performance. Besides, the longitudinal roughness also helps to overcome the effect of slip velocity up to certain extent. However, for any type of improved performance smaller values of porosity and slip velocity are required. The magnetic fluid lubrication results in faster response of the squeeze action. The positive effect of double-layered in conjunction with magnetic fluid lubrication presents a better picture.

Keywords - Truncated conical plates, Magnetic fluid, Porosity, Longitudinal roughness, Slip velocity, Load carrying capacity.

h_0	Central film thickness	σ	Standard deviation
h_1	Initial film thickness	α	Variance
h_2	Film thickness after Δt	ε	Skewness
$\overline{h_1}$	h_1/h_0	μ	Fluid viscosity
$\overline{h_2}$	h_2/h_0	$\bar{\mu}$	Magnetic susceptibility
a, b	Dimension of the bearing	ω	Semi vertical angle of the cone
k	Aspect ratio b/a	μ_0	Permeability of the free space
P	Pressure in the film region	Δt	Squeeze time
p	Expected value of the pressure	ΔT	Non dimensional squeeze time
t	Time	Ψ_1	Porosity of the upper layer
x, y, z	Cartesian co-ordinates	Ψ_2	Porosity of the lower layer
W	Load capacity	$\bar{s}$	Non dimensional slip velocity
$\overline{W}$	Non dimensional load capacity	$\bar{h}$	Mean film thickness

I. Introduction

Variance in load as well as relative velocity to create positive fluid pressure is the pith of squeeze film activity. Prakash and Vij (1973) studied the squeeze film between permeable plates of numerous shapes, for example, annular, elliptic, circular, rectangular and conical. In this examination the comparison was made between the squeeze film executions of different geometries of proportional area. With another parameter continuing as before and it was discovered the highest transient load carrying limit enlist by circular plates.

Fluid with solid magnetic properties has attracted significant attention late years. Lubrication in bearing system in specialized application in the area of Nano scale technology and science. Therefore, the utilization of magnetic fluid oil includes an extra significance from Nano science perspective. The use of magnetic fluid as a lubricant was considered by number of authors Agrawal (1986), Urreta et al. (2009), Bhat and Deheri (1995), Huang et al. (2011), Patel et al.(2011) in there ponders it has been seen that the execution the bearing system could be upgraded by utilizing a magnetic fluid as the lubricant. Besides, temperature rise was less.

For all intents and purposes no solid surface which is perfectly smooth on atomic scale. The impact of surface roughness assumes a crucial role in the advancement of science and innovation of tribology. There are two kinds of one dimensional roughness, which are utilized to assess the impact of surface roughness. One pattern longitudinal and the other is transverse.

The stochastic model introduced by Christensen and Tonder (1969a, 1969b, 1970) to ponder the impact of transverse and in addition longitudinal surface roughness on the execution of bearing system has been utilized by numerous researchers Patel and Deheri (2011), Lin et al. (2002), Rusma et al. (2011), Patel et al. (2013).

The model for the count of the slip impact which are given by Beavers and Joseph (1967). Patel and Deheri (2007) broke down the execution of a magnetic fluid based squeeze film between rough porous truncated conical shaped plates. The bearing surfaces were assumed to be transversely rough. The outcomes recommended that the pressure and load carrying capacity and reaction time increasing with increasing magnetization parameter. Although the roughness influenced adversely. Rao, Rani, Nagarajan and Hashim (2013) talked about a long journal bearing with a double- layered porous lubrication film utilizing couple stress and Newtonian fluid and presumed that a double- layered porous lubricant film configuration increased the load carrying capacity and decreased the coefficient of friction in a journal bearing. Uma Srinivasan (1977) determined analytical solution for the execution qualities of a double - layered porous slider bearing. The articulations for load, pressure, coefficient of friction, frictional drag and Centre of pressure were provided in closed form. The impact of the double- layer was to expand the load and the frictional drag however to decrease the coefficient of friction. However, comparison with transverse roughness less amount of work has been improved the situation longitudinal aspect.

Andharia and Deheri (2011) discussed the consolidated impact of magnetic fluid lubrication and longitudinal roughness on the squeeze film between truncated conical plates. The bearing performance enhanced because of the negative skewed roughness.

Thus, an attempt has been made to expand this examination Andharia and Deheri (2011) to display the conduct of a squeeze film truncated conical plates other than considering double- layered porosity and slip velocity.

II. ANALYSIS

The configuration of the bearing is shown in "**Fig. 1**". In the z-direction squeeze film velocity $\frac{dh_0}{dt}$. here we use the assumptions of hydrodynamic lubrication theory. The lubrication film is considered to be isoviscous and incompressible and the flow is laminar.

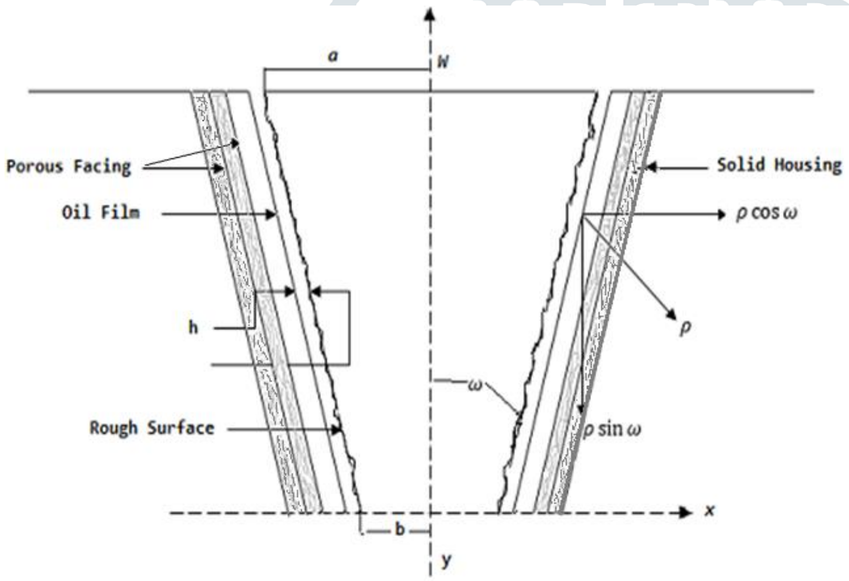


Fig. 1 Configuration of truncated conical plates

In view of Christensen and Tonder (1969a, 1969b, 1970), the film thickness h is expressed as $h = \bar{h} + h_s$. The deviation from the mean film thickness characterizing the random roughness of the bearing surfaces is denoted by h_s. The details regarding the roughness characterized in Christensen and Tonder (1969a, 1969b, 1970). The probability density function used, was

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

In magnetic fluid, axially symmetric flow between the truncated conical plates is taken under an oblique magnetic field $\bar{M}$ whose magnitude M is given by [Patel and Deheri (2007).

$$M^2 = k(a\,\mathrm{cosec}\omega - x)(x - b\,\mathrm{cosec}\omega), b \prec x \prec a \tag{2}$$

The basic flow equation of magnetic fluid based on rosensweing's model (1964).

$$\nabla \cdot \bar{M} = 0, \nabla \times \bar{M} = 0 \tag{3}$$

The θ is inclination angle of the magnetic field $\bar{M}$ with the lower plate, one can refer to Bhat (2003), Deheri and Andhariya (2011) [18]

The pressure distribution is decided by Prakash and Vij (1973) and Patel and Deheri (2007)

$$\frac{1}{x}\frac{d}{dx}\left[xh^3 \frac{d}{dx}\left(p - 0.5\mu_0\bar{\mu}M^2\right)\right] = \frac{12\mu\dot{h}_0}{\sin^2\omega} \tag{4}$$

Following the normal procedure talked by Andharia, Gupta and Deheri (1967) and using "Eq. 2" and "Eq. 4"
The stochastic averaging of the equation in the thought of Christensen and Tonder incorporating slip effect comes out to be

$$\frac{1}{x}\frac{d}{dx}\left[xm(h)^{-1}\frac{d}{dx}\left(p-0.5\mu_0\bar{\mu}k(a\operatorname{cosec}\omega-x)(x-b\operatorname{cosec}\omega)\right)\right]=\frac{12\mu\dot{h}_0}{\sin^2\omega} \tag{5}$$

Where

$$m(h)=\left[h^{-3}\left\{1-3\alpha h^{-1}+6h^{-2}\left(\sigma^2+\alpha^2\right)-20h^{-3}\left(\varepsilon+3\sigma^2\alpha+\alpha^3+12(\varphi_1H_1+\varphi_2H_2)\right)\right\}\right]\frac{4+sh}{1+sh} \tag{6}$$

Introducing dimensionless quantities

$$H=\frac{h}{h_o},X=\frac{x}{a},M(H)=h_0^{\ 3}m(h),\bar{\alpha}=\frac{\alpha}{h_0},\bar{\sigma}=\frac{\sigma}{h_0},\bar{\varepsilon}=\frac{\varepsilon}{h_0^{\ 3}},\bar{s}=sh_0,k=\frac{b}{a},\psi_1=\frac{\varphi_1H_1}{h_0^{\ 3}},\psi_2=\frac{\varphi_2H_2}{h_0^{\ 3}},$$

$$\mu^*=\frac{-\mu_0\bar{\mu}h_0^{\ 3}k}{\mu\dot{h}_0},P=\frac{-ph_0^{\ 3}}{\mu\dot{h}_0\pi(a^2-b^2)\operatorname{cosec}\omega} \tag{7}$$

Leads to

$$\frac{1}{X}\frac{d}{dX}\left[XM(H)^{-1}\frac{d}{dX}\left(P-\frac{0.5\mu^*(1-X\sin\omega)(X-k\operatorname{cosec}\omega)}{\pi(1-k^2)}\right)\right]=\frac{12\operatorname{cosec}\omega}{\pi(k^2-1)} \tag{8}$$

The Reynolds boundary conditions associated with the bearing system are

$$P(k\operatorname{cosec}\omega)=0,P(\operatorname{cosec}\omega)=0 \tag{9}$$

Solving the Equation we can found that

$$P=\frac{1}{2\pi(1-k^2)}\left[\mu^*(1-X\sin\omega)(X-k\operatorname{cosec}\omega)+6M(H)\operatorname{cosec}^3\omega\left\{(1-X^2\sin^2\omega)+2k^2\ln(X\sin\omega)\right\}\right] \tag{10}$$

Where

$$M(H)=\left[H^{-3}\left\{1-3\bar{\alpha}H^{-1}+6H^{-2}\left(\bar{\sigma}^2+\bar{\alpha}^2\right)-20H^{-3}\left(\bar{\varepsilon}+3\bar{\sigma}^2\bar{\alpha}+\bar{\alpha}^3+12(\psi_1+\psi_2)\right)\right\}\right]\frac{4+\bar{s}H}{1+\bar{s}H} \tag{11}$$

The load carrying capacity is calculated by

$$w=2\pi\int_{b\cos ec\omega}^{a\cos ec\omega}xpdx \tag{12}$$

Whose non-dimensional form is

$$W=-\frac{wh_0^{\ 3}}{\mu\dot{h}_0(a^2-b^2)^2\pi^2\operatorname{cosec}^2\omega}$$

$$=\frac{2}{(1-k^2)\operatorname{cosec}\omega}\left(\frac{\mu^*(1-k)^2\operatorname{cosec}^3\omega}{24\pi}+\frac{3M(H)\operatorname{cosec}^5\omega}{4\pi(1-k^2)}\left[(1-k^2)(1-3k^2)-4k^4\ln(k)\right]\right) \tag{13}$$

Lastly, the dimensionless squeeze time ΔT is obtained from "Eq. 13" as

$$\Delta T=\frac{wh_0^{\ 2}}{\mu\pi^2(a^2-b^2)\operatorname{cosec}^2\omega}\Delta t$$

$$=\frac{W}{2}\left(\frac{1}{\bar{h}_1^{\ 2}}-\frac{1}{\bar{h}_2^{\ 2}}\right) \tag{14}$$

Where

$$\bar{h}_1=\frac{h_1}{h_0}\ and\ \bar{h}_2=\frac{h_2}{h_0}$$

III. RESULT AND DISCUSSION

Here we observed that the load carrying capacity gets a boost of $\frac{\mu^*(1-k)^2\operatorname{cosec}^3\omega}{24\pi}$ as compared to conventional fluid based bearing systems. The expression for load carrying capacity is found to be linear in μ^* and therefore, the load would increase with increases in μ^* and this is reflected "**Fig. 2 – 6**". The load decreases considerably when the semi vertical angle of the cone increase. "**Fig. 7-8**". The load is observed to be decrease when the aspect ratio increases "**Fig. 9-10**". Further, as can been seen "**Fig. 11-12**". The standard deviation results in increased load also. It is appealying to note that the trends of load with respect to variance "**Fig.**

13" and skewness "**Fig. 14**"are almost alike. It is clearly seen that there is a significant load increase due to double layered porosity "**Fig. 15**". The slip affects the bearing performance adversely and this effect is further aided by porosity "**Fig. 16-18**".

Fig. 2. Variation of LCC(load carrying capacity) w.r.t. $\bar{\alpha}$ and μ*

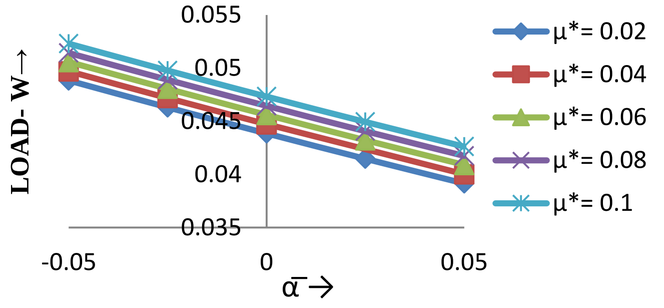


Fig. 3. Variation of LCC w.r.t. $\bar{\sigma}$ and μ*

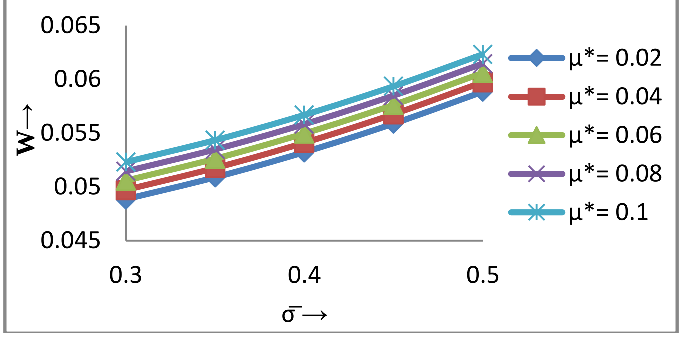


Fig. 4. Variation of LCC w.r.t. μ* and $\bar{\alpha}$

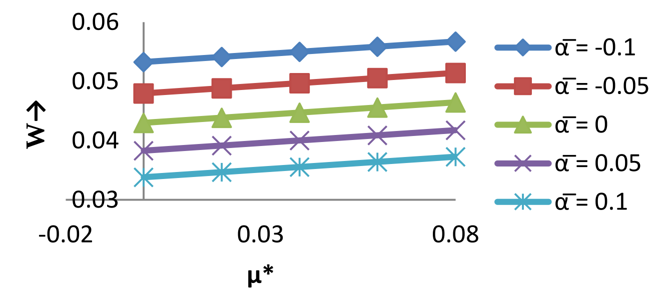


Fig. 5.Variation of LCC w.r.t. μ* and ω

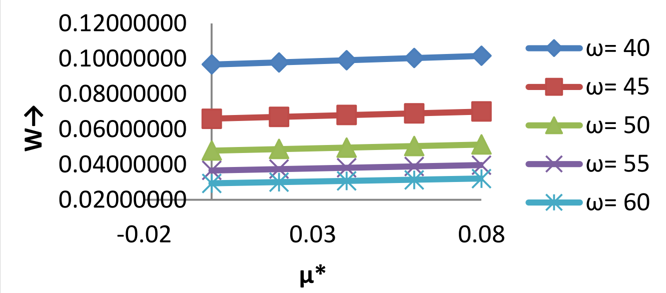


Fig. 6. Variation of LCC w.r.t. μ* and ψ

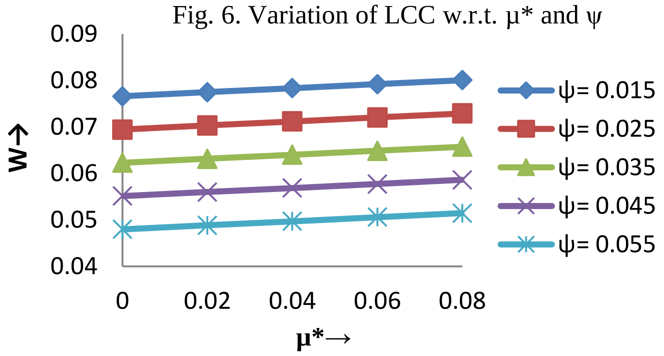


Fig. 7. Variation of LCC w.r.t. ω and $\bar{\alpha}$

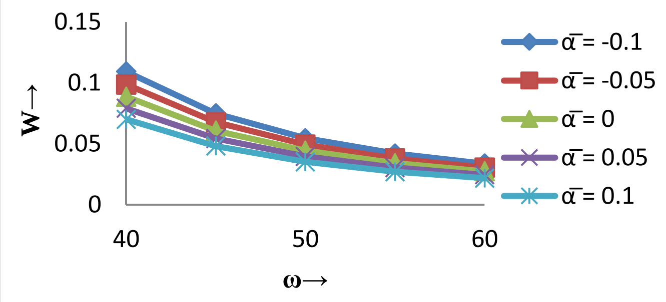


Fig. 8. Variation of LCC w.r.t. ω and $\bar{\varepsilon}$

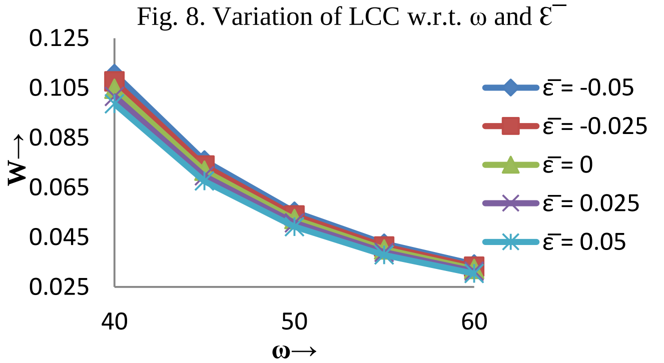
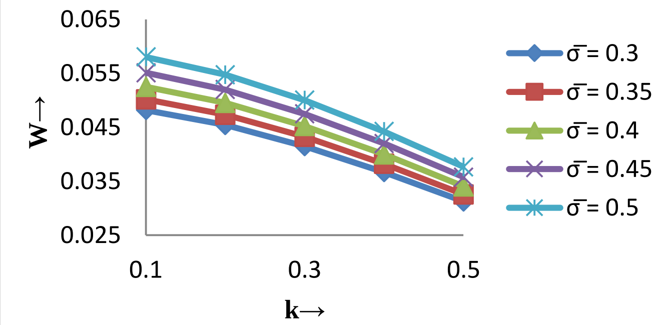


Fig. 9. Variation of LCC w.r.t. k and $\bar{\sigma}$



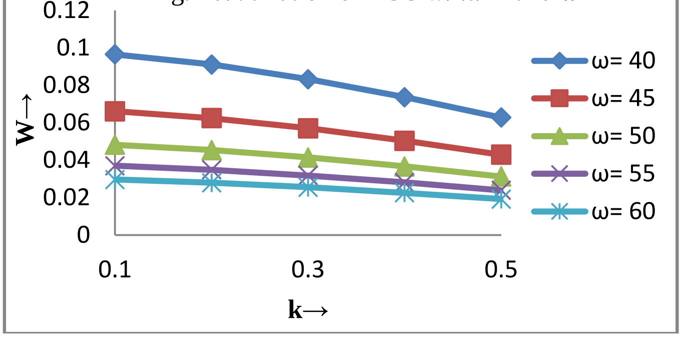


Fig. 10.Variation of LCC w.r.t. k and ω

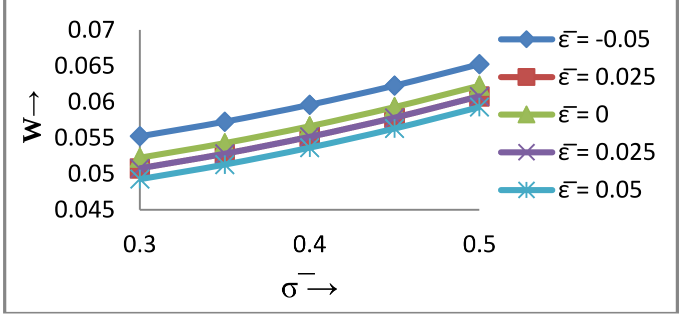


Fig. 11. Variation of LCC w.r.t.σ̄ and ε̄

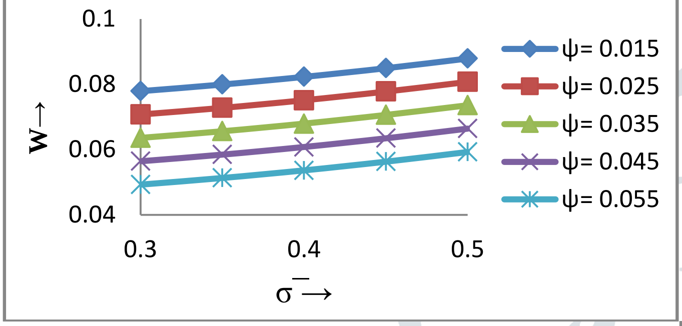


Fig. 12. Variation of LCC w.r.t.σ̄ and ψ

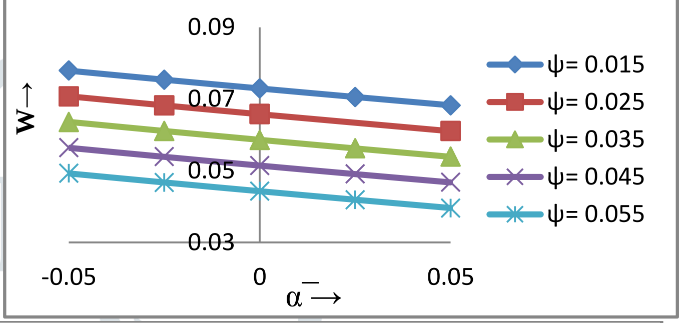


Fig. 13. Variation of LCC w.r.t. ᾱ and ψ

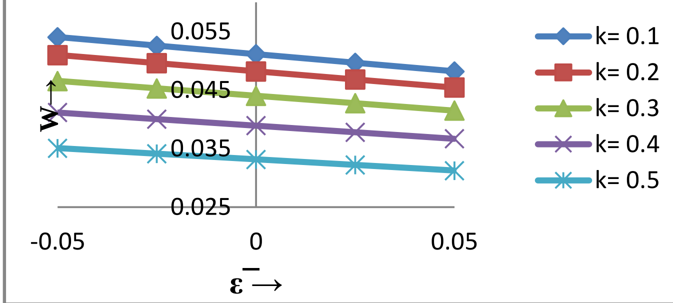


Fig. 14. Variation of LCC w.r.t. ε̄ and k

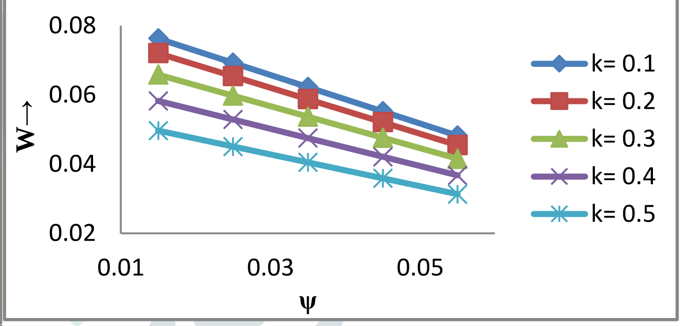


Fig. 15. Variation of LCC w.r.t. ψ and k

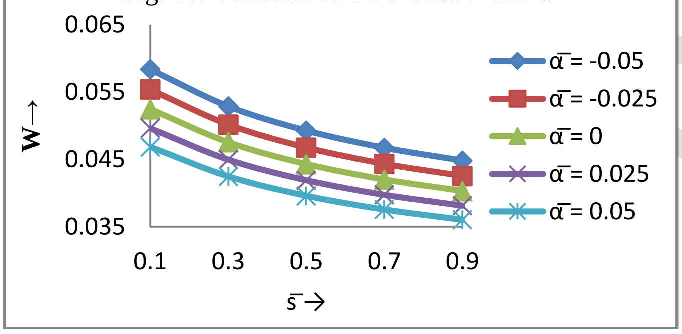


Fig. 16. Variation of LCC w.r.t. s̄ and ᾱ

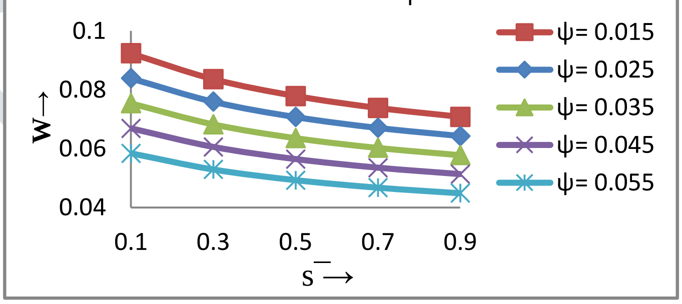


Fig. 17. Variation of load carrying capacity w.r.t. s̄ and ψ

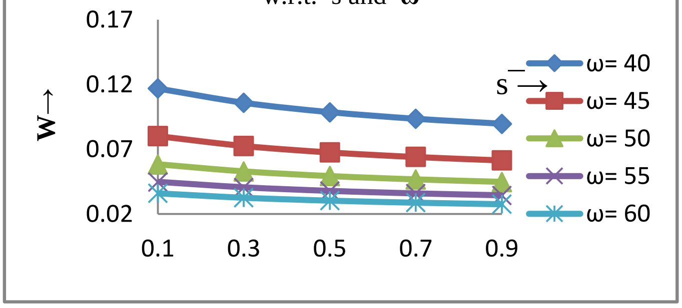


Fig.18. Variation of load carrying capacity w.r.t. s̄ and ω

IV. Conclusion

This investigation strongly suggests that the negative impact induced by positive variance, semi-vertical angle, aspect ratio and slip can be extensively lessened by the standard deviation and positive effect of magnetization parameter on account of adversely skewed roughness. Overall performance of the bearing is effective on the slip parameter is required to be minimized. The significance of this examination lies in the way that besides providing additional degree of freedom it offers ample scopes for having improved performance. As double layered porosity is considered, if developed appropriate this type of bearing design may turn out to be useful to the industry.

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