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EFFECT OF TRANSVERSE ROUGHNESS ON CHARACTERISTICS OF SQUEEZE FILM BETWEEN POROUS COMPLETE CONICAL PLATES

UTICAJ POPREČNE HRAPAVOSTI NA KARAKTERISTIKE NOSEĆEG ULJNOG FILMA IZMEĐU POROZNIH KONIČNIH PLOČA

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Ključne reči
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- Rejnoldsova jednačina
- raspodela pritiska
- kapacitet nosivosti ležaja
- konične ploče

Abstract

Present study incorporates discussion on the impact of transverse surface roughness between porous complete conical plates based on the characteristics of squeeze film. The study is made keeping Christensen's stochastic theory for hydrodynamic lubrication of rough surfaces in view. The associated Reynolds type equation has been solved with appropriate boundary conditions to get pressure, and thus, load-bearing capacity has been calculated. Furthermore, results of load bearing capacity for distinct values of semi vertical angle of cone, standard deviation, mean, skewness and aspect ratio are numerically obtained and are presented in graphical form. The outcome of the study suggests that the impact of semi vertical angle reduces the pursuance of bearing system with the reduction in load bearing capacity. In addition to this, it also has been proved that the negative mean, negative skewness, proper values of semi vertical angle and porosity can improve the performance of the bearing system.

Izvod

U radu je obuhvaćena diskusija o uticaju poprečne površinske hrapavosti između potpuno poroznih koničnih ploča, na osnovu karakteristika nosećeg uljnog filma. Istraživanje je obavljeno imajući u vidu Kristensenovu stohastičku teoriju hidrodinamičkog podmazivanja hrapavih površina. Rešavanjem odgovarajuće jednačine Rejnoldsovog tipa sa odgovarajućim graničnim uslovima, omogućeno je dobijanje pritiska, a time izračunavanje kapaciteta nosivosti ležaja. Osim toga, numerički su dobijeni i grafički predstavljeni rezultati kapaciteta nosivosti ležaja, na osnovu vrednosti vertikalnog polu-ugla konusa, standardne devijacije, aritmetičke sredine, koeficijenta asimetrije i koeficijent spljoštenosti. Istraživanje sugeriše da vertikalni polu-ugao smanjuje funkcionalnost sistema ležaja sa smanjenjem kapaciteta nosivosti. Osim toga, dokazano je da negativna sredina, negativni koeficijent asimetrije, ispravne vrednosti za vertikalni polu-ugao i poroznost mogu da poboljšaju performanse sistema ležaja.

INTRODUCTION

Squeeze film conduct occurs in designing utilizations like machine tools, gears, bearings, moving parts, car motors. The squeeze film crops up when lubricating surfaces press forward in the direction of the other with an ostensible velocity. As a result, the pressure develops during the squeezing action in the light of viscous resistance to expulsion of the lubricant; here it is very interesting to notice time taken for two surfaces to come into contact.

Prakash and Tiwari /1/ analysed the stochastic hypothesis of rough surfaces to swot up for squeeze film between two rotating annular discs, where one disc being a porous facing. The result of examination was contrasted with the estimated arrangement and along these lines; the scopes of affecting boundaries were acquired. Christensen and Tonder /2-4/ studied random character of the surface roughness, who used a stochastic approach to mathematically model the roughness of the bearing surfaces. They also analysed both transverse as well as longitudinal surface roughness based on a general probability density function. Prakash and Tiwari /5/ inspected the impact of surface roughness for pivoting porous annular discs on the squeeze film. It had been analysed that the impact of inertia reduced the load bearing capacity and abbreviated the reaction time. A couple-stress squeeze film between a sphere and a flat plate was discussed by using the theory of roughness of hydrodynamic lubrication by Naduvinamani et al. /6/, in which they examined hydrodynamic oil of couple- stress squeeze film between a sphere and a level plate. Subsequently, it was seen that the surface roughness extensively affected the squeeze film. The load bearing capacity and squeeze film time expanded an azimuthal roughness design contrasted with the comparing smooth case, and reverse trend opposite pattern was watched for a radial roughness pattern.

Besides, Naduvinamani et al. /7/ talked about the behaviour between two rectangular plates by considering the effect of roughness on the couple stress. It has been seen that the impact of roughness was increasingly striking for couple-stress when contrasted with the Newtonian liquids. Porous circular plates and squeeze film behaviour for coordinated packets was hypothetically talked by Prajapati /8/, where he analysed that the load was applied continually, the bearing surfaces moved toward one another even more quickly, while increment in the pocket radius decreased the load bearing capacity of the bearing. Prakash and Tiwari /9/ considered the effect of roughness between two circular plates, when one plate had a porous on the reaction of a squeeze film. An exact solution of film pressure was obtained for arbitrary wall thickness. Prakash and Vij /10/ studied squeeze films between porous plates of various shapes like circular, annular, elliptic, and rectangular. Patel and Deheri /11/ discussed the parallel plates slider bearing with effect of slip velocity, magnetic fluid, and surface roughness. It was observed that the magnetic fluid, due to negatively skewed roughness, could limit the negative impact.

Bujurke et al. /12/ made a hypothetical investigation of curved annular plates for impacts of roughness on the qualities of squeeze film. It had been seen that the impact of circumferential roughness pattern moved the purpose of most pressure towards the bay or outlet edge and when the mean load bearing capacity expanded or diminished for the radial roughness. The investigation broadened when the correlation is made with the relating smooth case, for both concave and convex pad geometries. Deheri et al. /13/ discovered that couple stress ferro-fluid lubricants increased squeeze film characteristics, and dimensionless load bearing capacity diminished when half cone angle of conical plate expanded. Rao et al. /14/ talked about the impact of roughness and the conical bearings with effects of squeeze film lubrication. It was explored that the bearing system improves the presentation as a contrast to the bearing working with conventional lubricant. Here, it is proposed to study the effect of surface roughness on characteristics of squeeze film between porous complete conical plates.

ANALYSIS

The bearing design is introduced as shown in Fig. 1

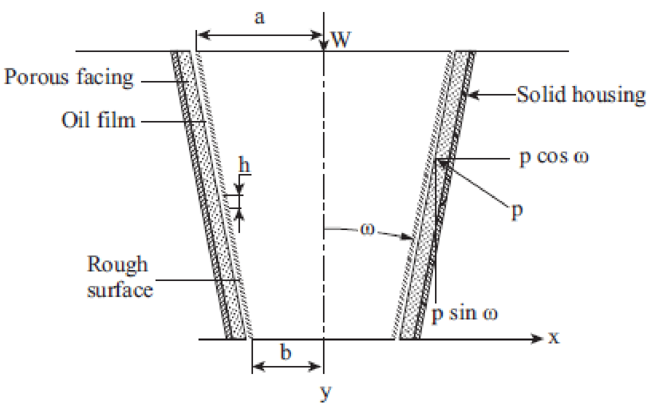

Figure 1. Configuration of the bearing system.

Following the strategy of Christensen and Tonder /2-4/, the thickness $h(x)$ is treated as

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

The associated probability density function $F(h_s)$ is given

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

The random variable h_s is obtained 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 is the expected value characterized by

$$E(R) = \int_{-c}^{c} R f(h_s) dh_s \, .$$

The insights about the characterization of the roughness aspects are discussed by Christensen and Tonder, /2-4/.

In view of Prakash and Vij, /10/, in the case of surfaces, the associated Reynolds equation for the porous facing is given by

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

As the plates are complete cone, Eq.(1) reduces to

$$\frac{1}{x}\frac{d}{dx}\left(x\frac{dp}{dx}\right) = \frac{12\mu(dh/dt)\sin\omega}{h^3 \sin^3\omega + 12\phi H} \, .$$

According to the stochastic averaging method of Christensen and Tonder /2-4/, Eq.(1) is transformed to

$$\frac{1}{x}\frac{d}{dx}\left(x\frac{dp}{dx}\right) = \frac{12\mu(dh/dt)\sin\omega}{g(h) + 12\phi H} \, , \tag{2}$$

where: $g(h) = h^3\sin^3\omega + 3\sigma^2 h\sin\omega + 3\alpha^2 h\sin\omega + 3h^2\sin^2\omega\alpha + 3\sigma^2\alpha + \varepsilon + \alpha^3 + 12\phi H$.

Using the following boundary conditions and solving Eq.(2)

$$p(a\,\mathrm{cosec}\,\omega) = 0 \, , \quad \left(\frac{dp}{dx}\right)_{x=0} = 0 \, ,$$

one gets the dimensionless pressure distribution as

$$P = -\frac{h^3 p}{\mu \dfrac{dh}{dt} a^2 \,\mathrm{cosec}\,\omega} = \frac{3}{G} \times \left(1 - X^2 \sin^2\omega\right) , \tag{3}$$

where: $G = g(h)/h^3 = \sin^3\omega + 3\sigma^{*2}\sin\omega + 3\alpha^{*2}\sin\omega + 3\alpha^{*}\sin^2\omega + 3\sigma^{*2}\alpha^{*} + \varepsilon^{*} + \alpha^{*3} + 12\psi$; $\sigma^* = \dfrac{\sigma}{h}$; $\alpha^* = \dfrac{\alpha}{h}$; $\varepsilon^* = \dfrac{\varepsilon}{h^3}$; $r^* = \dfrac{r}{b}$; $X = \dfrac{x}{a}$; $\psi = \dfrac{\phi H}{h^3}$.

Presently the load bearing capacity can be attained from the film pressure:

$$w = 2\pi \int_0^{a\,\mathrm{cosec}\,\omega} x p(x)\, dx \, . \tag{4}$$

Then the dimensionless load bearing capacity can be expressed as

$$W=-\frac{h^3 w}{\mu\frac{dh}{dt}\pi a^4\operatorname{cosec}^2\omega}=\frac{3\sin\omega}{2G}. \qquad (5)$$

RESULTS AND DISCUSSION

The present study reduces to the observation of non-porous smooth bearing, as observed by Prakash and Vij, /10/. Equations (3) and (4) explain dimensionless pressure distribution and the load bearing capacity. Furthermore, the variation of the load bearing capacity corresponding to semi vertical angle for distinct values of standard deviation, mean, skewness and porosity is presented in Figs. 2-5. From these figures, one can see that there is an adverse effect of semi vertical angle by diminishing the load. In particular, from Fig. 4 it is seen that the impact of skewness on load bearing capacity corresponding to semi vertical angle is marginal. Figures 6-8 indicate the value of load bearing capacity corresponding to σ^* for distinct values of α^*, ε^*, ψ. The figures also show that the value of load bearing capacity decreases as σ^* decreases. From Fig. 7 it is obvious that the impact of skewness on the load bearing capacity corresponding to σ^* is negligible when σ^* exceeds 0.4. The impact of mean on load bearing capacity for distinct values of ε^* and ψ is presented in Figs. 9-10. The figures suggest that the negative mean improves the performance of bearing by increasing load-bearing capacity. The joined impact of skewness and porosity is adverse on load and can be seen from the Fig. 11.

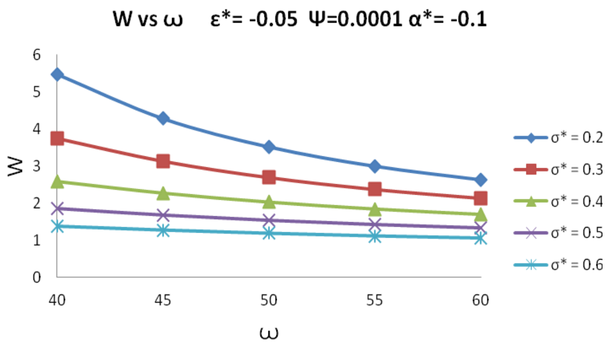

Figure 2. W versus ω for σ^*.

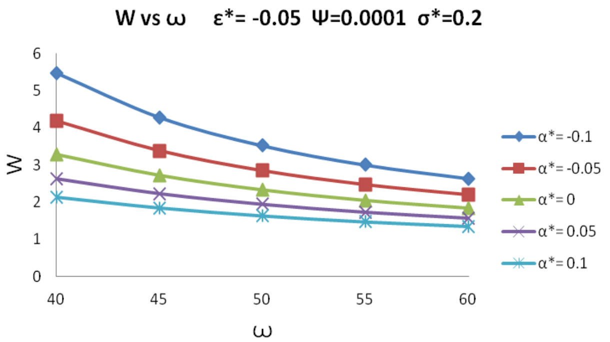

Figure 3. W versus ω for α*

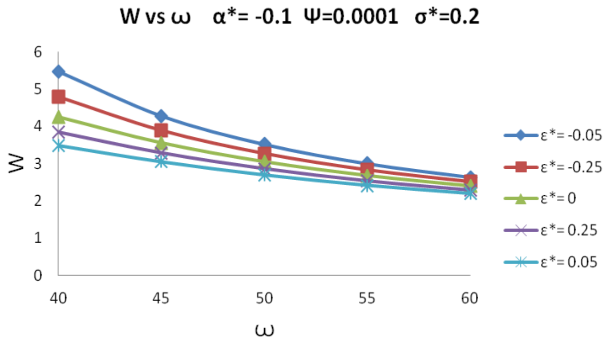

Figure 4. W versus ω for ε^*.

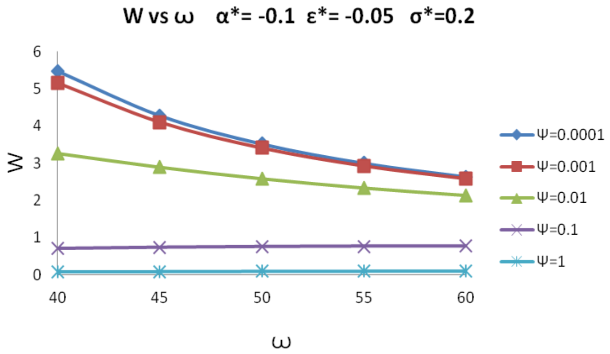

Figure 5. W versus ω for ψ.

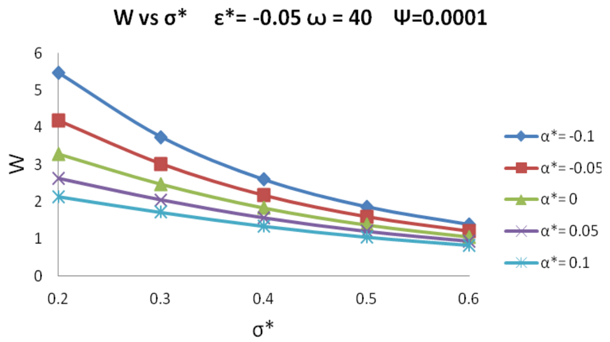

Figure 6. W versus σ^* for α^*.

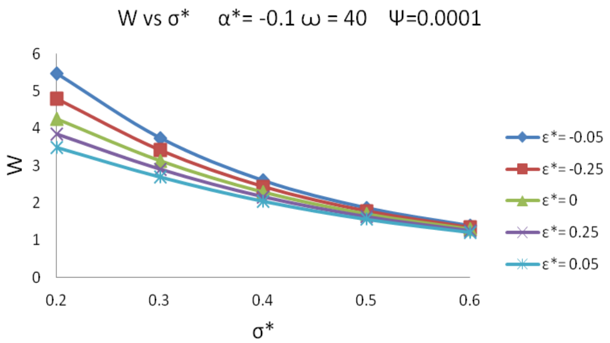

Figure 7. W versus σ^* for ε^*.

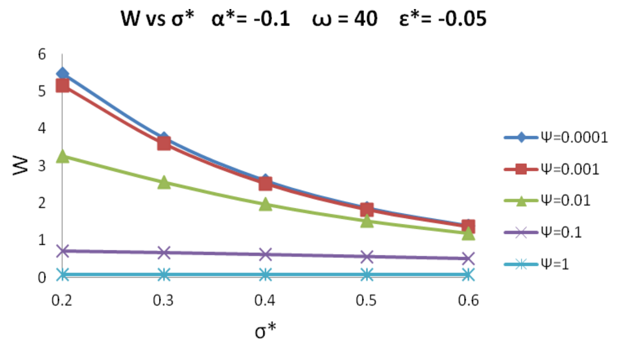

Figure 8. W versus σ^* for ψ.

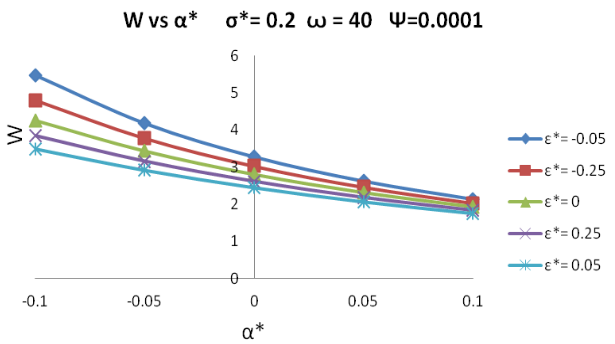

Figure 9. W versus α^* for ε^*.

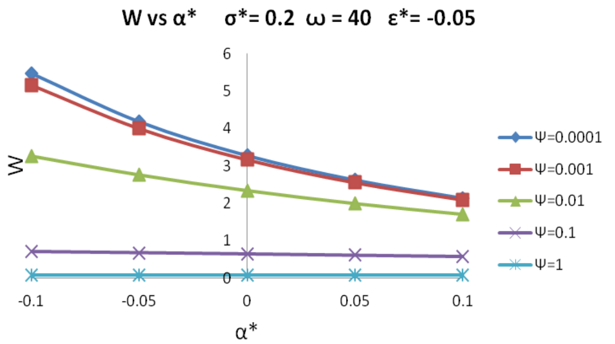

Figure10 W versus α^* for ψ.

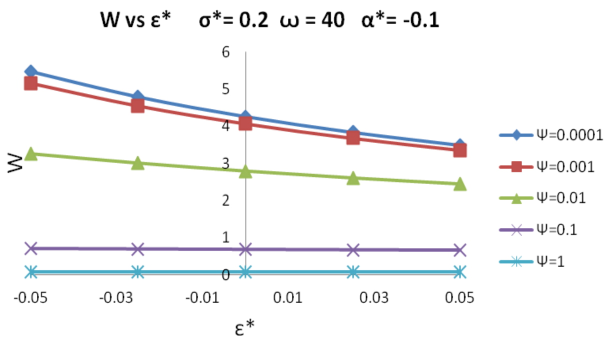

Figure11. W versus ε^* for ψ.

CONCLUSION

The present study recommends that the appropriate values of semi vertical angle and porosity may increase the performance of bearing, subsequently the porosity values are negligible and reach certain values of ψ. It has been also observed that roughness parameters and semi vertical angle decrease the load, while negatively skewed roughness and negative mean increase the load bearing capacity. Along with these lines, it very well can be said that the semi vertical angle and roughness must be thought of while structuring bearing arrangement for an industrial point of view.

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