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Short Communication

Axial pinch effect on the squeeze film action between curved circular plates

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The axial current-induced pinch effect on the action of the curved squeeze film between two circular plates, when the upper plate moves normal to itself and approaches the lower plate with uniform velocity, was studied. Expressions were obtained for the pressure distribution and the load-carrying capacity and a relationship between the time and the film thickness was obtained. It was found that increases in the pressure, the load capacity and the time of approach did not depend on the concavity or the convexity of the pads.

Introduction

Elco and Hughes [1] initiated a study on the effect of an axial current-induced pinch on the characteristics of bearings with electrically conducting fluids as lubricants and others [2, 3] continued this work. Gupta and Sinha [4] studied the effect of axial current-induced pinch on the squeeze film between porous annular discs. All the investigations show that the axial current-induced pinch effect increases the pressure distribution and thereby the load capacity and that a non-zero load can be sustained even when there is no flow.

Murti [5] introduced a new exponential function to describe the curved film between two circular plates. He observed that the concavity of the pad increases the load capacity.

This note reports a study of the axial current-induced pinch effect on the configuration proposed by Murti. Expressions are obtained for the pressure distribution and load capacity. A relationship between the time and the film thickness is also obtained.

Analysis

The upper plate moves with a uniform velocity $\dot{h}_0$ normal to itself towards the lower plate which is fixed. The film thickness is taken as [5]

$$h = h_0\, e^{-\beta r^2} \tag{1}$$

which in dimensionless form is

$$h/h_0 = e^{-\bar{\beta} R^2} \tag{2}$$

where

$$R^2 = r^2/a^2$$

Application of a potential between the conducting plates produces an axial current density J_z between them. J_z gives rise to an azimuthal magnetic induction B_θ. Interaction between J_z and B_θ provides a radial body force proportional to $J_z B_\theta$ which results in the pinch effect. Following the usual assumptions of hydromagnetic lubrication, the applicable governing equation as deduced from ref. 4 (eqn. (13)) is

$$\frac{1}{r}\frac{\mathrm{d}}{\mathrm{d}r}\left\{h^3\left(r\frac{\mathrm{d}p}{\mathrm{d}r} + cr^2\right)\right\} = 12\eta\dot{h}_0 \, . \tag{3}$$

Solving this equation under the boundary conditions that $\mathrm{d}p/\mathrm{d}r = 0$ at $r = 0$ and $p = 0$ at $r = a$ and after substituting for h from eqn. (1), the dimensionless pressure in the film region is obtained as

$$P = \frac{ph_0^3}{a^2\eta\dot{h}_0} = (1 - R^2)\frac{ch_0^3}{2\eta\dot{h}_0} + \frac{e^{3\bar{\beta}R^2} - e^{3\bar{\beta}}}{\bar{\beta}} \tag{4}$$

The dimensionless load capacity is

$$\bar{W} = \frac{Wh_0^3}{2\pi\eta|\dot{h}_0|a^4} = -\frac{ch_0^3}{8\eta\dot{h}_0} - \frac{e^{3\bar{\beta}}(1 - 3\bar{\beta}) - 1}{6\bar{\beta}^2} \tag{5}$$

The time for a reduction in film thickness from h_{01} to h_{02} is

$$\Delta t = \frac{2\pi\eta a^4}{W - \pi ca^4/4}\,\frac{1}{2}\left(\frac{1}{h_{02}^2} - \frac{1}{h_{01}^2}\right)\left(\bar{W} + \frac{ch_0^3}{8\eta\dot{h}_0}\right) \tag{6}$$

Results and discussion

When $c = 0$, eqns. (4) - (6) agree with those of Murti [5]. Equations (4) and (5) show that the pressure and the load capacity are increased owing to the pinch effect by the quantities $(1/2)(1 - R^2)ca^2$ and $\pi ca^4/4$, respectively. Equation (6) shows that the time of approach is increased by the pinch effect and that it is equivalent to the corresponding non-magnetic case with a load $W - \pi ca^4/4$. From eqn. (5), when there is no flow, *i.e.* $\dot{h}_0 = 0$, a load equal to $\pi ca^4/4$ is sustained by the bearing. Increases in the pressure, the load capacity and the time of approach do not depend on the concavity or the convexity of the pads because they are independent of the curvature parameter β.

Nomenclature

- a — the radius of each of the plates
- c — $\mu_e I^2/2\pi^2 a^4$, the current parameter
- h — the film thickness at radius r

h_0 the central film thickness at $r = 0$
$\dot{h}_0$ dh_0/dt
h_{01}, h_{02} the initial and final central film thicknesses
I the total current
p the pressure in physical units
P the dimensionless pressure
r the radial coordinate
R $(r^2/a^2)^{1/2}$
t time
Δt the time taken for a reduction in the central film thickness from h_{01} to h_{02}
W the load capacity in physical units
$\bar{W}$ the dimensionless load capacity
z the axial coordinate
$\underline{\beta}$ the curvature parameter
β $\underline{\beta}a^2$, the dimensionless curvature parameter
η the viscosity of the fluid
μ_e the magnetic permeability of the fluid

References

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