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Analysis of Load Carrying in Squeeze film in a Long Elliptical Bearing Operating with Ferro Fluid

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ABSTRACT:
In the present paper, a theoretical study of squeeze film behavior in an infinitely long journal elliptical bearing operating with ferro-fluid is presented. Jenkins Model with uniform strength of magnetic field is applied. Expressions for pressure and load carrying capacity are obtained. Results are compared with the circular bearing.

I. INTRODUCTION

The term magnetic liquid (or ferrofluid) does not refer to an intrinsic ferromagnetic liquid but refers to a stable colloidal suspension of small particles of ferromagnetic materials in a carrier fluid. such suspensions behave like any liquid and act as a ferromagnetic material. For the purpose of ensuring colloidal stability, a surfactant, such as oleic acid, is usually introduced into the suspension to create, around each single particle, a coating layer to prevent the agglomeration of the particles through magnetic and molecular attraction by keeping the distance between them sufficiently large. When a magnetic field is applied to the Ferro fluid, each particle experiences a force that depends on the magnetization of the magnetic material of the particles and on the strength of the applied field.

Ferro fluids were prepared during the last decade and studied first by Neuringer and Rosenweig [1]. Tarapov[2] studied magnetic fluid lubrication of cylindrical bearing. Walker and Buckmaster[3] considered a thrust bearing, while Tipei[4] derived a pressure differential equation for magnetic fluid lubrication and applied it to study short bearings. They found that a ferrofluid lubricant increased the pressure as well as load capacity of the bearings, improved bearing stability and stiffness, and reduced wear, noise and maintenance costs. Chi et al[5] theoretically and experimentally studied a three pad Journal bearing lubricated with a ferrofluid. All the above investigations used the Neuringer and Rosenweig [1] for the lubricant flow.

Sinha [6] analysed ferrofluid lubrication of cylindrical rollers with cavitation and Shukla and kumar[7] derived an equation for ferrofluid lubrication, both using the Shilomis model [8] for lubricant flow. They found that Brownian motion of the liquid together with rotation of the magnetic moments within the particles produced rotational viscosity which supported more load.

Ram and Verma [9] studied a porous inclined slider bearing lubricated with a ferrofluid flowing as per the Jenkins model [10]. Using a simplification of Maugin[11] that

$$\overline{M} = \overline{\mu}.\overline{H} \ .$$

The above model is more realistic than the Neuringer and Rosenweig [1] model because of its considerqation of the bearing material constant, which measures the angular momentum of the fluid per unit mass and per unit field strength.

II. NON CIRCULAR BEARINGS

Hydrodynamic journal bearings have been widely used to support high-speed rotating machinery, such as turbines, compressors and pumps. In such high speed machinery, there is every possibility for the onset of whirl or instability; therefore, to overcome the instability noncircular bearings are widely used. Among the several configurations of non-circular bearings, elliptical bearings are popular because of their simple structure and relatively low manufacturing cost [11]. Therefore, it is an important engineering problem to improve the operating characteristics of elliptical bearings in the high speed operating conditions for enhancing the quality of rotating machinery. The physical configuration of an elliptical hydrodynamic bearing is shown in the figure-1. The film thickness is expressed as

$$h = C_V + e \cos\theta + (C_H - C_V) \sin^2(\theta + \emptyset)$$

Where e = Eccentricity, $\emptyset$ = Attitude angle, θ = Circumferential angle of the bearing , C_H = Horizontal clearance , C_V = Vertical clearance.

In the present analysis , our aim is to study and compare ferrofluid squeeze film behavior in a long elliptical bearing using the flow models of Jenkins with uniform magnetic field.

III. ANALYSIS AND SOLUTION

Fig 1 represents the physical configuration of the squeeze film elliptical bearing, with journal of radius R inside a bearing and the gap h between them is filled with a ferrofluid under an external magnetic field of strength H. The origin 'O' on the circumference and the Z- axis perpendicular to it. It is assumed that it is infinitely long along its axial direction, with length L. The film thickness 'h' is taken as

$$h = 1 + \epsilon \cos\theta - m + m \sin^2(\theta + \emptyset)$$

where $\theta = \frac{x}{R}$ ------------------ (1)

Where ϵ is the eccentricity ratio and m is the ellipticity ratio.

Jenkins model , Uniform H

When the lubricant flows as per Jenkins model and H is uniform, the equation giving the film pressure 'P' [9-11]

$$\frac{d}{dx}\left\{\frac{h^3}{1-\frac{\rho\alpha^2\bar{\mu}H}{2\eta}}\frac{dp}{dx}\right\} = 12\,\eta\,\dot{h} \qquad \text{--------- (2)}$$

Where 'ρ' is the fluid density, α^2 is the material constant, $\bar{\mu}$ is the magnetic susceptibility, η is the fluid viscosity and

$$\bar{h} = \frac{dh}{dt} \qquad \text{--------- (3)}$$

Using equation (1) and the dimensionless quantities.

$$\bar{h} = \frac{h}{c},\ \beta = \frac{\rho\alpha^2\bar{\mu}H}{2\eta},\ \bar{p} = \frac{c^2 p}{\eta R^2 \bar{\epsilon}},\ \text{where } \bar{\epsilon} = \frac{d\epsilon}{dt} \qquad \text{-------- (4)}$$

Equation (2) transforms to

$$\frac{d}{d\theta}\left\{\bar{h}^3\frac{d\bar{p}}{d\theta}\right\} = 12\,(1-\beta)\cos\theta \qquad \text{---------(5)}$$

Solving equation (5) under boundary conditions

$$\frac{d\bar{p}}{d\theta} = 0,\ \text{when } \theta = \pi,\ \bar{p}(0) = 0 \qquad \text{---(6)}$$

Which ensure that $\bar{p}$ is maximum when $\theta = \pi$, the dimensionless pressure is

$$\bar{p} = \frac{6(1-\beta)}{\epsilon}\int_0^{\pi}\frac{1}{\bar{h}^2}\,d\theta \qquad \text{----------------(7)}$$

The load capacity W can be represented as

$$W = \left| LR\int_0^{2\pi} P\cos\theta\, d\theta \right| \qquad \text{- (8)}$$

IV. RESULTS AND DISCUSSION

The following are the design parameters used in the present work.

(i) Eccentricity ratio (ε) = 0.3, 0.4, 0.5, 0.6; (ii) Ellipcity Ratio (m) = 0, 0.05, 0.1 and 0.2 (m=0, represents Circular Bearing model) and (iii) Material Constant (β) = 0.3, 0.4, 0.5, 0.6.

From Fig 2 to 4 represent the dimension less pressure $\bar{p}$ verses bearing circumferential angle at various parameters like eccentricity ratio(ε) , ellipcity ratio (m) and Material Constant (β) of elliptical bearings operating with ferro- fluids. It is observed that eccentricity ratio increases the squeeze film pressure due to the narrow gap between bush and bearing. Similarly, Ellipticity ratio also increases the bearing pressure but as the material constant increases the squeeze film decreases due to the increase in the strength of the magnetic field.

Fig 5 gives the squeeze load verses bearing material constant β at different Eccentricity ratios for circular bearing. Figure-6 represents the squeeze load verses bearing material constant β at different ellipticity ratios. It is observed that load carrying capacity increses with the increse in eccentricity ration and ellipcity ration, but it decreases with the increase in the material constant.

V. CONCLUSIONS

Ferro-fluid squeeze film behavior in long journal elliptical bearing is studied using Jenkins model. Load carrying capacity of the elliptical bearing is more than the circular bearing. Bearing material constant decreases the load carrying capacity.

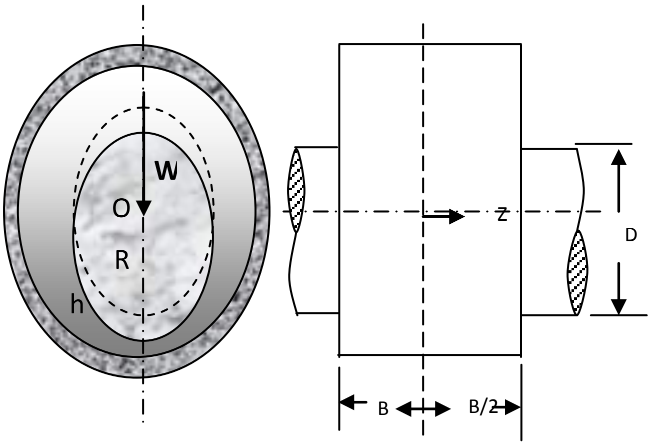

Fig 1: Physical configuration of Elliptical Squeeze film Bearing

R = Shaft Radius
B = Length of the Bearing
C_H = Horizontal Clearance
C_V = Vertical Clearance
O_B = Bearing Center
O_J = Journal Center
e = Eccentricity
h = Fluid Film Thickness.

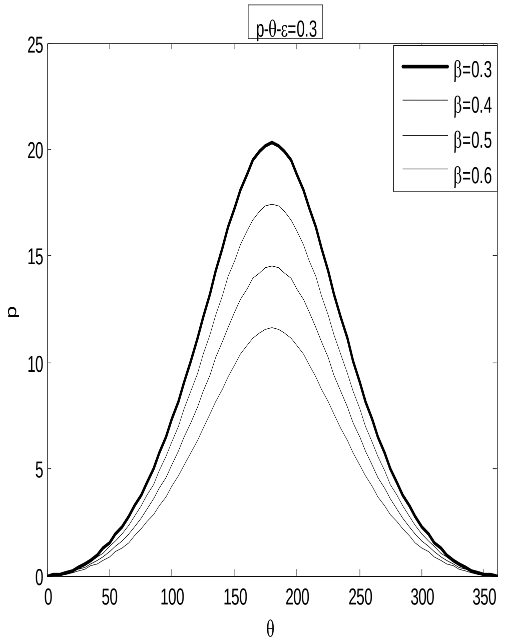

Fig 2: Squeeze film pressure vs Bearing circumferencial angle at constant Eccentricity ratio and Preload.

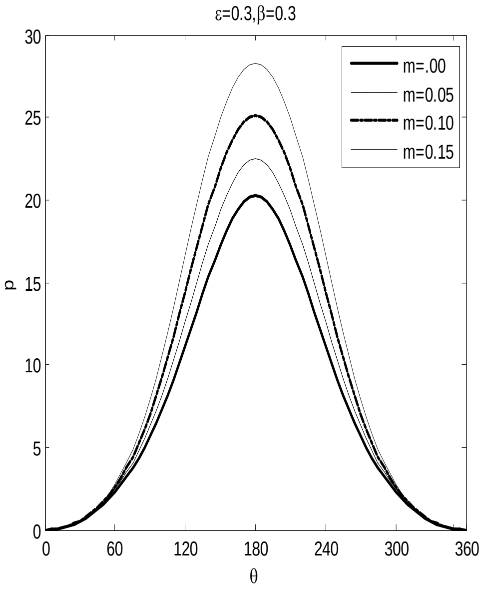

Fig 3: Squeeze film pressure vs Bearing circumferencial angle at constant Eccentricity ratio and Material constant β.

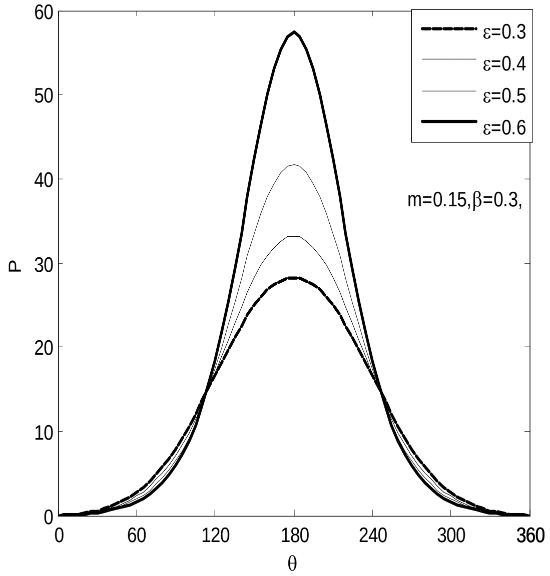

Fig 4: Squeeze film pressure vs Bearing circumferencial angle at constant Ellipticity ratio and Material constant β.

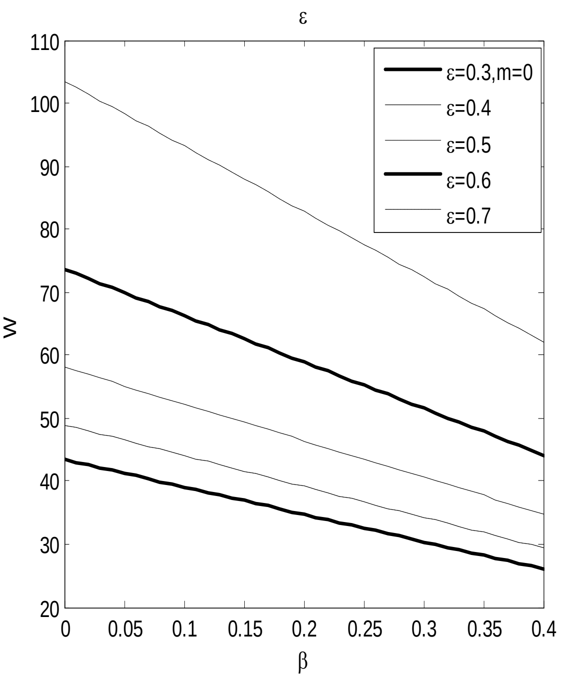

Fig 5: Squeeze Load vs Bearing Material Constant β at different Eccentricity ratios.

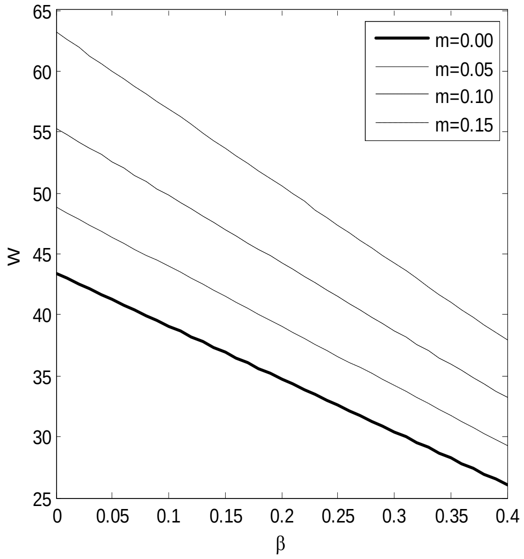

Fig 6: Squeeze Load vs Bearing Material Constant β at different Ellipticity ratios.

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