THEORETICAL ANALYSIS OF DOUBLE FILM BEARINGS

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ABSTRACT

This paper is concerned with a theoretical analysis of two types of double film bearings; namely, circular-circular and rectangular-rectangular, lubricated with incompressible fluid.
In order to have a clear understanding of the performance characteristics of these two types of double film bearings, the performance characteristics that include load carrying capacity, flow rate, power, and stiffness of single film circular and rectangular bearing is presented.
The results revealed that, the given mathematical model can be used in the design of a double film bearings.
A comparison between the performance characteristics of circular-circular and rectangular-rectangular double film bearings are presented, assuming that they have the same area and the same supply pressure.

INTRODUCTION

Fluid film lubrication is defined as the art of reducing the friction developed between two surfaces moving relative to each other, to overcome the effect of stick-slip phenomina, increasing the life of machine tool slideways and improving the accuracy and surface finish of workpieces. It may be a single film or double film.
Previous work showed that many investigations have been made on single film bearings[1 - 6] whereas , the analysis of double film bearings received very little attention. Salem[6] has analysed a double film self aligning pressurized air bearing. However, he has not taken into consideration the effect of external hydraulic resistance on the bearing performance.
It is the purpose of this paper to analyse two types of double film bearings namely, rectangular-rectangular and circular-circular.

THEORETICAL ANALYSIS

To have a better understanding of the performance characteristics of double film bearings it is necessary to review the performance characteristics of

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Load carrying capacity

$$L = P_1 \cdot \pi r_2^2 \frac{1 - (r_1/r_2)^2}{2 \text{ Ln } r_2/r_1} = P_1 \cdot A_c \cdot G_c \qquad (9)$$

$$A_c = \pi r_2^2 = \text{bearing area}$$

$$G_c = \frac{1 - (r_1/r_2)^2}{2 \text{ Ln } r_2/r_1} = \text{shape factor}$$

Stiffness

$$\lambda = \frac{3 P_s}{h} \; A_c \cdot G_c \cdot \frac{R_b \cdot R_1}{(R_1 + R_b)^2} \qquad (10)$$

where

$$R_b = \frac{6 \mu \text{ Ln } r_2/r_1}{\pi h^3} \qquad (11)$$

DOUBLE FILM BEARING

Figure (1-a) shows a double-film bearing circuit.
The bearings are fed with incompressible fluid at a supply pressure (P_s) through an external capillary resistance (R). The flow through the lower film resistqnce (R_{b1}) is Q_1 , while Q_2 is the flow through both the capillary resistance (R_2) and the upper film resistance (R_{b2}).
Figure (1-b) is an anology of Ohm's law which represents the flow through a double-film bearing. From this figure, the following relations can be written.

$$Q = \frac{P_s - P_1}{R_1} \qquad (12)$$

$$Q_1 = \frac{P_1}{R_{b1}} \qquad (13)$$

$$Q_2 = \frac{P_1 - P_2}{R_2} \qquad (14)$$

$$Q_2 = \frac{P_2}{R_{b2}} \qquad (15)$$

From (14) , (15)

$$P_2 / P_1 = \frac{R_{b2}}{R_2 + R_{b2}} \qquad (16)$$

and from (12) , (13) , (15) and (16)

$$P_1/P_s = \frac{R_{b1} \; (R_{b2} + R_2)}{R_{b1} \cdot R_{b2} + R_{b1} (R_1 + R_2) + R_1 \cdot R_{b2} + R_1 \cdot R_2} \qquad (17)$$

$$\lambda_{D.F} = \frac{3P_s.A_r.G_r}{h.Y}\left[\frac{R_{b1}.R_{b2}.R_2(R_2+R_{b2})(R_{b1}.R_1+R_1R_{b2}+R_1R_2)}{(R_2+R_{b2})^2(R_{b1}.R_1+R_1.R_{b2}+R_1R_2)+Y(R_2R_{b2})}\right] \quad (25)$$

CIRCULAR-CIRCULAR DOUBLE FILM BEARING

The above procedure that has been followed to analyse the performance characteristics of the rectangular-rectangular double film bearing can be followed to obtain the performance characteristics for circular-circular.

The following equations for the load carrying capacity, flow rate and stiffness are written respectively :-

LOAD CARRYING CAPACITY

$$(L_{D.F})_c = W + P_s.A_c.G_c.\frac{(2\,R_{b1}.R_{b2} + R_{b1}.R_2)}{Y} \quad (26)$$

FLOW RATE

$$(Q_{D,F})_c = \frac{\pi\,P_s}{6\,\mu\,\mathrm{Ln}\,r_2/r_1}\,.\,\frac{R_{b1}(R_2+R_{b2})\,h_1^3 + R_{b1}R_{b2}\,h_2^3}{Y} \quad (27)$$

STIFFNESS

$$(\lambda_{D.F})_c = \frac{3\,P_sA_cG_c}{h.Y}\,.\,\frac{R_{b1}R_{b2}R_2(R_2+R_{b2})(R_{b1}R_1+R_1R_{b2}+R_1R_2)}{\left[(R_2+R_{b2})^2(R_{b1}R_1+R_1R_{b2}+R_1R_2)+Y\,R_2R_{b2}\right]} \quad (28)$$

DISCUSSION OF RESULTS

The theoretical results for circular-circular and rectangular-rectangular double film bearings and a comparison between these types of bearings are presented. The discussion of the performance characteristics are carried out under the condition of equal film thickness [6].

Figure (2) shows the relation between the load carrying capacity and film thickness for two types of the bearings. It is clear that the load carrying capacity increases as the film thickness decreases. It can also be seen that the load carrying capacity of rectangular-rectangular bearing is higher than that of the circular-circular double film bearing. That occurs because the effective area of rectangular bearing is larger than that for the circular bearing. Moreover, it is clear that the difference in the load carrying capacity increases as the film thickness decreases.

Figure (3) shows the effect of the film thickness for the double film bearing on the stiffness. It can be noticed that the stiffness of circular-circular is higher than that for rectangular-rectangular double film bearings. The stiffness, for both types of bearings, increases with an increase in the film thickness, reaching a maximum value then decreases with further increase in film thickness. This may happen because the effect of the capillary resistant that works as a compensating element.

Figure (4) shows the relation between the total flow rate and film thickness of these two types of double film bearings.

R_2 = The capillary resistance of the floating pad.
R_{b2} = Resistance of upper film bearing.
λ_1 = stiffness of lower film.
λ_2 = stiffness of upper film.
$\lambda_{D.F}$ = stiffness of double film bearing.
μ = viscosity.

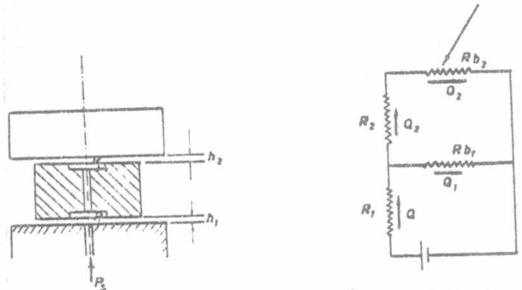

Fig.(1_a) Fig.(1_b)

Double film bearing circuit

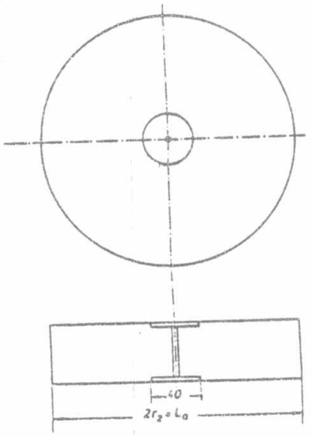

Fig.(2_a) Circular recessed bearing pad.

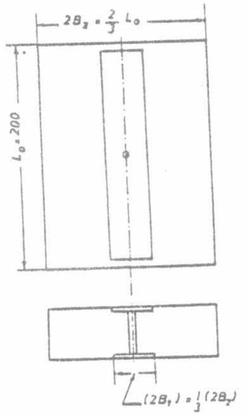

Fig.(2_b) Rectangular recessed bearing pad.