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EXPERIMENTAL STUDIES OF PRESSURE DISTRIBUTION IN TILTING PAD THRUST BEARING WITH SINGLE CONTINUOUS SURFACE PROFILED SECTOR SHAPED PADS

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Abstract – The effect of the film shape on the load carrying capacity of a hydrodynamically lubricated bearing has not been considered an important factor in the past. Flat faced tapered bearing and the Raileigh's step bearing of constant film thickness have been the primary forms of film shapes for slider bearing studies and design data developments. There are indications in the literature that surface profiling/texturing can have significant and positive influence on the load carrying capacity of hydrodynamic pad thrust bearings. Therefore, the objective of this paper is to compare the experimental results of pressure temperature distributions in slider bearing with flat surface and with different single continuous surface profiled (Cycloidal,Catenoidal,Quadratic) sector shaped pads. Pressure results presented in this paper can provide a platform for validation of theoretical models. An experimental study has been performed to investigate the influence of single continuous surface profiled sector shaped pads in tilting pad thrust bearing. It has been found that with cycloidal shaped surface profiled sector shaped pads the pressure generated within fluid film is enhanced which in turn causes enhancement in load bearing capacity of hydrodynamic bearing.

***Keywords –** Film shape, cycloidal surface profiled pads, sector shaped pads, load bearing capacity.*

I. INTRODUCTION

Most of the research conducted in the past in the field of hydrodynamic lubrication of thrust bearings has focused on rectangular pads where the velocity of the runner always remains constant. However, the majority of thrust pads commonly used in practice are the sector-type pad with a variable velocity with respect to its radius. It is common practice to analyze a sector-type thrust bearing by finding its equivalent rectangular pad bearing and then using the available design data for sliders. However, to analyze the tilting pad thrust bearings, one should recognize the fact that the assumption of constant film thickness at the leading or the trailing edge as found in the case of a rectangular pad is not true for the sector-type pad. Moreover, the film thickness distribution and the location of the pivot in the case of a sector-shaped pad are mutually dependent upon each other which make the analysis procedure more complicated.

Due to early industrial necessity for bearings, many thrust pad bearings were theoretically studied in the 1950s by investigators for design and development of good performing bearings. It has been observed that in the past many researchers [1–6] have analyzed thrust bearings having various surface profiles on the pads. Charnes et al. [1] have reported higher load carrying capacity with stepped pad thrust bearing in comparison to the conventional plane inclined thrust bearing. Authors performed adiabatic analysis and have reported reduction in temperature with stepped pad thrust bearing in comparison to plane thrust bearing. Abramovitz [2] studied the effects of pad curvatures on thrust bearing performances. Bagci and Singh [5] and Gethin [6] have reported that the film shapes have considerable influence on the bearing performances. Anant Pal singh [7] has investigated effects of continuous circumferential surface profiles on the performance characteristics of a sector-type thrust bearing. A computer-aided finite difference numerical solution of the Reynolds equation in polar form is used to determine pressure distributions for an optimum inclination of a sector pad. He reported that As compared with conventional taper fluid film shape, new surface profile (cycloidal, catenoidal, exponential, polynomial) are found to offer a significant increase in the load-carrying capacity as well as a considerable reduction in the coefficient of friction.

Hargreaves [8] has studied theoretically and experimentally the effects of surface waviness over the load carrying capacity of finite slider bearing. The author recorded enhanced load carrying capacity in the presence of surface waviness on the stationary pad. Das [9], Naduvinamani et al. [10], and Dobrica and Fillon [11] have reported that the shape of the converging wedge influences the bearing performance significantly. Researchers [10] have investigated infinitely wide rough slider bearings isothermally for exponential, hyperbolic, and secant film shapes using couple stress fluids. The authors have reported that the increase in pressure is more for the exponential and hyperbolic sliders. Moreover, investigators [11] have studied the THD behavior of a slider bearing having a pocket and reported that the maximum pressure is higher for the pocketed bearing in comparison to plane slider bearing. Andharia et al. [12] studied the influence of film shape on the performance of longitudinally rough, infinitely wide slider bearing for isothermal conditions. Andharia et al. [13] have reported better load carrying capacity with exponential, secant, and hyperbolic film shapes in comparison to the inclined plane film shape.

II. DETAILS OF EXPERIMENTATIONS:

2.1 Experimental test rig:

Following mentioned are the details and schematic representation of experimental test setup, which is available in Walchand College of Engineering, Sangli.

This experimental setup of tilting pad thrust bearing has been used to study the performance characteristics of bearing for different loading conditions and speeds.

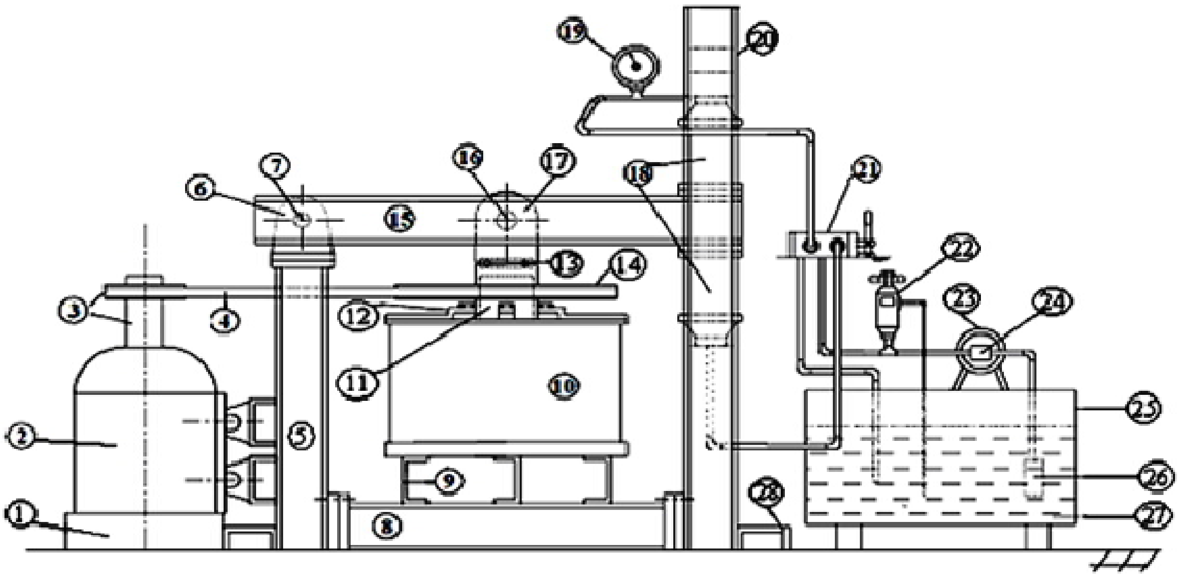

Fig. 1: Experimental test setup

No	Name	No	Name
1	Motor Base	15	Loading lever
2	Motor	16	Lever centre pin
3	Motor pulley and shaft	17	Loading piece
4	V belt	18	Hydraulic jack
5	Short column	19	Pressure gauge
6	Bracket to hinge lever	20	Long vertical column
7	Bracket pin	21	Direction control valve
8	Base of test rig	22	Pressure control valve
9	Bearing housing supports	23	Induction motor
10	Bearing housing	24	Reciprocating pump
11	Thrust bearing shaft	25	Oil tank
12	Radial supports with ball bearing for shaft	26	Strainer
13	Ball bearing	27	Hydraulic oil
14	Bearing pulley	28	C channel for support

.Table1: Specifications of experimental setup

Sr. No.	Parameter	Parameter value
1	Inside bearing diameter (D_1)	177 mm
2	Outside bearing diameter (D_2)	291mm
3	Number of pads (n)	8 nos
4	Mean diameter (D_m)	234 mm
5	Radial length of pad (L)	57 mm
6	Circumferential width of pad (B)	57 mm
7	Lubrication type	Flooded
8	Viscosity of lubricating oil ISO VG46 at 52°C, (μ)	0.023 Ns/m^2
9	Mechanical equivalent of heat of oil (J)	0.2 kg-m/J
11	Specific heat of lubricating oil	1674.72 J/kg°C
12	Specific weight of lubricating oil	858.08 g/m^3

2.2 Instrumentation:

Two performance parameters pressure and temperature are selected and attempts are made to measure fluid film pressure within the bearing for varying speed and loading conditions.

For pressure measurement strain gauge mounted on diaphragm is used. Considering the various parameters of strain gauge and diaphragm, diaphragms of various thicknesses are selected. The calibrations of these diaphragms along with strain gauges are done in laboratory with the help of dead weight pressure gauge. The material of diaphragm is spring steel .The strain gauge are of 350Ω and 2mm long. Figure 3 shows arrangement of strain gauge mounted diaphragm inside pad.

Tilting pad thrust bearings are widely used in pumps at different engineering fields so speeds of total 203 pump models which use tilting pad thrust bearing are collected from 4 different pump manufacturing companies as population. Then repetition of speed in selected population is calculated as frequency of that speed in the selected population. 480, 580, 817, 960 and 1152 rpm are the 5 selected test speeds for experiments. Thrust load points are selected as 1600, 3200, and 4800 to 3200 kg.For varying loads there is provision of beam operated by hydraulic power pack. This beam is used to apply load.

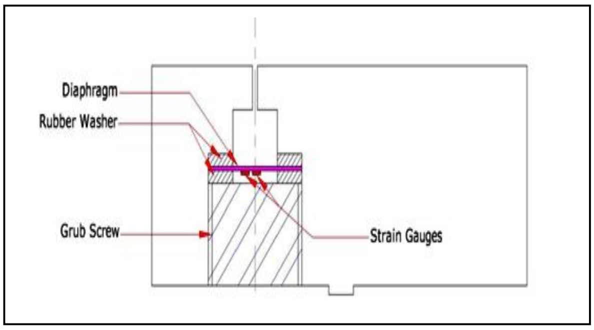

Fig. 2: Mounting of strain gauge diaphragm inside sector shaped pad.

Table 2: Experimental pressure locations

SR. No	PRESSURE LOCATIONS	CIRCUMFERENTIAL POSITION (IN %)	RADIAL POSITION (IN %)
1	P1	93	55
2	P2	50	75
3	P3	72	91

III. MACHINING OF CYCLOIDAL PROFILE OVER PAD SURFACE

Cycloidal, Catenoidal and Quadratic profiles are machined over sector shaped pad surface using VMC. A small program has been written for generating the required cutter path. The machining process for cutting the profile is performed with pad surfaces in the horizontal plane. The machined profile of cycloidal is verified by measuring the relevant dimensions using coordinate measuring machine (CMM).

IV. RESULTS:

Figures given below show experimental pressure distributions along the sliding direction for different single continuous surface profiles and plane surface profile on pads with different loading conditions and speeds.

Two types of graphs are shown below. Figures 3,4 represent experimental pressure distribution along the circumferential width of pad (along sliding direction) for constant speed, variable loading conditions and fixed surface profile.Whereas Figures5,6 represent experimental pressure distribution along the circumferential length of pad (along sliding direction) for fixed constant load and speed but for various profiles.

It is observed that cycloidal profile of pad generates about 24 to 25% more maximum pressure in bearing in comparison to conventional plane profile pad.

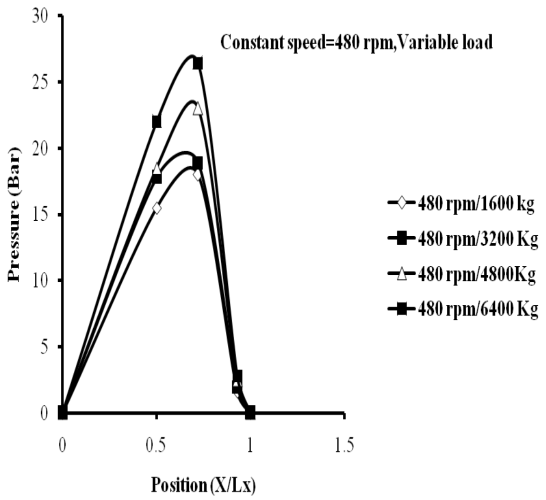

Fig. 3: Pressure variations for Cycloidal profile,480 rpm speed and variable loads

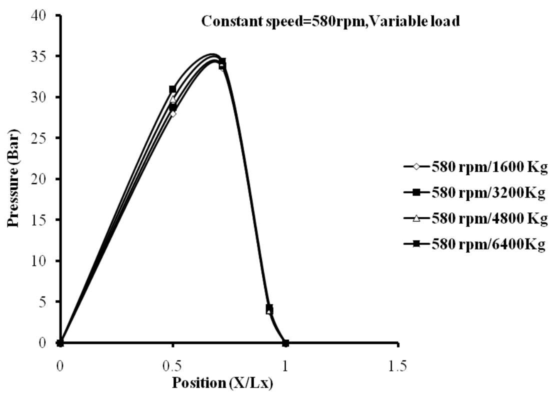

Fig 4: Pressure variations for Cycloidal profile,580 rpm speed and variable loads

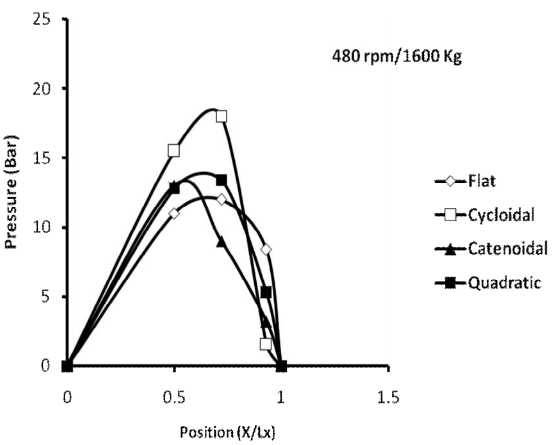

Fig. 5: Comparison of pressure distribution for various surface profiles with speed of 480 rpm and load 1600Kg.

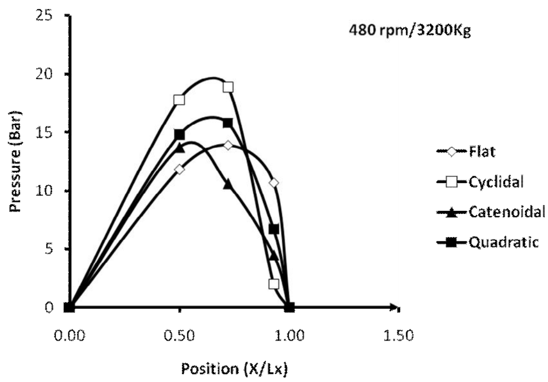

Fig. 6: Comparision of pressure distribution for various surface profiles with speed of 480 rpm and load 3200 Kg.

For remaining all loading and speed conditions graphs follow trend as that of given in above figures. With increase in speed and load pressure increases Experimental pressure distribution curves obtained with this study follows same trend as that of given in previous study by R. K. Sharma and Pandey [14]. pressure distribution curves of this study for validation purpose, it is observed that experimental pressure distribution curves obtained with this study follows same trend as that of given in previous paper [14].

V. CONCLUSION:

One-dimensional continuous fluid film shapes have considerable effects on the load-carrying capacity and friction power loss. The performance of the cycloidal shapes seems excellent for the bearing.

Also by the study it is found that oil tapping method is the most reliable and effective method of measuring temperature of fluid film

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