Study of Tilting Pad Thrust Bearing Characteristics with Bronze Pads

[1] Prashant Shelar, [2] Prof. A.K.Kale
Dept. of Mechanical Engineering, Walchand College of Engineering, Sangli.

***Abstract* -** Tilting Pad Thrust bearings are generally designed to transfer high and axial loads from the rotating shaft. These bearings are widely used in rotating machines such as Turbines, Compressors, Pumps, etc. because of their low friction, good load bearing characteristics and high damping characteristics. The surface above the Pads has a significant impact over the bearings life. Thus, previous literature indicates that profiles have significant factors which influence the load carrying capacity of bearing. Therefore, the objective of this paper is to study the performance parameters of a Bronze material with Catenoidal surface over the over the pad. Thus, an experimental study has been performed which finds out the Pressure and Temperature results which provides a validation of theoretical models.

***Keywords* -** bearings life, catenoidal surface, damping characteristics, load bearing capacity, low friction.

1. INTRODUCTION

In the era of technological development, there is need of more analysis over the bearing pad surface, compact size of bearing which influences to high load carrying capacity and decreasing Power consumption. Abramovitz [1] theoretically studied the effect of pad curvature on operating condition. He assumed convex type of surface over the pad and concluded that with the use of this surface, it would result in 10% increase in load carrying capacity as compared to flat pad. Thus, at early industrial development the study on bearing were theoretically made and hence it must be now be experimentally verified.

Many investigators have studied and analysed the process regarding the development of surface profile of pads. Anant Pal Singh [2] investigated performance parameters of sector shaped thrust bearing on the continuous surface profile. He used Computer Aided Finite difference numerical solution to determine pressure distributions of a sector pad. He found out that with the use of new surface profiles such as Cycloidal, Catenoidal and Quadratic, there is effective increase in load bearing capacity, decrease in power consumption and reduction in coefficient of friction. Bagci and Singh [3] studied the work of Anant Pal Singh and extended the work. He investigated the performance characteristics of bearing having Catenoidal, Polynomial, Exponential, Cycloidal and Truncated cycloidal film shapes. Dobrica and Filon [4] proposed a Thermohydrodynamic (THD) steady model and this model was applied to well-known geometry of a slider pocket bearing. He found out that peak pressure developed in the pad transfer toward the trailing edge. Hargreaves [5] presented both theoretical as well as experimental results of surface waviness on pad bearings of rectangular slider pads. He found out that surface waviness on the bearing pad increases the load bearing capacity. Sharma and Pandey [6] compared the experimental results of pressure distribution with various single continuous surface profiles of pads such as cycloidal, catenoidal, polynomial and plane pads. He showed that the Cycloidal profile of pad generates about 30 % more pressure than the flat pad. Naduvinamani [7] studied the combined effects of couple stresses and surface roughness on the performance characteristics with various film shapes such as cycloidal, plane, secant, hyperbolic and exponential. Glavatskih [8] described the method to improve temperature monitoring of fluid film bearings and showed that the proposed method improves sensitivity to thermal transients in convention bearing and temperature monitoring in the PTFE faced bearings. Abhijeet Patil [9] compared the experimental results of pressure distribution on various profiles of pad such as plane, cycloidal, catenoidal and quadratic. He found out that in cycloidal surface shaped sector pads, the pressure generated within fluid film increases which increases the load bearing capacity of hydrodynamic bearing.

2. BEARING MATERIAL

Bearing life mainly depends upon the choice of bearing material, so it is important to select the bearing material correctly to service conditions and operating mode. The coefficient of friction of Bronze alloy lies between 0.08-0.14.

The Bronze bearing provides Low coefficient of friction, Good wear behaviour, High compressive strength,Structural uniformity and Corrosion resistance.

3. MACHINING OF CATENOIDAL PROFILE OVER PAD SURFACE

The Catenoidal Profile equation [2] is given as,

$$h = h_0 \left(\cos h \left(\frac{1}{L} \cos h^{-1} \alpha\right) \varkappa\right) \quad \ldots\ldots.(1)$$

From the equation (1), the variation of thickness is calculated.The Catenoidal profile over the pad is manufactured by using a VMC machine. The surface variation is inMicrometres, so high accuracy is needed. In VMC machining, a set of program is generated which develops aProfile over the bearing pad surface. The developed catenoidal profile is then measured and verified using a Coordinate MeasuringMachine (CMM).

4.DETAILS OF EXPERIMENTATION

4.1 Experimental test rig:

Following mentioned is an Orthographic view, details of test rig and other specifications of test rig of an experimental setup available in Walchand College of Engineering, Sangli.

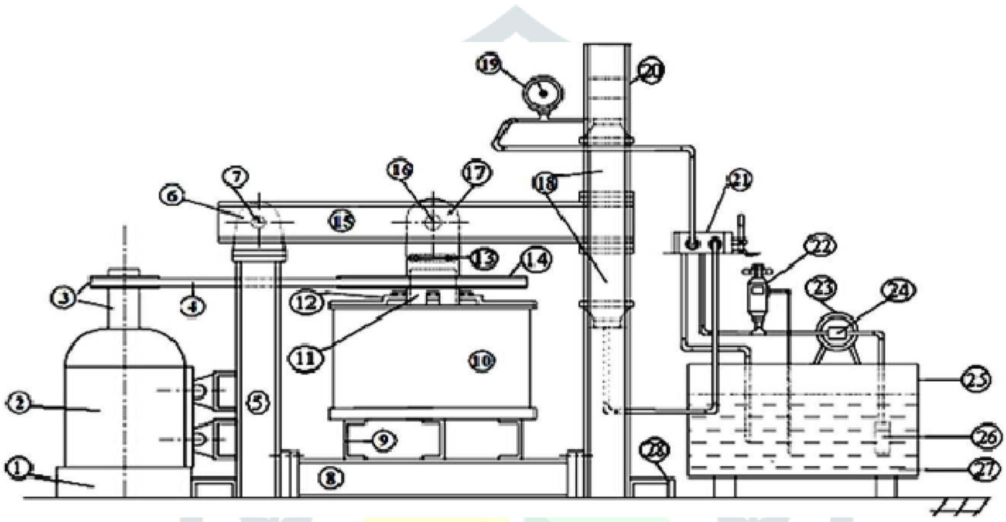


Figure 1 Experimental setup

Table 1 Details of Test Rig

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 valve
7	Bracket pin	21	Direction control valve
8	Base of Test rig	22	Pressure control valve
9	Bearing housing support	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

Table 2 Specifications of Test setup

Sr. No.	Parameter	Parameter Value
1	Inside bearing diameter (D_1)	177 mm
2	Outside bearing diameter (D_2)	291 mm

3	Number of pads (n)	8 nos.
4	Mean diameter (D_m)	234 mm
5	Radial length of pad	57 mm
6	Circumferential width of pad (B)	57 mm
7	Lubrication type	Flooded
8	Viscosity of oil	At 40°C -94 centistokes At 100°C-14.3 centistokes
9	Density at room temperature	865 kg/m^3

4.2 Instrumentation:

There are two performance parameters to be measured that are Pressure and Temperature. The sensors are specially selected and used to measure the respective readings. The methods for measuring the performance parameters are studied from previous literature surveys.

4.2.1 Pressure Measurement:

For Fluid Film Pressure measurement, Diaphragm method is used. Here, the strain gauge is mounted over the diaphragm. Strain gauge is of 350Ω and 2 mm long. The diaphragm is made of Brass material and of 2.10 mm, 2.20 mm and 2.30mm thickness. The pressure locations are selected from Abhijeet Patil [9]. The diaphragms are calibrated in laboratory with the help of Dead weight Pressure Gauge.

Table 3 Pressure Locations

Pressure Nos.	**Radial Position (in %)**	**Circumferential Position (in %)**
P1	55	93
P2	75	50
P3	91	72

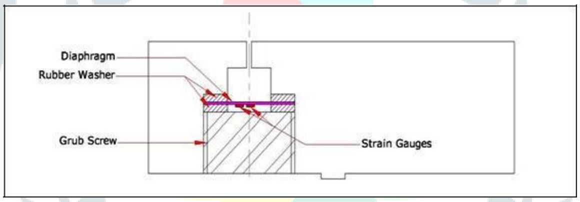


Figure 2 Diaphragm Method of strain gauge for Pressure gauge arrangement

Figure 3 Pressure gauge arrangement

4.2.2 Temperature Measurement:

By studying previous literatures, Temperature Grid Method is selected. Guidelines given by Glavatskih [8] are used for selecting proper temperature sensor. A T-type thermocouple (copper-constantan) sensor is selected which measures in the range of -200°C to 350°C and sensitivity is about 43µV/°C. This sensor is fitted in a slot of 3mm depth.

Table 4 Temperature Locations

Temperature Nos.	Radial Position (in %)	Circumferential Position (in %)
T1	50	75
T2	85	75

T3	85	85
T4	75	85
T5	50	50
T6	50	85
T7	75	50
T8	Sump Temp.	

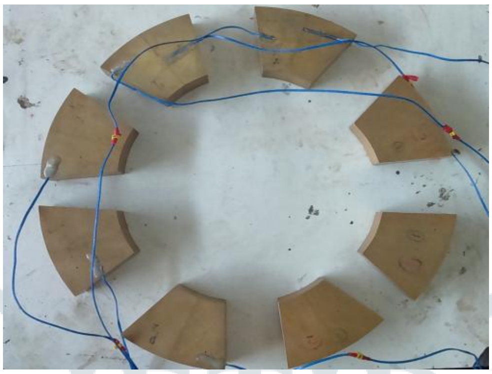


Figure 4 Arrangement of thermocouples over the pad

4.2.3 Speed, Load and Cooling rate Variation;

- Tilting pad thrust bearings are used in various engineering fields. They are widely used in 203 pumps. The speeds from this pump testing are selected.

- For Load variation, Hydraulic Jack is used. The load is varied by using a Direction Control Valve.

- The cooling rate affects the performance parameters of the system. A Flow control valve is used to vary the cooling rate from 0° to 90°. Depending upon the number of process parameters, L_8 Orthogonal Array is selected.

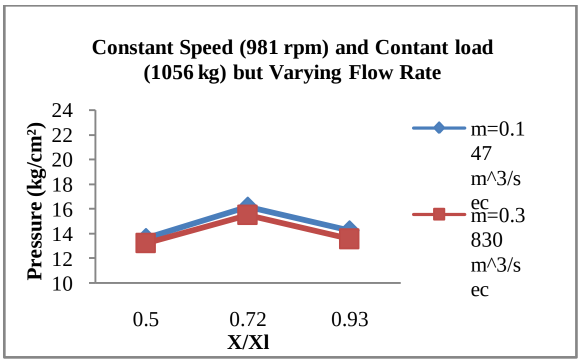
Table 5 Process parameters and their levels

Level	Speed (rpm)	Load (kg)	Cooling Flow Rate (m^3/sec)
1	981	1056	0.147
2	1152	3695	0.383

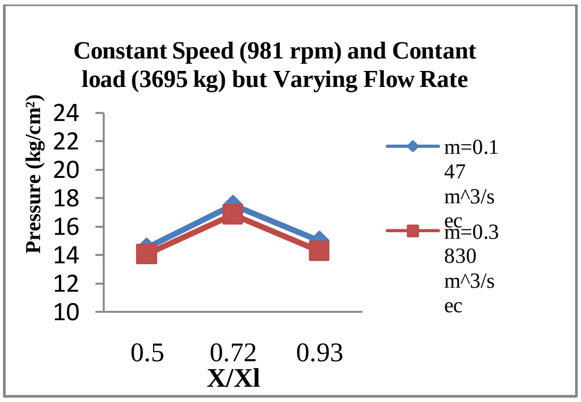
V. RESULTS

5.1 Pressure Readings

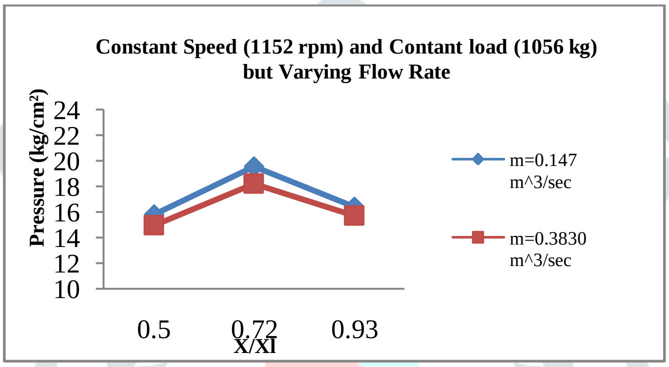
Figure given below shows the experimental pressure variation along circumferential direction (X/X_L). The experimental readings are tabulated to find out the maximum fluid pressure and maximum fluid temperature.



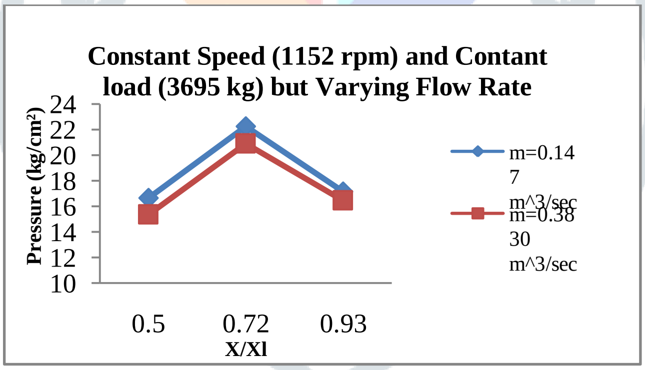
Graph 1 Speed (981 rpm) and Load (1056 rpm) with Water Flow Rate as 0.147 m³/sec and 0.383 m³/sec



Graph 2 Speed (981 rpm) and Load (3695 rpm) with Water Flow Rate as 0.147 m³/sec and 0.383m³/sec



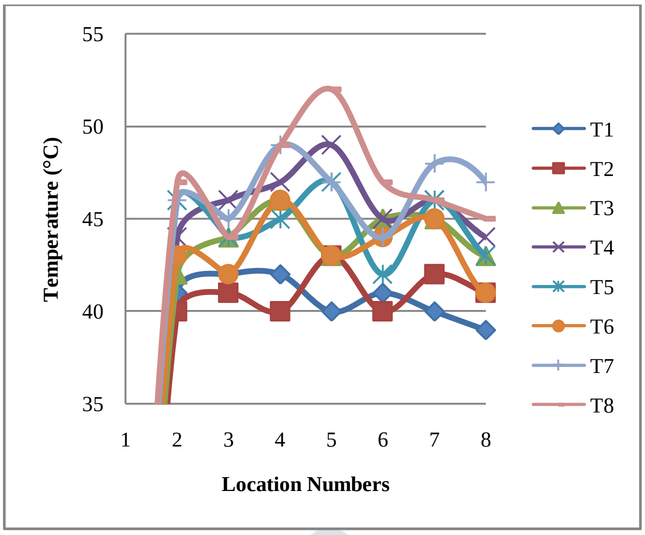
Graph 3 Speed (1152 rpm) and Load (1056 rpm) with Water Flow Rate as 0.147 m³/sec and 0.383m³/sec



Graph 4 Speed (1152 rpm) and Load (3695 rpm) with Water Flow Rate as 0.147 m³/sec and 0.383m³/sec

5.2 Temperature Readings

The Graph shows respective temperature variations at different locations over pad.



Graph 5 Temperature variation on different locations

VI. CONCLUSION:

The Bearing temperature increases with the increase of speed and load. The temperature grid method gives a good temperature over the pad. The maximum temperature is observed towards the trailing edge of pad.

The Fluid pressure increases with increase in thrust load. The experiment shows that the pressure shifts to trailing edge and the maximum pressure is observed towards the trailing edge of pad.

VII. REFERENCES:

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