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Pressure and Temperature Analysis of Tilted Pad Thrust Bearing Made of Teflon Material

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***Abstract*— Tilted pad thrust bearing are designed to transfer high axial loads from rotating shafts with minimum power loss. They are used in many different applications including: hydroelectric generators, turbines (steam, hydraulic, and gas), pumps, high speed blowers, electric motors, etc. Mostly pads made of two layers i.e. face layer made of TEFLON material and backing layer made of steel is used. Location where maximum pressure and temperature is generated in case of centrally pivoted tilted pad thrust bearing is known with the help of research paper published previously. This research paper throws light on verifying the maximum pressure and temperature results obtained previously in case of centrally pivoted tilted pad made of Teflon material.**

Keywords—tilted pad thrust bearing; teflon; pressure; temperature

I. INTRODUCTION

Tilting pad thrust bearing is an assembly of number of bearing pads, Runner, lubricating oil, cooling coils and casing. Runner of tilting pad thrust bearing is attached to rotating shaft whose thrust has to be taken care of. Bearing pads are individual plates which are free to tilt about their individual pivots located at center. Such bearings usually have three or more pads and enclosed in housing. For reliable operation in high-speed and medium to high load applications, tilting pad thrust bearings are the preferred choice, due to increased support area to accommodate axial loads and utility to adjust to varying conditions during operation. Bearing house is fully flooded with lubricating oil for lubrication.

II. WORKING OF TILTING PAD THRUST BEARING

As shown in Fig. 1, load carrying surfaces, that is runner and pads are completely separated by an oil film during operation, eliminating the risk of surface wear as long as a film of sufficient thickness is maintained. When the runner is stationary the pads will lie with their surfaces parallel to runner face. As rotating shaft is starts to rotate, runner rotates along with it to form an oil film between the pad and runner. Each Pad will tilt to the some angle which forms converging wedge. The flow constriction due to wedge acts as a bottleneck, which causes slowing down the flow rate across the pad from the inlet edge towards the trailing edge. The gradual reduction of oil volume in the gap leads to rise in pressure of the oil fill which lifts the shaft. As the pressure increases, viscous flow resistance prevents the oil from running out of the gap instantaneously and maintains oil film.

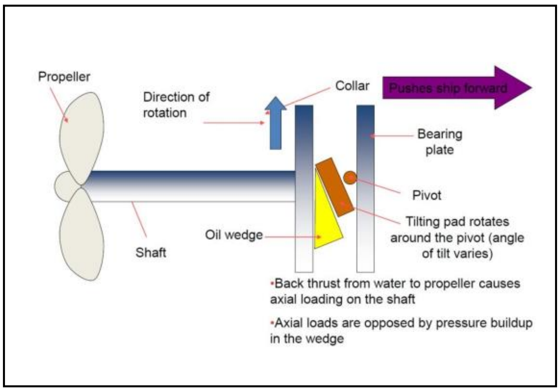

Fig. 1. Working of tilting pad thrust bearing

III. DESCRIPTION OF TEST RIG

It mainly consists of four distinct parts as follow:

A. Driving Motor Along With Driven Pulley

Driving motor is A.C induction motor. It is of capacity 7.5 HP with rated speed of 1430 rpm. But actually motor is running at 1484 rpm and runner rotates at 981 rpm.

B. Oil Sump And Runner Along With Driven Pulley

Oil sump is a casting body which acts as bearing and in this housing oil used is SAE 40. Inside this a pocket is fitted. This pocket is basically a circular shaped housing for the fitment of sector shaped pads. Pocket has eight equally placed radial slots and equally placed dowel pins. Each sector shaped pad has a corresponding radial projection and dowel holes. This ensures proper and firm placement of all pads circumferentially. In all there are eight pads and all pads can tilt about an axis passing through its geometric center along a radial slot. Theoretically it has been found that peak oil film pressure generated within oil film along the sliding direction is in the vicinity of pivot position, slightly shifted towards trailing edge of pad.

C. Hydraulic Power Pack, Loading Beam And Frame, Actuating Cylinders

Loading system consists of lever, loading piece, brackets, with their base plate. Hydraulic cylinder which is mounted on loading frame provides the load as per requirement through loading lever beam. Loading frame consists of two vertical I

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columns with two I beams welded together. Two plates welded at right bottom connect the frame to base or bearing seat by nuts and bolts. Similarly, bearing seat is connected to motor support. C channel is welded at bottom of frame. It is used to fix the frame to the foundation. Loading member is supported in brackets at one end and loaded by hydraulic cylinder at other end.

Lever must be rigid enough to transmit load without much deformation. The lever is made up of four I beams. Two beams are welded together. Hole is drilled at center and bracket end of lever. The loading piece is held in the center of lever with the help of a pin. Two brackets are bolted to base plate and base plate is bolted to the motor supporting frame. A common pin is passed through holes of bracket and lever. At other end of lever hydraulic cylinder is held between the horizontal I beam and lever. A cap on test bearing shaft holds the lower race of thrust ball bearing and the upper race is kept in loading piece cap.

D. Cooling System For Oil Cooling

Heat generation corresponds to loss of mechanical energy. Due to shear of lubricant film oil temperature rises. Bad effects of temperature rise in context of bearing performance are:

1. Temperature rise decreases viscosity of lubricating oil. This leads to minimum oil film thickness and wear occurs more easily. The viscosity of fluid is measure of its resistance to the motion.

2. Temperature rise changes the bearing clearance through thermal deformation of bearing metal, and thus affecting bearing performance.

3. Boundary lubrication performance of lubricant film will be suddenly and almost completely lost if oil film temperature exceeds a certain a critical temperature.

4. If oil temperature exceeds 150 ℃, the rate of oxidation of lubricating oil significantly increases.

Therefore, bearing setup has to be provided with cooling arrangement. Inside the bearing housing (oil sump), above the bearing pocket a copper tubing of 1 inch diameter is provided. Number of turns of this copper tubing surrounds the oil sump from inside. One end of this copper tubing is connected to a reservoir of water and other end is drained. The reservoir has been provided with constant water supply by the tap through flow control valve. The reservoir has water level indicator pipe on which scale has been marked. By adjusting valve, constant level of water in the reservoir can be maintained.

The cooling effect is provided by circulating water around the oil sump. For better and effective cooling, the rate of water flow is increased by placing reservoir tank at a height of 8 feet.

IV. CHARACTERISTICS OF TEFLON MATERIAL

1. Teflon against steel has one of the lowest coefficients of friction.

2. The load bearing capacity of the Teflon sheet is in the range of 130-140Kg/sq.cm.

3. The PV values are found to be in excess of 10,000. (Pressure (P) is the load placed on a bearing assembly. Velocity (V) is the surface speed at which an object, such as a shaft, moves. P-V is defined as the combination effect of the pressure of the object and the velocity at which it moves on the bearing surface.).

4. Service temperatures of -250 to +250°C are possible.

V. INSTRUMENTATION FOR PRESSURE MEASUREMENT

Diaphragms of various thickness are available. The material of diaphragm is Brass. Strain gauges are mounted on diaphragm for pressure measurement. The strain gauges are of 350 Ω and 2 mm long. The calibration of these diaphragms is done in laboratory with the help of dead weight pressure gauge. This instrument applies pressure in terms of bar and deflection of diaphragm is displayed in terms of mV on strain gauge indicator. Thickness of diaphragm on which strain gauges are mounted for pressure measurement is of 2.35 mm thickness and 16mm diameter. Reading of calibration is given in Graph 1.

Pressure changes over width and length of the bearing pad and the interest of study is in maximum fluid film pressure. Hence it is important to locate the appropriate location at which one can get representative data of pressure. Number of pressure tapings on pad may result in reduction in structural strength of bearing pad. Many authors carried out pressure measurement at various locations on tilting pad thrust bearing. From previous studies, locations for pressure measurement are given in Table 1. Pad along with pressure sensor mounting is shown in Fig 2. Radial position is measured from center of the bearing shaft. But angular position is measured from leading edge of the pad with center of pad circumference as center for angular measurement.

1. Pressure point 1:

Pressure point is selected towards leading edge side.

2. Pressure Point 2:

This point selected near trailing edge of the pad. This point is not only near the edge of the pad but also near the central arc of the pad. Maximum pressure varies near to this location.

3. Pressure Point 3:

This point is decided near trailing edge of the pad.

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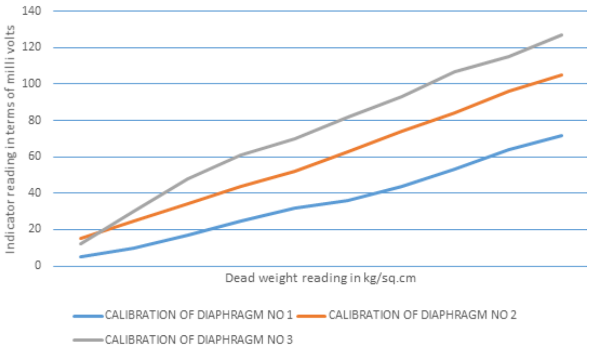
TABLE 1. PRESSURE SENSOR LOCATION

Sr. No.	Pressure Points	Angular position (degree)	Radial position(mm)
1	P1	11.25	95.74
2	P2	38.2	120.5
3	P3	34.3	105.76

Graph 1. Calibration of diaphragms



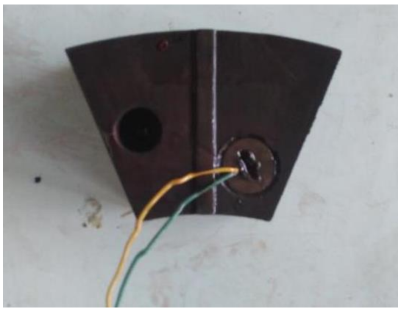


Fig. 2. Pad mounted with pressure sensor

VI. INSTRUMENTATION FOR TEMPERATURE MEASUREMENT

There are number of techniques available nowadays to predict the performance of hydrodynamic bearing such as operating film thickness monitoring, oil pressure monitoring, shaft vibration monitoring and temperature monitoring .The first three these are very difficult measure in practice and required the costly instruments, operating oil film thickness and oil film pressure measurement gives the results which are difficult to interpret.

Temperature monitoring is most effective and low cost technique as compared with above mentioned techniques. Temperature sensor in bearing should be at location where the maximum temperature occurs otherwise it is very poor indicator of overall performance of the bearing.

Out of the different temperature measuring methods available, temperature grid method is used for temperature sensor mounting. T type thermocouple (copper-constantan) sensor is selected. Type T, thermocouples are suitable for measurements in the range of -400 to 1200 ºC range. Thermocouples are arranged in a grid form on the pad as shown in the Fig 3. Thermocouples should be embedded in the pad material. It should be 1.5 mm to 2.5mm from face of pad. Temperature sensor locations are given in Table 2. 25/75 location represents 25 percent of width of pad and 75 percent of redial length of pad. Pad along with temperature sensor mounting is shown in Fig 3.

TABLE 2. TEMPERATURE SENSOR LOCATION

Temperature sensor No.	Location
1	25/75
2	75/75
3	25/25
4	75/25
5	50/50

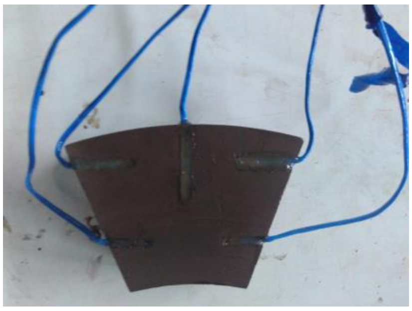


Fig. 3. Pad mounted with temperature sensor

VII. OBSERVATIONS

A. *Heat Gained By Water Or Frictional Loss*

TABLE 3. HEAT GAINED BY WATER OR FRICTIONAL LOSS

Particulars	Load (Kg)			
	175	**1055**	**1936**	**2641**
Water initial temperature(° C)	29.1	29.57	30	30.1
Water final temperature(° C)	34.1	36.8	39.8	42.4
Temperature gained by water(° C)	5	7.23	9.8	12.3
Oil initial temperature(° C)	32.4	33.2	30.7	30.9
Oil Final temperature(° C)	38.5	41.6	41.7	44
Temperature gained by oil(° C)	6.1	8.4	11	13.1
Mass flow rate of water m_w(Kg/sec)	3.25 * 10^-2	3.25 * 10^-2	3.25 * 10^-2	3.25 * 10^-2
Heat gained by water or Frictional Loss	0.68	0,98	1.33	1.67

Heat gained by water or Frictional Loss = $m_w * C_p *$ temperature gained by water

B. Pad Temperature At Different Locations On Pad

TABLE 4. PAD TEMPERATURE AT DIFFERENT LOCATIONS ON PAD

Particulars	Load (Kg)			
	175	1055	1936	2641
Initial pad temperature(^{o}C)	30	30	30	30
Final pad temperature(^{o}C) at location 1	42	43	46	49
Final pad temperature(^{o}C) at location 2	45	46	49	52
Final pad temperature(^{o}C) at location 3	42	42	45	48
Final pad temperature(^{o}C) at location 4	42	43	47	48
Final pad temperature(^{o}C) at location 5	44	45	49	52

C. Pressure Readings At Different Locations On Pad

TABLE 5. PRESSURE READINGS AT DIFFERENT LOCATIONS ON PAD

Pressure(bar) point location	Load (Kg)			
	175	1055	1936	2641
P1	2.659	4.1785	6.8376	9.1168
P2	6.3637	9.5456	14	17.1821
P3	3.7435	5.6153	8.4230	10.7620

VIII. CONCLUSIONS

A. By referring to observation A, it can be concluded that frictional loss increases as load on pad increases.

B. By referring to observation B, it can be concluded that temperature of pad increases as load on pad increases.

C. By referring to observation B, it can be said that maximum temperature of pad is observed at the same 75/75 location, where it was shown by other research works. So temperature result matches with previous research work for pad made of Teflon also.

D. By referring to observation C, it can be concluded that pressure carried by pad increases as load on pad increases.

E. Maximum pressure on pad is observed near 75/75 location.

F. Maximum pressure on pad is observed near to maximum temperature location.

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