

# A STUDY OF BEARING AND ITS TYPES

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## ABSTRACT

*A bearing is a machine element which supports another moving machine element (known as journal). It permits a relative motion between the contact surfaces of the members, while carrying the load. A little consideration will show that due to the relative motion between the contact surfaces, a certain amount of power is wasted in overcoming frictional resistance and if the rubbing surfaces are in direct contact, there will be rapid wear. In order to reduce frictional resistance and wear and in some cases to carry away the heat generated, a layer of fluid (known as lubricant) may be provided. The lubricant used to separate the journal and bearing is usually a mineral oil refined from petroleum, but vegetable oils, silicon oils, greases etc., may be used. Bearings can be split into two groups: Rolling bearings and Sliding bearings. Rolling bearings attempt to eliminate friction and sliding between surfaces in a junction by introducing interfaces such as balls or rollers which rotate or roll in as opposed to sliding. Examples of this type of bearings are axial ball and roller bearings.*

***Keywords: Machine element, Relative motion, Frictional resistance, Rubbing surfaces, Lubricant, Rolling bearing, Sliding bearing.***

## I. INTRODUCTION

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 behaviour 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. TYPES OF BEARINGS

The sliding contact bearings, according to the thickness of layer of the lubricant between the sliding surfaces are classified as follows:

### 2.1 Thick Film Bearings

The thick film bearings are those in which the working surfaces are completely separated from each other by the lubricant. Such type of bearings is also called as *hydrodynamic lubricated bearings*.

### 2.2 Thin Film Bearings

The thin film bearings are those in which, although lubricant is present; the working surfaces partially contact each other at least part of the time. Such type of bearings is also called *boundary lubricated bearings*.

### 2.3. Zero Film Bearings

The zero film bearings are those which operate without any lubricant present.

### 2.4. Hydrostatic or Externally Pressurized Lubricated Bearings

The hydrostatic bearings are those which can support steady loads without any relative motion between the journal and the bearing. This is achieved by forcing externally pressurized lubricant between the members.

## III. HYDRODYNAMIC LUBRICATED BEARINGS

In hydrodynamic lubricated bearings, there is a thick film of lubricant between the sliding surfaces. A little consideration will show that when the bearing is supplied with sufficient lubricant, a pressure is build up in the clearance space when the runner is rotating. The load can be supported by this fluid pressure without any actual contact between the sliding surfaces. The load carrying ability of a hydrodynamic bearing arises simply because a viscous fluid resists being pushed around. Under the proper conditions, this resistance to motion will develop a pressure distribution in the lubricant film that can support a useful load. The load supporting pressure in hydrodynamic bearings arises from either

1. The flow of a viscous fluid in a converging channel (known as wedge film lubrication), or
2. The resistance of a viscous fluid to being squeezed out from between approaching surfaces (known as squeeze film lubrication).

### 3.1 Assumptions in Hydrodynamic Lubricated Bearings

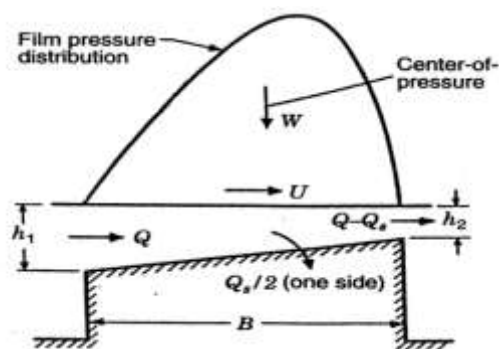
The following are the basic assumptions used in the theory of hydrodynamic lubricated bearings:

1. The lubricant obeys Newton's law of viscous flow.
2. The pressure is assumed to be constant throughout the film thickness.

3. The lubricant is assumed to be incompressible.
4. The viscosity is assumed to be constant throughout the film.
5. The flow is one dimensional, i.e. the side leakage is neglected.

Unlike rolling bearings which have a limited lifespan, principally due to their fatigue wear through the occurrence of high point loads at the contact between running elements and raceways, sliding bearings have, at least in theory, an indefinite operational lifespan. As long as an oil film of sufficient thickness is maintained and contamination is avoided, the bearing will continue to do its job indefinitely. However, more and more onerous demands are being placed on such bearings and their associated methods of lubrication in order to maximise performance in terms of efficiency and load carrying capacity. Examples are bearing of electrical generators and turbines. Sliding bearings are vulnerable to damage during rapid changes in operating parameters e.g. during the start-up process. During running, the faces of the bearing pads are separated from the shaft / collar by a thin oil film which provides a buffer in between the two surfaces (hydrodynamic lubrication). While preventing contact between the surfaces, this buffer also provides a means of cooling. However, when the machinery is stationary this film disappears and contact between the surfaces occurs. Therefore, at start-up, friction between the surfaces is inevitable until an adequate film is build up. This makes the bearing susceptible to surface damage. The use of a facing (surface coating) can help to limit this susceptibility.

The operating principle involved can be illustrated by considering a flat surface sliding over a tapered land. Motion of flat surface or thrust runner draws fluid such as lubricating oil into wedge shaped zone over the tapered land. Pumping into zone of reducing downstream clearance by shearing action of runner then pressurizes the oil. The change in separation  $h$  adjusts the inflow and outflow to provide the balance of integrated pressure over the bearing area with applied load. A group of tapered land thrust pads arranged with oil distribution grooves in annular configuration to form a complete thrust bearing.



**Fig 1: A Flat Surface Sliding Over a Tapered Land**  
**[Applied Tribology- Bearing Design and Lubrication]**

#### IV. THRUST BEARING TYPES

Six common types of thrust bearing are shown in Table 1. The first four are hydrodynamic, with their oil film pressure generated by internal pumping action. Hydrostatic bearing uses an external oil pump to supply the pressurised supporting film. Since parallel planes do not provide pumping action, Flat land bearings depend upon thermal expansion of oil, thermal warping, and irregularities of bearing surfaces, and possibly other effects. Characteristic application practices of these various types are as follows:

Typical unit load and sizes for each type are listed in Table 1. For the typical Babbitt surface used in most machinery thrust bearings, normal upper design load limits are commonly set in the range 250 - 500 Psi to allow for uncertainties and load transients. Failure loads in tests are usually in the range 1200 - 1500 psi. At operating speeds, these failure loads will commonly involve a peak film pressure of two to three times this normal loading. The bearing Babbitt will then flow when local oil film pressure reaches the Babbitt yield strength - as temperature rises to 250-300° F range. At very low speeds, Babbitt wear becomes a limiting factor when overall film thickness drops to less than 3-10 times overall oil film thickness drops to less than 3-10 times the nominal surface roughness of mating runner.

Tapered land bearings provide reliable, compact design for variety of midsize to large, high speed machines such as turbines compressors and pumps. Flat land extending about 10-20 % of the circumference at trailing edge of each segment is commonly included for higher capacity and to minimize wear during starting, stopping, and at low speeds. Because the operation of tapered land bearing is sensitive to load, speed, and lubricant viscosity, this bearing type is commonly designed to match rated operating conditions of specific machines.

Pivoted pad thrust bearings are being used more frequently in turbines, compressors, pumps, and marine drives in much the same general size and load range as the tapered land designs. Each of the 3-10 or more pads in the bearing is commonly supported on a central pivot, which leaves it free to adjust to form nearly optimum oil wedge for supporting high loads even with widely varying speeds and lubricants and both directions of rotations.

Recent modifications for increasing the load capacity, lowering the temperature and lowering the power loss include offsetting the pivots to 60-65 % beyond the leading edge of the pad, replacing steel with copper for backing of the Babbitt bearing material to give peak surface temperature, and using non-flooded lubrication to minimize parasitic power loss.

Spring or other flexible supports for the thrust segments are used in some of the largest thrust bearings carrying millions of pounds of thrust. This flexible mounting avoids high contact stresses imposed by loading individual pivots.

Step bearing provide a simple design for smaller bearings. With the use of coined or etched step, they are well suited to mass production for small bearings and thrust washers for use with low viscosity fluids such as water, gasoline and solvents. Step height should be small with the same order of thickness as the minimum film thickness for optimum load capacity, yet large enough to allow for some wear.

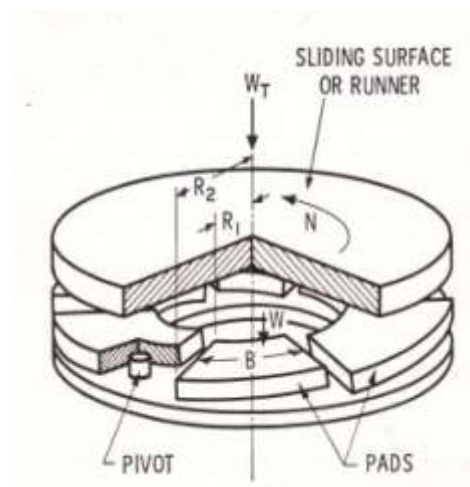
Flat land bearings will carry only 10-20 % of the load of other thrust bearing types, because flat parallel surfaces do not provide pumping action needed to build oil film pressure in a converging wedge shaped clearance. Instead, flat land bearing relies on thermal expansion of oil and warping of bearing material by heating from the passing oil film.

**TABLE 1. Types of Thrust bearings [Applied Tribology- Bearing Design and Lubrication]**

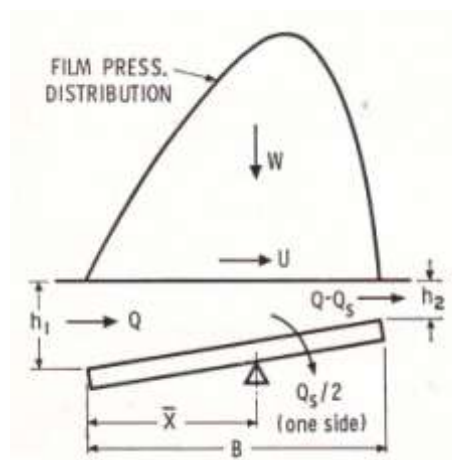
Type	O.D (in.)	Unit Load (psi)
Taper	2-35	150-400
Tilt pad	4-120	250-700
Spring support	50-120	350-700
Step	0.5-10	100-300
Flat	0.5-20	20-100
Hydrostatic	3-50	500-3000

**V. TILTING PAD THRUST BEARINGS**

Tilting Pad Thrust Bearings are designed to transfer high axial loads from rotating shafts with minimum power loss, while simplifying installation and maintenance. Here the load carrying surfaces are completely separated by an oil film, eliminating the risk of surface wear as long as a film of sufficient thickness is maintained. In order to attain hydrodynamic (full-film) lubrication, the pad must sit at an angle to the oil flow so that a converging “wedge” is produced (refer figure 2a). Each bearing consists of a series of pads supported in a carrier ring; each pad is free to tilt so that it creates a self-sustaining hydrodynamic film. The carrier ring may be in one piece or in halves with various location arrangements. They are used increasingly in marine drives, turbines, compressors and pumps. This flow constriction acts as a bottleneck, effectively slowing down the flow rate across the pad from the inlet edge towards the trailing edge. The gradually reducing available volume in the gap leads to a pressure build-up in the oil film giving rise to a force which “lifts” the shaft. (Refer figure 2b). Another contributory effect is the viscous flow resistance which prevents the oil from running out of the gap instantaneously as the pressure increases.



**Fig.2 a) A cut-away of a tilting pad**



**Fig.2 b) Pressure distribution within the thrust bearing and runner arrangement bearing**

### 5.1 Research and Development on The Tilting Pad Thrust Bearing

In order to keep a machine workable for long periods, friction and wear of its parts must be kept low. It was in the 1880s when OIL FILM Lubrication was first observed and investigated during the experimental work of Beauchamp Tower with theoretical contributions from Osborn Reynolds.

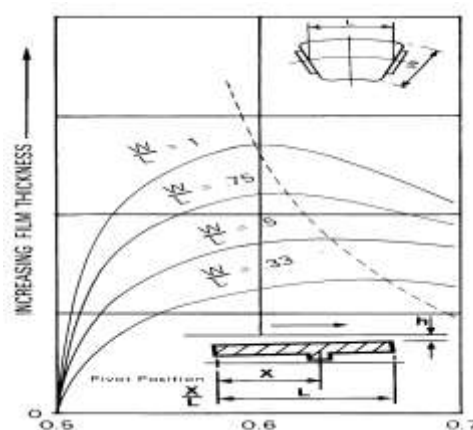
The pivot pad bearing was invented by Anthony G. M. Michell in 1905 and independently by Albert Kingsbury in 1910 in a slightly different version. A G M Michell followed up, and made an important extension to, this initial work when he developed the mathematical basis for his revolutionary breakthrough in applying oil film lubrication to flat thrust faces.

In 1905 Michell patented a type of bearing in which the load was carried upon the oil films generated by a series of pivoting white metal faced pads. The principle was applied to both thrust and journal bearings, and is now universally known as the MICHELL BEARING.

## VI. THE MICHELL PRINCIPLE

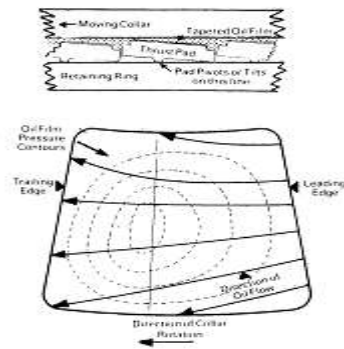
There are two elements in a Michell Thrust Bearing- the rotating thrust collar and the pivoting thrust pads. These two elements never come in contact while the bearing is in operation; being forcibly separated and kept apart by tapered oil films, self generated from the normal oil supply. Figure 2b, illustrates how these indestructible pressure oil films are generated and maintained between the working surfaces of the thrust pads and collar.

It is an important basic fact that the tapered pressure oil film or wedge of lubricant is self generated by the motion of the thrust collar and is not dependent on any extraneous pressure from an oil pump. All Michell thrust pads are designed and proportioned so that they tilt and generate a thick oil film to carry the thrust load. Figure 3, shows an example of pressure distribution and typical oil flow lines across the face of a Michell thrust pad. With the working faces kept apart in this simple and well ordered manner, there is no metallic contact, no metallic friction, no wear and no renewal of parts – provided of course good uncontaminated oil is always present in sufficient volume at the thrust bearing.

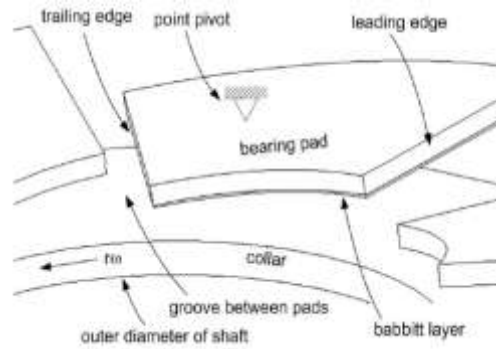


**Fig. 3 Pressure Distribution and Oil Flow Lines Across**

The white metal is used on the faces of the thrust pad because, white metal has the ability to absorb or embed the minute particles of grit and foreign matter which occasionally find their way into lubricating oils of even the best kept systems. In addition to this it is the most suitable facing material to combat the boundary (partial lubrication) condition which prevails on starting and stopping.



**Fig. 4 Pivoted pad bearings**



**Fig. 5 Illustration of tilting pad bearing and terminology**

Tilting-pad bearings have the great advantage over fixed incline bearings that the pad convergence ratio

$$K = \frac{h_{le}}{h_{te}} - 1$$

is a function of the position of the pivot only, where  $h_{le}$ ,  $h_{te}$  are the oil film thickness at the leading edge and trailing edge respectively. K is independent of the operating conditions (when thermal effects and side leakage are negligible). The load carrying capacity depends strongly on K and fixed incline bearings therefore do not work well under varying operating conditions. This problem was solved by the introduction of the pivot-pad bearing. A schematic illustration of a tilting-pad thrust bearing is seen in figure 5.

Michell's construction was based on a line pivot not allowing for radial pivoting. Kingsbury used a spherical pivot, which allows the bearing-pad to tilt in all directions to compensate for misalignment between the pad and the rotor. Due to this additional advantage of Kingsbury's design the spherically pivoted bearing is in more widespread used.

The present day bearing designs are very similar to the original design. In figure 6, some examples of modern tilting-pad thrust bearings are shown. To enhance the performance some modifications of the design have been introduced over the years. Leveling systems have been introduced to ensure equal loads on all pads. In large bearings crowning of the pads due to thermal gradients between the oil film side and the backside of the pads may constitute a problem due to a negative influence on the oil film thickness distribution. In order to reduce thermal crowning circular supports, internal cooling of the pads or sandwich constructions has been introduced by bearing designers.



**Fig. 6 Thrust bearings with different features: Leading edge grooves (top left), spray lubrication (top middle), load equalization (top right), PEEK coated pad (bottom left); oil injection pockets (bottom right).**

Other designers have eliminated the pivot and positioned the pad on a bed of springs allowing for a thinner pad in which the thermal deflection is opposed by pressure bending induced by the springs. Traditionally, bearings

are operated in an oil bath under fully flooded conditions. In slow speed bearings movement of the oil in the oil bath does not induce a large energy loss. In high-speed bearings however the churning loss may constitute a significant part of the total friction loss. In such bearings oil is often directly sprayed onto the collar in the groove between the pads or supplied through leading edge grooves. In large applications starting up a loaded rotor from zero velocity causes high temperatures to develop due to dry friction and the white metal surface may melt. To avoid this, hydrostatic jacking is often used. In recent years attention has turned to using polymer materials such as Polyetheretherketones (PEEK) as coating materials instead of white metal because of their low friction coefficients against steel. Hydrostatic jacking may then be avoided.

## VII. CONCLUSION

This paper focus on importance of bearing and details about the types of bearing. We have studied mainly four types of bearing as they are having unique characteristics and applications in mechanical field. Thrust bearing is not in common use, but it is very useful mainly in heavy duty applications. Michell principle shows the tilting fundamentals of thrust bearing which will then leads to proper pressure and lubrication wedge distribution.

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