SUBMERSIBLE MOTOR ENGINEERING

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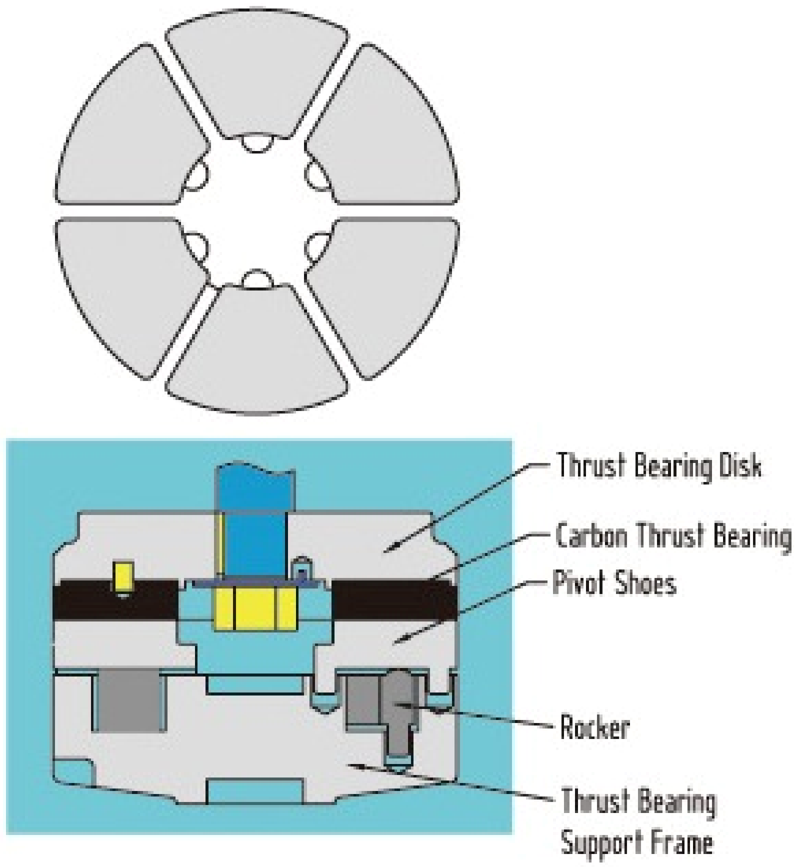
Understanding Thrust Bearings in SME Submersible Motors 1/5/03

General

All SME submersible motors are fitted with Kingsbury type Hydrodynamic Self Adjusting Tilting Shoe Thrust Bearings to take the axial “down thrust” from the pump. These are a complex and clever part of a reliable submersible motor and probably not understood very well.

These thrust bearings will take a surprisingly heavy axial “down thrust” load and provided that they have been installed correctly, rated correctly, and looked after properly, they will provided may years of trouble free operation.

(SME motors also have an “up thrust” bearing to take up thrusts – usually these occur for a very short time at start up. These are a fairly simple device, which consist of a resin/cloth fibre ring, which rubs against the underside of the Stainless steel Thrust Bearing Support plate. These bearings are not continuously rated and only take light loads.)




Typical Thrust Bearing Assembly.


Pivot Shoe Assembly

Carbon Thrust Disc

Principle

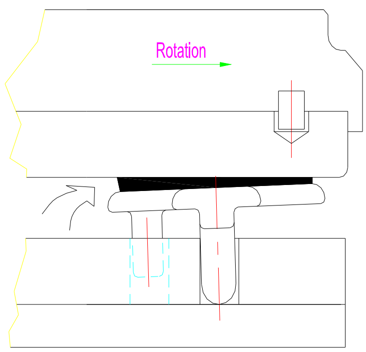
The Hydrodynamic thrust bearing transmits the rotating shaft's axial thrust load to the frame of the motor, which is mechanically supported in the well.
The axial thrust load is transmitted through the bearing on a self-renewing film of lubricant, which is water in most SME motors.
The pressure in the fluid film supports the load without the thrust disc or pivot shoes making contact.

Theory

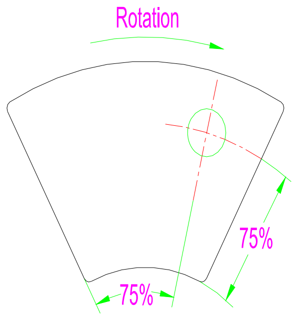
Fluids tend to stick to most surfaces due to viscosity, and in the case of Kingsbury type thrust bearing, we rely on the fluid sticking to the surface on the rotating thrust disc. This fluid is then dragged between the thrust bearing disc and the face of the pivot shoe by centrifugal force, and forms a wedge shaped film.

This wedge shaped film is essential for the successful operation of the thrust bearing. When the bearing is operating correctly there is no contact between the disc and the face of the pivot shoe. The only time there is contact is when the motor is stopping or starting. This means there should be only negligible wear between the faces – and no wear while the motor is operating.

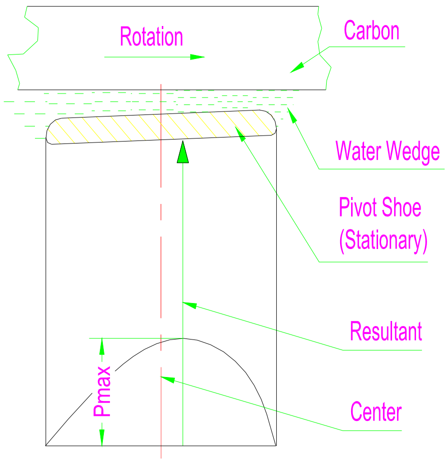
The sketch below shows how the pivot shoe tilts over and allows the fluid to be forced between the carbon thrust disc and the face of the pivot shoe by a combination of rotational drag and centrifugal force. The pivot point should be spherical which allows the shoes to rotate or pivot so that the fluid can form a wedge. The shoes need to be loosely constrained while still free to pivot.



The carbon thrust bearing drags the fluid around in a circular direction, but this fluid also experiences a centrifugal force, which is pulling the fluid towards the circumference of the bearing. The combination of these 2 forces means that the fluid is circulating and going outwards at the same time and it has been found that the peak pressure point is somewhere beyond the centre in the direction of rotation. Quite often this is assumed to be on the face of the pivot shoe approximately 75% across the face of the pivot shoe and 75% out towards the circumference. This is known as the 75/75 Rule in Thrust Bearing design and is where the bearing has peak loading, minimum film thickness, and high temperatures. If the thrust bearing only operates in one direction it is common to offset the pivot point so it is nearer to the 75/75 point.



From the Pressure Distribution Curve below it can be seen that peak load is not on the centre line of the pivot shoe, but offset in the direction of rotation.



Issues that need to be considered during the design of a hydrodynamic thrust bearing are maximum total loads, load per mm2 on the bearing surface, number of shoes, thrust disc surface speed, fluid viscosity, and maximum allowable fluid temperature. Hydrodynamic thrust bearings commonly have 6 pivot shoes because of the difficulty of ensuring that all the shoes share the load evenly. More shoes increase the likelihood of uneven loading because of variations in dimensions due to mechanical tolerances.

The thrust-bearing disc transmits the axial thrust load from the rotating shaft (rotor) through the fluid film to the stationary pivot shoes. A typical film thickness under rated thrust load can be 0.03 mm for a high performance thrust bearing.

Other Issues

Cleanliness. It is very important the inside of the motor is very clean with no loose material that could circulate in the water. All the Thrust Bearing components should be ultrasonically cleaned prior to assembly as any lapping paste that is not removed from the pivot shoes or the carbon disc will tend to circulate in the fluid. (Pivot shoes should also be demagnetised after grinding and lapping to ensure they do not attract any magnetic particles that might be present. Any foreign material, larger than the film thickness, that passes through the thrust bearing can damage the surface of the carbon surface of the thrust disc and can get imbedded in the surface of the carbon. (It is unlikely to scratch the face of the pivot shoes as these are especially hardened). Any water that is used to top up inside the motor should also be clean, but most tap water is fine.

Surface Finish and Tolerances. It is essential that the surface of the carbon thrust-bearing disc is machined flat and exactly perpendicular to the shaft with negligible runout on the face. The surface must be lapped to give a very smooth flat finish. The surface of the face of the pivot shoes is also ground and lapped to give a very smooth flat finish, and in addition the height of each pivot shoe in a set must be identical and the base of the pivot leg must be spherical so that the pivot shoes are free to pivot and share the load equally. Due to mechanical tolerances there will always be some variations in dimensions, but in general they should be tightly controlled. The design of the SME thrust bearing allows the whole thrust bearing assembly to swivel on the thrust button, which also allows the pivot shoes to share the load more evenly.

Speed of Rotation. It is important that thrust bearings are not operated at low speeds, or speeds well below their design operating speed. At the low speeds there will not be enough rotational speed to force the fluid through between the pivot shoe faces and the thrust disc, so the faces will be in contact as the motor rotates and this will lead to wear and heat generation due to friction. This can be a problem when using VVVF drives or soft starters and we recommend a maximum run up time of 4 seconds. It can also be a problem when the motor is switched off as the water in the column could flow back down through the pump in the reverse direction and cause the pump to rotate which will cause the bearing to rotate at a low speed. In most installations a check valve is fitted just above the pump, which will prevent this from happening, even though it is quite common for a small drain hole to be drilled in the check valve to allow the column to drain slowly after the motor/pump is switched off.

Temperature. The temperature of the fluid inside the motor can have a big influence on the performance of the bearing because the viscosity of the fluid will change with temperature and if the water temperature gets close to boiling point the water will loose all it's viscosity and the bearing will fail.

Lubrication and Film Thickness. For the bearing to operate properly the lubricating fluid must always be present between the carbon thrust disc and the faces of the pivot shoes. This fluid heats up as it passes through between the 2 faces of the bearing and needs to be cooled and recirculated before it passes through the bearing again. The fluid entering the bearing should always be reasonably cool before it enters between the bearing faces so it can cool the bearing as it passes through.

Shock Loading. This can occur when a pump starts to cavitate. These bearings will tolerate some shock loading, provided the peak shock load does not exceed the maximum load the bearing can take. If the maximum load is exceeded the carbon will make contact with the pivot shoes and high wear and high temperatures will result. In extreme cases the carbon will be pounded onto the pivot shoes and will then start to break up.

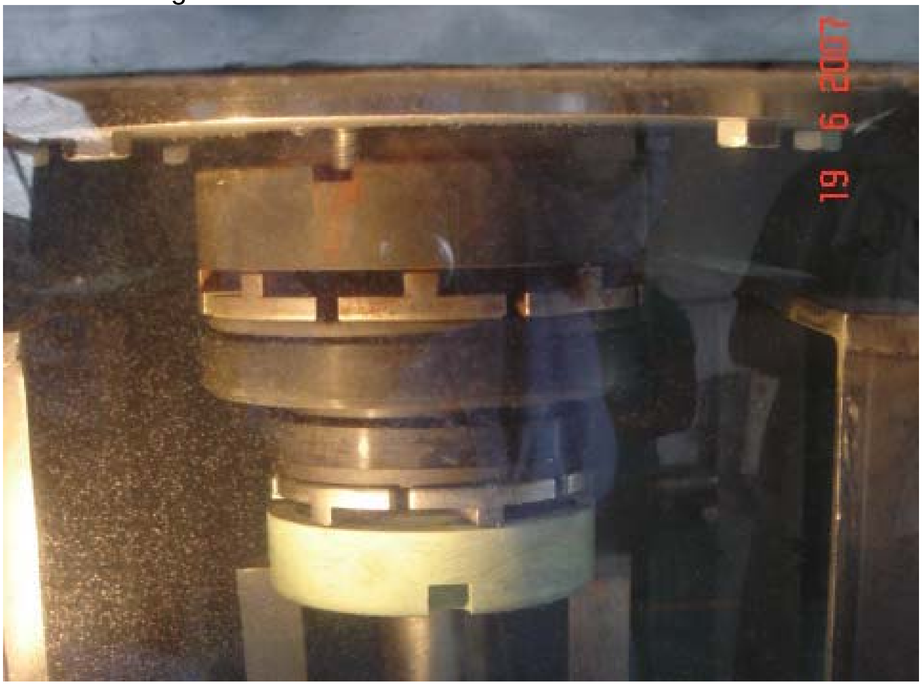
Load distribution to the pads/pivot shoes. It is essential to ensure that the height of each pivot shoe is exactly the same so that each pivot shoe shares the load evenly. If one shoe is shorter than the other shoes then it will have a bigger gap between the face and the carbon and will not carry as much load as the other shoes. Likewise if one shoe is higher than the other shoes it will tend to carry a much higher load than the other shoes. (Please note that even if the load is not exactly evenly distributed across all the shoes in the thrust bearing it will still work, because all SME bearings are very conservatively rated).

Pressure Distribution in the film / Flow Requirements across the bearing. As the thrust load increases the pressure in the gap between the pivot shoes and the carbon will reduce. Any small scratches or indentations in the surface of the pivot shoes or the carbon will reduce the load carrying capacity, as some of the pressure in the fluid will be dissipated into these "voids". It is essential that fluid inside the motor is free to circulate through the bearing and mix with the fluid around the bearing to dissipate the heat generated in the bearing. It is also important to ensure the carbon material used in the thrust disc has very low porosity to prevent the high pressure water from being dissipated into the carbon.

Power Losses. As the thrust load increases on the bearing the power loading on the motor will increase. There is a direct linear relationship between the power consumed in the bearing and the thrust load. Typically for a 6 shoe 8" SME thrust bearing with 3000 Kg of "down thrust" the extra power required from the motor is 900 watts. This power is dissipated in heating the fluid and bearing surfaces.

<u>Testing Thrust Bearings</u>.

Thrust Bearing under test



SME have a Thrust Bearing Test rig, which allows us to test different bearing designs and different materials, especially for the thrust disc. We can load the bearings up to 12 tonnes, and we usually run them for several hours at 10 tonnes. After testing we check the surfaces of the thrust disc and the pivot shoes to ensure that there is no wear. SME rate their thrust bearings at a much lower load that they have been tested at – typically about 40% of the tested load.