SELF CONTAINED BEARINGS FOR SPECIAL APPLICATIONS
3 CASE STUDIES

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ABSTRACT

This paper discusses some of the methods available for the circulation of oil in self-contained bearings and their cooling. Three specific designs are considered and used to illustrate how both standard and very special requirements can be satisfied. Previous and current standard range vertical thrust and guide bearings are described as well as recent innovatory design work concerning the use of heat pipes for oil cooling and the development of a unique self-pressurised low power loss bearing.

Introduction

The objective for designers of self-contained bearings is to supply a product to a performance specification which is able to provide itself with a continuous supply of cool oil for the bearing surfaces. The bearing has to be able to carry out from within its own engineered resources the functions of circulating and cooling an amount of oil fixed within the confines of the bearing. There are a range of techniques available to assist in fulfilling these functions. Oil circulation is often achieved for example by fixed or loose rings dipping into the sump and conveying oil from these to the top of the bearing. In many cases water is available as a cooling medium and may be introduced into the bearing casing using suitably designed cooling tubes.

In this paper a number of methods useful in self-contained bearings are discussed with reference to three specific design case studies. These designs have been chosen to illustrate some of the range of ideas available to meet standard requirements and also how it is possible with new design thinking to accept very special duties.

Vertical Bearings

Many machines, pumps, motors, turbines, have vertical shafts and require bearings capable of withstanding axial loads and providing radial restraint. Usually the radial load is small but on occasion it may be considerable. Traditional oil ring circulation is not an option for vertical shaft bearings. It is usual instead to immerse the bearing faces in a bath of oil and use natural pumping actions caused by rotation of the shaft and thrust collar.

Figure 1 is a sectional elevation of the self-contained, water cooled, Michell vertical thrust and guide bearing from a previous standard range. Oil circulation through the radial journal or guide bearing is induced by pumping holes located near the bottom of the thrust collar. Oil is drawn into an annular space on the inside of the collar and pumped outwards and upwards to the journal pads. The rising oil spills over weirs to the outer part of the casing and flows downwards past the water jacket to recommence the pumping cycle. The rotating face of the thrust collar also pumps oil from the centre of the thrust bearing between the thrust pads. This oil after leaving the collar periphery, mixes with the stream of oil from the cooling zone and is itself thereby cooled.

This type of bearing was for many years a satisfactory solution for the range of imposed duties and many examples are still in service. However the double mode of pumping from the central space imposes certain limitations. At low speeds the predominate flow is that induced by the pumping holes to the journal while at high speeds the greater flow is that across the thrust face. In this case the flow in the cooling area can be upwards with oil flowing over the weirs to feed the journal pads. At certain speeds stagnation is possible and this can lead to overheating or at worst to failure.

Rose and Brockwell (1) have shown that in recent years there has been an increasing requirement for higher speed vertical bearings. The Michell Bearings design team, responding to changing needs, set out to design a new standard range of vertical bearings which would not have any risk of the limitation described above.

Figure 2 is a cutaway illustration of the new design standard range thrust and guide bearing which resulted from the Michell study and shows all the essential features.

Figure 3 is a cross-section of the same bearing and the single oil circulation route, from thrust face to the journal bearing to water cooler and back to the centre of the bearing casing by way of channels beneath the thrust pads can be seen clearly. Now all the oil is constrained to a single path over both thrust and journal surfaces, thus removing any chance of stagnation in oil circulation.

Oil circulation utilizing the pumping action of the thrust face has been found to be extremely powerful particularly in the single oil path form illustrated. Rapid circulation of the oil is important in ensuring a sufficiently high velocity past the cooler. In this case cooling is provided by water passing through wire wound tubes immersed in the oil. This form of cooler has been found to offer significantly higher rates of heat exchange than were obtainable using the water jacket design shown in Figure 1. As Figures 2 and 3 show, elimination of the water jacket permits a much simpler casting for the bearing casing. In those cases where water is not available or when the performance required of the bearing is not so arduous, bearings, can be air cooled by the addition of fins to the outside of the casing. Further improvement in air cooling capability can be obtained by the use of a shaft mounted fan above the bearing and a cowl around the fins.

Vertical bearings such as illustrated by Figures 2 and 3 are designed in a standard range of ten sizes accommodating shaft diameters from less than 50 mm to a maximum of 308 mm. Figure 4 is a photograph showing the disassembled parts of a bearing in the middle of this range. Thorough prototype testing was carried out for all sizes of bearings and some of this experimental work is described in detail by Rose and Brockwell (1). Many Michell standard vertical thrust and guide bearings are now installed at sites all over the world. The same principles that apply to standard bearings are equally applicable to vertical bearings outside the size range and numerous larger bearings are also in service at various locations.

All vertical bearings are members of the same family and are recognisable as such. In contrast, the other two bearings to be described are out and out specials designed to satisfy particular requirements. In both cases the bearing and its functioning was well established but it was necessary to undertake innovatory design and development work to establish satisfactory cooling and oil circulation arrangements.

Cooling Using Heat Pipes

The emergency feed and cooling water pumps in nuclear power stations are devices which may never need to be called upon during their service life. But, when they are required, it is essential that they operate in a completely reliable way with the minimum of outside services. The specification for the thrust bearings in this application called for a normal thrust load of 42 kN to be accommodated at 3000 r/min. It was further specified that air cooling was the only form permitted and that the oil bath temperature should be no more than 70

degrees Celsius for a maximum ambient temperature of 25 degrees Celsius.
The technology to accommodate this load and speed in a self-contained bearing is well known using an IR ring for oil circulation as shown in Figure 5. In an IR ring oil is collected from the inside of the rim thus counteracting the centrifugal effect of oil being thrown from the outside of a conventional oil ring at high speeds. The difficulty facing designers in this case was to find a way of providing sufficient cooling to enable the bearing to operate at a reasonable temperature for a performance level normally appropriate to water cooled bearings. The solution was found in the development of heat pipes specifically for the extraction of heat from the bearing sump. A heat pipe is a closed device containing a working fluid under a reduced pressure. When one end is immersed in the hot environment the working fluid vaporises and travels to the cool end where it condenses on the walls of the pipe and heat is transferred to the atmosphere as shown in Figure 6. In the case in question, air is blasted over the cool ends using a shaft fan to maximise heat dissipation.
Initial analysis and design work was followed by extensive prototype testing of both heat pipes and bearing. The result was that the performance to specification was achieved with ten degrees of temperature to spare. Figure 7 shows the bearing on test in the manufacturer's own works and Figure 8 the final installation with the customer's pump.
This bearing was developed for a special application in Britain where water cooling was not a permissable design option. Subsequently to the initial contract further test work has been carried out to prove the bearings at very high ambient temperatures up to 55 degrees celsius, appropriate to desert and tropical conditions, where water may be expensive and not necessarily plentiful commodity.

Self Pressurized Low Loss

In the other special application to be described, there was no shortage of water since the site was an offshore platform near the West Coast of Africa. The problem in this case was an extremely high rotational speed for a self-contained bearing