LARGE LOW MAINTENANCE HORIZONTAL TURBINE BEARINGS

A DESIGN CASE STUDY FROM A REMOTE INSTALLATION IN AFRICA

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ABSTRACT

This paper is a design case study based on some new bearings supplied for a set of large water turbines in a remote central African location which posed a number of demanding problems. It was important to design for low operating costs throughout the life of the machines. This meant designing for a small maintenance requirement and including special features to allow for local servicing and inspection of the bearings within a very restricted space. It was necessary also to pay special attention to the sealing arrangements and include some seals which are wear free, and which will not need to be adjusted or replaced during the lifetime of the machine.

Combined thrust and journal bearings and plain journal bearings have been provided for an initial installation of three turbine generators. It is planned that eventually eight such machines will be built.

INTRODUCTION

Particular problems arise for bearing designers when equipment is to be installed in very remote locations. In the present case, a total of eight water turbine generators are planned for a central African location which is about 1600 km for any sizable settlement. There will be no power supply at site before start up of the first turbine other than from a diesel generator.

The very distance from any services and the difficulties of communication makes it imperative to provide a bearing system with extremely low life time costs. This has meant not only designing for as small a maintenance requirement as possible but also including features to enable in situ inspection and servicing of the bearings within the confined circumstances of the turbine housings. The turbine housings are themselves fully immersed in water with the only means of internal access being a 900 mm diameter vertical shaft.

GENERAL DESCRIPTION

Figure 1 is a sketch of the general equipment layout showing a turbine bulb containing the electrical generator and bearings. The turbine runner is mounted downstream of the housing as shown. At the generator end of the shaft is a combined thrust and journal bearing able to accept axial loads and shaft rotation in either direction. The bearing is mounted in a solid, conical bulkhead which it is expected, will not be moved during the life of the machine. This places several constraints upon the designer; among them that the seal on the generator side of the bearing be of a type that does not wear and thus will not need to be replaced or adjusted at any stage in the future. It is also necessary to ensure that the bearing can be stripped down axially from the runner side of the bulkhead.

At the runner end of the shaft is a journal bearing mounted in a similar way to the thrust and journal bearing. In this case however, the supporting bulkhead has removable quadrants which will permit access to the outboard seal if necessary. However the space restrictions are still considerable as Figure 1 shows and this remains an inconvenient task. The bearing casing is made partially conical to give maximum space between it and the bulb casing. This assists access both to the bearing seal and to the main water seal which is located immediately outboard of the journal bearing.

The bearings are joined by a large diameter tube which surrounds the shaft. This serves as a connection between the oil baths of the two bearings and forms part of the lubrication system to be described later. Overall bearing performance and lubrication information is contained in Table 1.

TABLE 1

BEARING PERFORMANCE

THRUST AND JOURNAL BEARING

SHAFT DIAMETER	500 mm
SPEED	120 RPM (418 OVERSPEED)
THRUST LOAD DOWNSTREAM	600 KN
THRUST LOAD UPSTREAM	1400 KN
THRUST SURFACE	0,3865 sq.M^2
JOUARNAL LOAD	350 KN
JOURNAL SURFACE	0,175 sq.M^2
TOTAL POWER ABSORBED	8,25 KW(53,5 AT O/SPEED)
OIL VISCOSITY GRADE	ISO VG 68
OIL INLET PRESURE	90 KN/sq.M^2
OIL INLET TEMPERATURE	40 DEG C
OIL FLOW	3120 L/HR

JOURNAL BEARING

SHAFT DIAMETER	500 MM
SPEED	AS ABOVE
JOURNAL LOAD	330 KN
JOURNAL SURFACE	0,175 sq.M^2
POWER ABSORBED	1,2 KW(B,0 at O/SPEED)
OIL DETAILS	AS ABOVE
OIL FLOW	780 L/HR

Thrust and Journal Bearing

A cross-section of the thrust and journal bearing is given by Figure 2. The housing is a three piece welded steel construction in the form of a cylinder with the axis horizontal. A mounting flange encircles the casing about a third of the way from the end facing the generator. The lower half casing, Figure 3, is in one piece while the top, Figure 4, is in two parts which are joined at the mounting flange. It is anticipated that, once mounted, the bottom half casing and the generator end of the top half casing will never be moved.

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A spherically seated split bush is positioned in the casing close to the plane of the mounting flange, so that the journal load is directly supported and there is little or no bending moment at the mounting point. The bush is retained in a special inner seating which is split at the horizontal joint line.

Thus, by first removing the outer section of the sleeve from the housing, the bush is made free for axial withdrawal. Figure 5 shows the bush assembled in the lower half casing and generator. The double thrust bearing is of the self levelling type in which the thrust pads are supported by a double layer of pivoted equalising segments. These are designed, within the limits imposed by friction,to ensure that the load is shared equally between the thrust pads.

To permit removal of the bush and inner thrust ring, it was necessary to design a separate thrust collar, Figure 6, split in halves and mounted in a groove in the shaft. Close tolerance machining of the joint faces, keyways, shoulders and bores of the collar and shaft are critical to the accuracy of the thrust collar after assembly. True location of the halves is ensured by heavy keys and the halves are joined by 12 hydraulically pre-tensionsed bolts.

Oil enters the bearing by means of a single inlet and a circumferential gallery in the seating of the journal bearing. This is machined half in the spherical bush and half in its seating. There are twin oil ports at the horizontal centre line admitting oil to the bearing clearance. Twin axial gutterways are cut into the whitemetal and these are continued all the way to the end of the bush adjacent to the thrust chamber to permit a proportion of the oil to pass immediately into the thrust bearing. The remaining oil lubricates the bush and falls to drain at the generator end. An oil flinger bolted to the shaft and then a multi stage labyrinth seal prevent oil leakage at this end of the bearing, while a combination of a well vented annular chamber and a strip brush seal ensure that no oil vapour is sucked from the bearing casing by windage created by the turning electrical rotor. This seal is designed to be wear free. However, it can be inspected and if necessary removed from the turbine side of the casing after the bush has first been removed.

JOURNAL BEARING

The journal bearing, Figure 7, at the turbine end of the bulb is much simpler in construction than the combined thrust and journal bearing. The casing is in two halves split at the horizontal centre line. The journal is supported by a similar split inner carrier ring around the spherical bush to permit axial withdrawal. Oil inlet to the bearing and drain arrangements are again similar to those of the thrust and journal bearing.

The oil baffle at the runner end of the casing is a multi stage labyrinth, adequately vented and with a drain sized to take the full oil flow so as to avoid leakage in event of a bush failure involving the complete removal of whitemetal. In this case there is no source of windage external to the seal and a brush seal, such as fitted to the thrust and journal bearing, is not required.

LUBRICATION

In common with other parts of the equipment, the lubrication system has been designed for simplicity and reliability. Each generator has an independent lubrication system situated in the turbine bulb which supplies oil to the bearings. Figure 8 is a schematic diagram of the arrangement. Oil is delivered by the motor and pump unit, via duplex filters, to a distribution main which supplies oil to the inlets of the two bearings. A third supply is used to top up a stand-by gravity tank mounted at the highest point of the bulb. In event of a total oil system failure, this tank will provide an emergency oil supply, independent of any services, sufficient to enable the machine to run down safely.

The discharge from the journal bearing enters and fills the tube which surrounds the shaft and joins both bearing housings.The oil discharge from the tube joins that from the thrust bearing chamber and passes to the settling tank. Secondary drains (not shown) from the seal spaces allow oil to fall directly to the tank.