PTFE faced bearings; Thissavros – A case study

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Introduction

The Thissavros pumped storage power plant (3 x 128 MW), owned and operated by the Public Power Corporation, is a major hydroelectric installation on the Nestos river in northern Greece. Support for the weight of the rotating parts of the reversible vertical Francis pump-turbine units, as well as the hydraulic load, is provided by a combined thrust and journal bearing. During commissioning of the plant problems were encountered with the thrust bearings which were of a traditional whitemetal design. Heavy wiping of the pad surface occurred as a result of thrust runner deformation. As modification to the thrust runner was not an option a solution was sought which entailed only changes to the thrust pads.

In recent years PTFE faced thrust pads have emerged as an alternative to whitemetal. Originating in the hydro industry, they have many benefits among which are the ability to operate in adverse alignment conditions. Beginning with a description of PTFE faced thrust bearings the paper describes the bearing failures at Thissavros, and then details how PTFE faced thrust pads were used to overcome the problems of operation with the original deformed thrust runner.

1. Background

PTFE has been available as an engineering material for some time in a variety of forms, and is well associated with bearing technology. Its use, however, as a surface material for hydrodynamic bearings is relatively recent. Originating in Russia and China in the 1970's for use in hydrogenerator power plant, its use is attracting much attention in other parts of the world.

The construction of a PTFE faced bearing is similar in many respects to that of a conventional bearing. Like its whitemetal counterpart the PTFE faced pad is generally sector shaped, relies on some form of pivoting mechanism at its rear surface to produce a convergent lubricating film, has sufficient thickness to support the resultant hydrodynamic loading, and uses oil as the working medium.

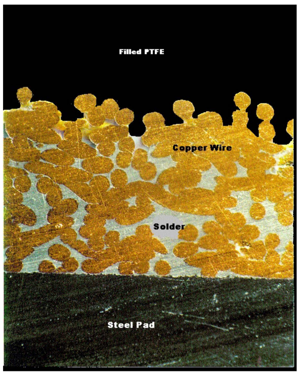

Fig.1 Cross-section through part of a PTFE faced thrust pad

However it is the pad surface that differentiates the PTFE faced bearing from the more familiar whitemetal version. In the latter a relatively thin layer of the tin-based alloy is bonded metallurgically to the steel substrate of the pad, often in the case of older designs, with the addition of dovetail or rectangular retention grooves. The alloy surface is then machined to a flat or very slightly crowned profile. Leading edge chamfers or radii are added to help induce the hydrodynamic action at start up. In some cases a system to allow high-pressure oil injection between the working surfaces is added to assist start up under heavy loading. This applies typically at specific loads greater than 2.4 MPa (350 lbf/in^2).

The PTFE faced pad, in contrast, has a relatively thick layer of a PTFE/wire mesh composite attached to the steel body of the pad instead of the whitemetal. The method of bonding the PTFE to the steel body using wire mesh as an intermediate material is key to the successful operation of the pad. Fig. 1 shows a cross section through part of a typical thrust pad. The wire provides not only the means of attachment, but also serves as a compliant layer, which allows expansion and contraction of the PTFE in operation. Note that the coefficient of linear expansion of PTFE is an order of magnitude greater than that of the supporting steel. Attachment of PTFE by adhesives, as is often done in some simple slide bearings used on bridge supports for example, would rapidly fail at the joint due to the differential expansion rates encountered at the sliding speeds and temperatures typical of hydrodynamic bearings.

What makes this type of bearing so attractive, however, are the significantly higher specific loadings that are possible (Ref. 1). The reasons for this lie in the thermal and frictional properties of PTFE which lead to a number of important benefits. Because PTFE has a higher melting point than conventional whitemetal, hydrodynamic bearings may comfortably be operated at higher temperatures and hence at higher pressures which means the bearing has a higher margin of safety against abnormal overloads, leading to an increase in machine reliability and availability. The exceptionally low coefficient of static friction for PTFE also means there is no need for high-pressure oil injection between surfaces to overcome the frictional effect of high loads at start up. The material is more tolerant than whitemetal, making it ideally suitable for difficult or arduous applications (Ref. 2).

These benefits attributable to PTFE faced thrust pads have been used to great effect in overcoming a particularly difficult problem at Thissavros

2. Thissavros

Built between 1991 and 1997 the Thissavros pumped storage facility in northern Greece is the principal feature of the Nestos River Development.

At the heart of the facility are the three vertical axis 128MW hydrogenerator units. The hydraulic elements of the units are the reversible Francis pump turbines. An important part of the turbine is the combined thrust and journal bearing which is mounted between the turbine and the generator. The bearing, in addition to supporting the radial loads, is primarily used to support the mass of the rotating components and the hydraulic forces acting on the pump turbine runner. As the machines are reversing units the bearings are designed to be bi-directional. A comprehensive description of the units and their operation can be found in Ref. 3

3. Design of machine

The main characteristics of the pump-turbines, reproduced from Ref. 3, are listed below in Table 1.

Turbine operation	
• Maximum net head (m)	157
• Output (MW)	128
• Discharge (m^3/s)	90
• Minimum net head (m)	92
• Output (MW)	56.8
• Discharge (m^3/s)	86
Pump operation	
• Maximum net head (m)	161
• Input (MW)	111.7
• Discharge (m^3/s)	62.3
• Minimum net head (m)	100
• Input (MW)	130
• Discharge (m^3/s)	107.5
Nominal speed (rev/min)	214.28
Runner diameter (m)	5
Number of blades	5
Runner weight (tonnes)	42

Table 1 Main characteristics of the pump-turbines

The turbine/generator unit includes an arrangement of three guide bearings, all of which have radially adjustable pivoting pads. One is located at the non drive end of the generator, another just above the turbine, and a third, which is combined with the thrust bearing, is located in the lower bracket of the motor generator. Fig 1 shows a cross section of the pump turbine assembly including the lower guide bearing and the combined thrust and guide bearing.

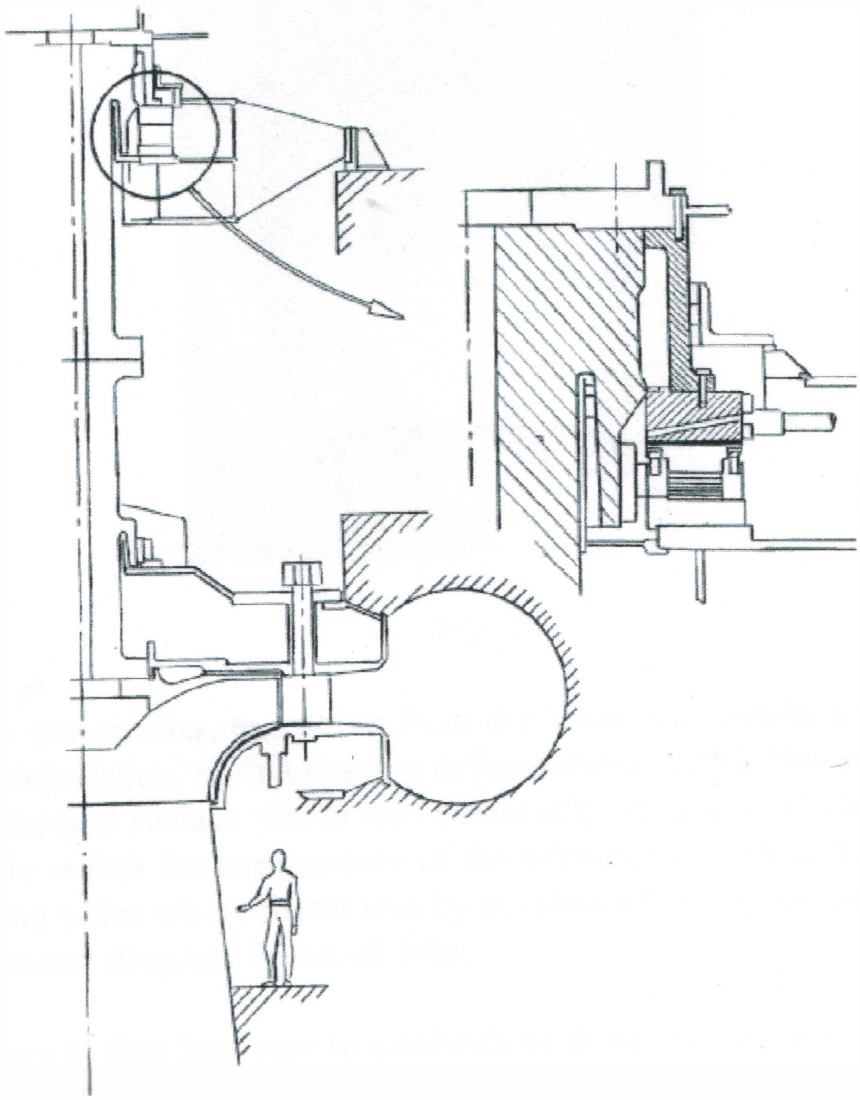

Fig. 2 Cross section through the pump turbine with reference to the thrust and guide bearing

4. Design of original bearing

The thrust and guide bearing is shown in Fig 2. The main characteristics are listed in Table 2.

Outside Diameter of Thrust Pads (mm)	2562
Inside Diameter of Thrust Pads (mm)	1668
Number of Pads	12
Thrust Surface Area (m^2)	1.68
Speed of Rotation (rev/min)	214.28
Velocity at Mean Pressure Diameter (m/sec)	24.2
Thrust Load (kN)	5280
Mean Thrust Pressure MPa	3.14

Table 2 Main characteristics of thrust and guide bearing

The thrust pads, which are centre pivoted to allow for rotation in both directions, are mounted on plate springs to provide for a degree of pad to pad load equalisation. The springs take the form of rectangular bars of steel arranged in three groups; each group consisting of four bars stacked one upon the other. The bars, simply supported at their ends, are orientated such that the thrust pad pivot is at right angles to the bars. In this way the springs also provide a degree of self-alignment in the radial direction. The centrally located pivot consists of a loose piece, which is screwed to the back of the pad.

With the exception of the whitemetal face, the entire pad external surface was coated with a thick layer (approx. 20 mm) of polyester based insulation. The purpose of this insulation was to reduce heat loss from the thrust pad and thereby reducing thermal gradients and so preventing excessive pad distortion. High-pressure oil injection was also provided to assist in stopping and starting the machine and leading and trailing chamfers were provided to assist in oil film formation. The original pad design is shown in Fig. 3.

The construction of the thrust runner is worthy of particular note. Unlike more conventional designs where the thrust runner is an integral part of the shaft forging, or is part of a separate thrust block, the runner in this case is a loose annular ring attached to the rotating structure by a connecting sleeve. Flanged at both ends the sleeve connects the thrust runner to the underside of the generator. The forces on the thrust bearing runner are transmitted to the generator by the connecting sleeve, which is predominately in axial compression. Radial holes drilled through the runner from the inner to outer diameters, provide self-pumping for circulation of oil through the bearing. The material of the thrust runner is a cast iron.