Two Case Studies for the use of PTFE Thrust Bearings in Hydropower Applications

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Introduction

In any hydropower scheme the main load carrying bearings at the interface between stationary and moving parts of the system are of crucial importance to the long-term availability of generating capacity and robustness of supply. The tilting pad, fluid film bearings typically used in hydropower applications are based on well-proven engineering and, in most cases, extremely reliable. Nevertheless, bearing-related problems that threaten operations can arise for a variety of reasons. Typical causes are changes in the operating regime of the plant compared with the original specification or engineering interventions, for example in the form of design changes, in other parts of the assembly that impact adversely on the overall system.

This paper provides case study descriptions of two such major problems occurring in the main bearings of hydropower equipment. In both cases the problems were resolved by the installation of replacement bearings in which one of the working surfaces is covered with a layer of PTFE (Polytetrafluoroethylene). PTFE-faced fluid film bearings have been used for many years in the former Soviet Union, China and Eastern Europe. Advantages claimed for these bearings, in comparison with their conventional, whitemetal (babbitt)-faced counterparts, are increased load carrying capacity in normal use and removal of the need for high pressure oil injection. In conventional whitemetal bearings high pressure oil injection is used to reduce friction at start up, when stopping the bearing and in the course of maintenance procedures that require the main shaft to be rotated.

1. Background

Reference 1 provides a review of the background to the development of PTFE-faced bearings and goes on to describe the successful installation of such a bearing at a well-known pumped storage hydrogenerator station in the UK. Since that initial installation in September 1996, PTFE-faced bearings are gradually gaining acceptance in Western Europe, the Americas and Japan. This paper provides the opportunity to describe two more recent installations in which the original bearing was replaced with a PTFE alternative with good effect. Taken together the examples have a number of important lessons for systems designers and for operators alike.

2. Case Study 1: Pump Turbine Bearing at Thissavros, Greece.

In this case three newly installed turbine bearings installed as part of a 384 MW pumped storage project in Northern Greece all experienced similar bearing failures during commissioning. In each case serious damage to the whitemetal surface occurred at the first attempt to commence reverse rotation with a heavy bias towards the inner half of the thrust pads. As is usual in large rotating machines the pads of the thrust bearing bore against a plain collar that forms part of the rotating assembly. Later analysis was to show that principal cause of failure was excessive deformation of this collar under load. Interestingly, all the machinery at Thissavros was based on a well established designs, but incorporated a number of minor design changes compared with predecessor plant. These changes had the effect of reducing the stiffness of the collar under load and this in turn created conditions in which the original bearings could not survive.

2.1 Design and Installation

The Thissavros pumped storage project in northern Greece, with a maximum output of 384 MW, is the principal element of the Nestos River development. The project, designed for hydropower and irrigation, is based on three 128MW reversible Francis pump-turbines. HydroVevey are the suppliers of the pump-turbine. Led by consortium leader, Metka of Greece, other members of the group included Cegelec for the electric components and control-command system, and GEC Alstom Electromecanique for the motor-generators. The customer/project owners are the Public Power Corporation of Greece. Reference 2 gives further details of the power plant.

The reversible Francis pump-turbine unit used at Thissavros is shown in figure 1. Support for the weight of the rotating parts, as well as the hydraulic load, is provided by a combined thrust and journal bearing (shown highlighted) which forms part of the pump-turbine supply. The main parameters of the thrust bearing, which is part of a HydroVevey patented design are listed in the table below. Other bearings in the overall system include an oil lubricated lower turbine guide bearing and an upper guide bearing mounted on top of the generator.

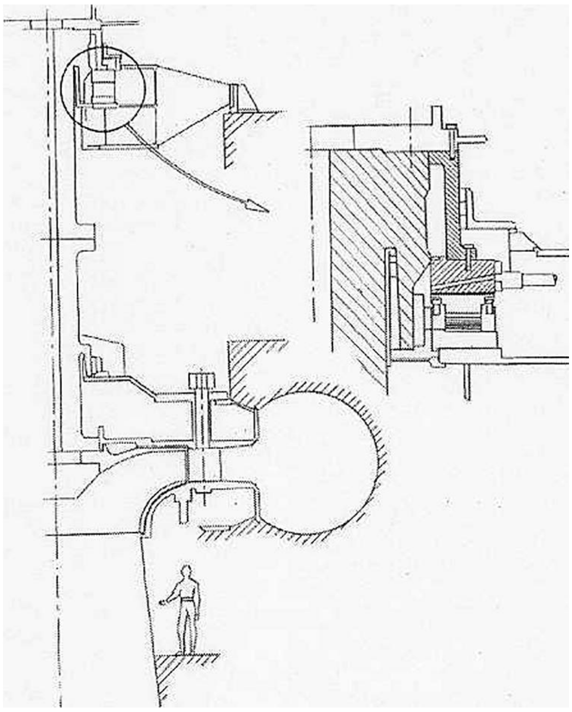

Fig. 1.

Outside Diameter of Pads:	2560 mm
Inside Diameter of Pads:	1670 mm
No. of Pads:	12
Thrust Surface Area:	1.68 m^2 (after addition of PTFE)
Speed of Rotation:	214.3 rev/min
Velocity at Mean Pressure Diameter:	24.2 m/sec
Thrust Load:	5180 kN
Mean Thrust Pressure:	3.14 MPa

Table 1. Main Thrust Bearing details: Thissavros

Each of the thrust pads, which are centre pivoted to allow rotation in both directions, is mounted on a nest of rectangular plate springs to provide for load equalisation. The springs also provide a degree of self-alignment in the radial direction. Except for the original whitemetal face, the entire pad external surface is coated with a thick layer (approx. 20mm) of thermal insulation. This is provided to reduce heat loss from the thrust pad and thereby prevent excessive pad distortion due to thermal gradients. High-pressure oil injection is also provided to assist in stopping and starting the machine.

The thrust runner, manufactured in cast iron, is mounted to the thrust shaft by a coupling sleeve. The thrust runner is provided with a series of radial holes, which serve to pump oil to an external cooler.

2.2 Early Operation

Phased commissioning of the units began in October 1997. This was confined to operation in the turbine mode only. Each of the three units achieved between 1800 hours and 2800 hours of successful operation in the turbine mode. However when operation was attempted in the pumping mode for the first time, all three bearings exhibited a heavy wipe over the inner half of the pad causing a rise in temperature which necessitated a shutdown of the machine. A typical failure is shown in figure 2.

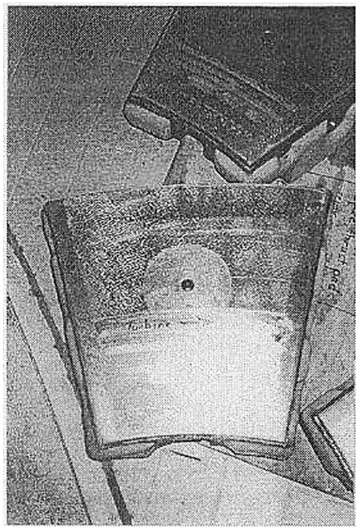

Fig. 2.

Damage to all 12 pads was similar, extending from the inner diameter to a point just inside the high pressure oil injection depression, with a sharply defined demarcation line between this damaged area and the remainder of the pad surface which was essentially undamaged. The failure mode was a shallow surface wipe in which the temperature of the whitemetal surface had been raised locally to a level around the melting point where metal loss by erosion/adhesion can occur with associated scoring damage by solidified metal droplets in the oil film.

The cause of failure was at first less easy to establish as there was no obvious single root cause; nevertheless the fact that the failure was confined to the inner regions of the pad does suggest that uneven loading was present. This could have been due to mechanical or thermal deflections, or both. Finite element analysis later was to show that significant distortion of the thrust runner had taken place because of thermal distortion of the coupling sleeve. A plot of deflections in the region of the runner is shown in figure 3.

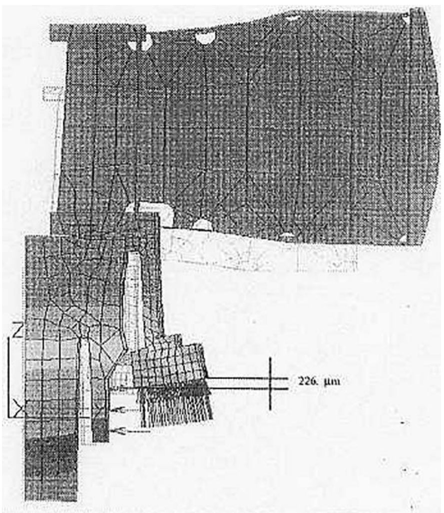

Fig. 3.

2.3 PTFE Thrust Pads

In the PTFE pad a composite layer of compressed copper wire and PTFE replaces the whitemetal layer on the surface of the pad. In the pads supplied to Thissavros the grade of PTFE was a filled variety consisting of 33% carbon and 2% graphite. This composite of PTFE and wire is soldered to the steel substrate of the pad. A cross-section of the pad is shown in figure 4

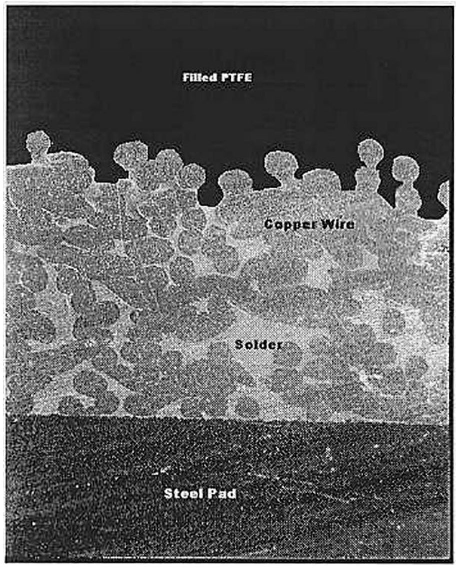

Fig. 4.

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