Michell Bearings

The Development of a PTFE Faced Thrust Bearing for Dinorwig Pumped Storage Power Station

by

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ABSTRACT

The use of PTFE as the working surface of pivoted pads used in the heavily loaded thrust bearings of hydrogenerators confers some advantages in terms of higher specific loadings and increased margins of safety. These advantages have been realised in recent, successful installations in the UK, Japan and Greece. Further development work involving the use of filled rather than unfilled PTFE as the pad surface material and the re-incorporation of high-pressure oil injection has been necessary prior to the introduction of a second set of PTFE faced pads for use at the Dinorwig Pumped Storage Power Station. The facility at Dinorwig is the largest of its type in Europe and one of the most important such schemes in the world. Following successful laboratory based experimental work, installation of the pads in one of the motor/generator units at Dinorwig is programmed for 2000.

Introduction

PTFE (Polytetrafluoroethylene) faced thrust bearings are a development of the tried and trusted pivoting pad bearing installed in hydrogenerator machines as the main thrust bearing. The pivoting pads are invariably faced with a layer of whitemetal or babbitt. However in the case of the PTFE bearing this surface is replaced by a relatively thick dual layer made from PTFE and compressed copper wire. The load bearing surface is PTFE and the copper wire provides strength and a means of adherence to the steel backing of the pad.

The use of PTFE confers many benefits upon the bearing; the most important of which is the ability to operate at significantly higher specific loads. This benefit can be used to produce smaller more energy efficient bearings, or in the case of marginal applications, to produce a bearing which has significantly greater tolerance to abuse and transient overload.

The development of PTFE faced thrust bearings originated in the former USSR from the 1960's and more latterly in China. In both countries there are hundreds of machines fitted with PTFE faced bearings operating at specific loads of up to 10 MPa. Recent development work at Michell Bearings has led to successful applications at Ffestiniog Pumped Storage Power Plant, in Wales, UK; at Hidaka Power Station in Hokkaido, Japan; and at Thissavros Pumped Storage Power Station in Greece.

The purpose of this paper is to report on new developments and progress leading to the installation of PTFE bearings at Dinorwig Power Plant, one of Europe's largest and most demanding pumped storage generating facilities. Both Dinorwig and Ffestiniog are facilities owned and operated by First Hydro, an Edison Mission Energy company.

Background

Development at Michell Bearings began in 1995 with tests on small scale (135 mm width) thrust pads faced with unfilled PTFE. Enough confidence was gained from these tests to proceed with full-scale trials on an actual hydrogenerator. The machine chosen was Unit 4 at Ffestiniog Pumped Storage Power Plant. The strategic objective even in those days was eventually to install a PTFE bearing at the much larger Dinorwig facility. Since both Ffestiniog and Dinorwig plants are owned by the same operator, an ideal opportunity existed to demonstrate the PTFE faced bearing under the controlled conditions that prevail at Ffestiniog. The bearing designed for Ffestiniog, with pivoted pads faced with unfilled PTFE, was installed in September 1996. Completely satisfactory operation has continued since that time with, at the time of writing, an accumulated operating time of approximately 10,000 hours. Details of the background development work, design and installation at Ffestiniog are given in References 1& 2.

A further development at this time was the supply of a PTFE faced thrust bearing for a new application at Hidaka Power Station on Hokkaido, the North Island of Japan. This is a 10 MW run-of-the-river Francis turbine application with equipment supplied by Fuji Electric (now Voith Fuji Hydro). Again unfilled PTFE was supplied as the working surface on pads measuring approximately 200 mm square. With a specific loading of 5 MPa the pads went into service in March 1998 with no reported operational problems since that date.

A concern with PTFE faced bearing are the possible effects of long term wear, particularly in more heavily loaded applications. Thus, in parallel with the development of bearing designs for particular applications, investigations were also conducted on filled grades of PTFE. These are materials where unfilled (virgin) PTFE is compounded with various fillers in order to improve the mechanical properties, particularly hardness and wear resistance. Details of this phase of the development are given later in this paper. In March 1999, one of these filled grades based on 33% carbon and 2% graphite, was used as the pivoting pad facing material with great effect to correct a major bearing failure problem at Thissavros Pumped Storage Power Plant in Northern Greece. In the following months the bearings in all three machines at this facility were converted from the existing babbitt faced pads to PTFE faced pads allowing the machines to be used in both pump and generator modes for the first time.

Installation at Dinorwig Pumped Storage Power Plant

Dinorwig is a pumped storage power station comprising six 313 MW pump/turbine motor/generators. With an installed capacity of 1800 MW, Dinorwig is one of the world's largest pumped storage schemes. The units at Dinorwig are bi-directional with their hydraulic runners acting as both pump and turbine depending on the operating mode.

The thrust bearing, which supports both the hydraulic and static loads, is situated on the upper bracket of the motor/generator. The bearing is of the spring mattress type in which a set of 58 compression coil springs is used to support each pad. The thrust pads boast some unusual features that have evolved during the life of the machine. These include: a face profile consisting of a spherically crowned central region, a surrounding conical region, and leading and trailing chamfers; the use of continuous high-pressure oil injection at the pad surface/thrust collar interface; and direct water cooling. The bearing is bath lubricated with both internal and external water coolers.

Operation of the units at Dinorwig has changed dramatically over the years. The original intention was to cater for periods of peak demand, typically by pumping to store energy during the night and generating once or twice during critical times of the day. Following deregulation and restructuring of the electricity supply industry, the motor/generator units now alternate between pumping and generating many times during the day and night. The number of mode changes in a 24 hour period is typically 25. Clearly, this places much greater demands on the system as a whole and on the bearing in particular, than were envisaged when the plant was designed. The extent of the increase in demand on the bearings can be readily appreciated when it is noted that the maximum thrust load is present at every start up and shut down and during spin-pump and spin-generate modes. It is not surprising then that the present pad life is on average 2 years

Early problems that were encountered at Dinorwig with the original babbitt bearing were associated with collar rippling leading to fatigue type failures of the pads. Fatigue due to thermal ratchetting was also evident. Aeration of the oil and general contamination were also problems that beset the bearing. The various unusual features of the Dinorwig bearings listed earlier are all part of previous attempts to overcome these problems. A further modification was the installation of a thicker collar runner to combat the effects of thermally induced ripples.

In July 1998 a set of unfilled PTFE pads were manufactured and installed in Unit 3 at Dinorwig. These pads were direct conversions from an existing set of babbitted pads and except for the removal of the babbitt (including the removal of the high-pressure oil injection system) and replacement with a PTFE/copper wire dual layer, no other modifications were made.

After a set of commissioning runs the machine was put into commercial service. In the following days the bearing was subject to extensive operation during which time it amassed a total of 336 hours in the pump mode and 827 hours in the generating mode. The total number of stops and starts were approximately 500. After a period of 50 days the bearing was opened up for inspection. The condition of the pads at this stage was remarkably good considering the number of stops and starts that had taken place under load without the benefit of high-pressure oil injection. The PTFE surface was highly polished to an almost glass like finish. Near the mean diameter of the pads there were indications, albeit confined to a small area of the pad, that some form of local deformation had taken place. No evidence of PTFE wear particles was evident. The pads removed for inspection were put back and service operation recommenced.

After only a few hours, however, filter debris in the lubrication oil system indicated that wear of the PTFE was taking place. Although temperature measurements gave no contra-indications, proximity probe readings, which were later confirmed, showed that relatively large amounts of wear debris were passing through the oil film. Therefore, the unit was closed down and opened up for re-examination. Investigation of the debris and of the failed pad topography later was to give some indication as to what had taken place.