The Development of PTFE Faced Thrust Bearings for Hydro Generator Power Plant

by

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Abstract

In 1995 Michell Bearings commenced a study into the PTFE faced bearing with the objective of producing a commercially available product aimed at the hydro generator market. With collaboration from a leading machine manufacturer and a major end user a full size bearing went into commercial operation in September 1996.

This paper describes in detail the development of this new type hydro generator bearing technology beginning with the testing of a small scale prototype, through to the installation of a full size bearing in a 90 MW pumped storage unit at Ffestiniog Power Station in North Wales, UK. The paper then goes on to describe the development of a PTFE bearing intended for use in the prestigious Dinorwig Pumped Storage Power Station also in North Wales. Details of the results from a limited series of tests in the Dinorwig machine are presented. The effects of a variety of fillers on the friction and wear behavior of the PTFE layer are also reported. The paper concludes with a comment about the environmental benefits provided by the use of PTFE bearings.

Introduction

The PTFE faced thrust pad is not a new concept with respect to hydrodynamic tilting pad thrust bearings. Their use in hydro generator power plant in the former USSR and China is extensive. Outside these countries however little experience exists of their use, and little documentation about them is available .

The construction of the bearing is similar in many respects to conventional tilting pad bearings. The pad is generally sector shaped, has sufficient thickness to support the hydrodynamic loading resulting from the sliding motion, relies on some form of pivoting mechanism to produce a convergent film shape, and uses oil as the working medium.

It is the nature of the pad surface however that sets it apart from the more familiar whitemetal or babbitted version. In the latter a relatively thin layer of a tin or lead based alloy is metallurically bonded to the substrate of the pad, often (in the case of older designs) with the addition of dovetail retention grooves. This surface is then machined to a flat or slightly crowned profile. Leading edge chamfers or radii are then added to help induce the hydrodynamic action at start up. In some cases high pressure oil injection is added to assist start up under heavy loading, typically at mean specific loads > 2.4 MPa, or to provide low friction during starting or barring of the machine.

By comparison the PTFE faced pad has a relatively thick layer of a PTFE/wire mesh composite attached to the surface of the pad instead of the whitemetal. The method of bonding the PTFE to the pad is the key to the successful operation of the pad as the wire mesh layer not only provides the means of attachment, but also serves as a compliant layer which allows expansion and contraction of the PTFE in operation. It is worth noting that the coefficient of linear expansion of the PTFE is an order of magnitude greater than that of the supporting steel of the pad. Attachment of the PTFE by adhesives, as is often done in some simple slide bearings used on bridge support bearings for example, would rapidly fail at the joint due to the differential expansion rates encountered at the high sliding speeds typical of hydro generator power plant.

What makes this type of bearing so attractive however is the significantly higher specific loadings that are possible. The reason for this are the unique properties of the PTFE. This in tum confers upon the PTFE bearing a number of benefits. Due to the higher pressures that are now permissible there are reduced power losses, typically 20~30% due to the smaller thrust surface. There is no need for high pressure oil injection. The reduced size also results in reduced costs of the capital plant because of smaller shaft forgings, smaller bearing housing, smaller lubrication system, and a smaller cooler. The bearing has a higher degree of safety margin which leads to increased machine reliability and availability. The material is more forgiving than whitemetal making it ideally suitable for difficult or arduous applications. When combined with a PTFE faced journal bearing the complete bearing is electrically insulated. Finally it is claimed that lower braking speeds are possible due to the superior friction and wear during stopping and starting.

Early Development

The first stage in the development programme was the manufacturing problem of how to attach the PTFE to the steel of the pad. Existing designs used a wire mesh inter-layer as the bonding mechanism. The process consists of forming a compressed copper wire mesh layer approximately 7 mm thick. On to this layer is pressed a sheet of PTFE some 10 mm thick. The composite PTFE/wire mesh is then bonded to the steel of the pad by soft soldering. The pad surface is then machine by a combination of milling and grinding to produce a finished PTFE thickness of approximately 3 mm.

A die is an essential tool in the production as it is used to pre-compress the wire mesh and to shape and form the PTFE, bonding it to the wire mesh. The wire mesh used in the design is a woven hose in which the copper wire is 0.35 mm in diameter. The choice of wire diameter is based mainly on the ease by which it can be manipulated by hand when loading the die. At this stage the way in which the wire is folded and laid up in the mould cavity is very important. The objective is to ensure that the pressed shape of the copper wire mesh presents a continuous, unbroken edge which cannot be subject to de-lamination in service. The pressing of the PTFE commences with the production of a blank cut to shape from a sheet of PTFE. The PTFE at this stage is fully sintered, and subsequent heating and pressing during the bonding process does not change the structure of the material. By the combination of heating and pressing in a hydraulic press, with the wire mesh and PTFE located in the mould, the PTFE is forced to flow into the interstices of the compressed copper wire mesh. Penetration of the PTFE is approximately 1~1.5 mm deep. On removal from the die the composite takes up a characteristic curved shape as the PTFE, which has the much greater expansion coefficient, cools to room temperature. For this reason the soldering process which follows has to be carried out under pressure to ensure that the composite is fully flattened against the steel of the pad when the solder is applied. The solder used is a conventional tin/lead solder typical of the type used in electrical work. When soldering the most important aspect is cleanliness, and attention to correct fluxing and wetting with the solder is essential. In the design of the surface of the steel pad a trough is formed which helps retain the molten solder long enough for capillary action to draw solder into the wire mesh. Penetration of the solder in this way ensures that approximately 80% of the remaining voids in the compressed wire mesh are filled with solder. Some designs of pad also employ a grooved surface on the steel to aid in mechanically locking the wire mesh to the steel. The latest designs reported here however employ a flat surface free from grooves, as the soldering process when correctly executed, produces a more than adequate bond. A section through the PTFE/wire/steel is shown in Fig 1.

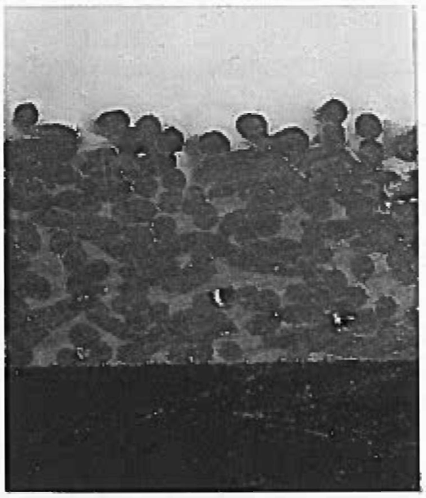

Fig 1

The first bearing to be made this way was based on a standard vertical bearing with a "normal" thrust capacity of 700 kN. The design of this bearing and the test work which followed is reported in Ref 1. The results of testing clearly demonstrated the claims made of this design of bearing in that substantially higher loadings were possible that those normally associated with whitemetal bearings. Sufficient confidence had been gained from these small scale tests to go into production on a full size hydro generator bearing.

In due course a bearing was eventually supplied to the Ffestiniog Pumped Storage Power Plant in North Wales. This plant, which is owned and operated by First Hydro, an Edison Mission Energy Co., consists of four 90 MW pumped storage units. The design installation and commissioning of a PTFE bearing for Unit No 4 at Ffestiniog is described in detail in Ref. 2. On first inspection of this bearing in May 1997, approximately six months after going into commercial operation, it was found to be in excellent condition. At this stage the bearing had accumulated 2903 operating hours, and had undergone 900 starts & stops.