PTFE Thrust Bearings for Hydro Generators and Their Application to Dinorwig & Ffestiniog Pumped Storage Power Plants, UK

By William O. Moss, First Hydro Company, Dinorwig, Wales, UK and
Eur.Ing. Robert T. Knox, Michell Bearings, Newcastle upon Tyne, UK

ABSTRACT

This paper will show how two companies, First Hydro Company and Michell Bearings, undertook the development of a Polytetrafluoroethylene (PTFE) bearing for hydrogenerator applications. This type of bearing which uses PTFE on the sliding face is capable of operating over a range of loads and speeds which are considerably higher than those normally associated with babbitt. The work commenced with a series of investigations and trials on a set of small scale PTFE faced thrust pads. The series of pilot tests on the contractor's test bed was followed by the design of a set of PTFE bearings for a unit in Ffestiniog Pumped Storage Power Station, North Wales, UK. Manufacture and installation were successfully carried out in 1996 and to date the bearing is operating successfully with no signs of wear. Development has now moved to the production of an advanced test rig which will allow the full scale testing of a set of PTFE spring mattress thrust pads that will eventually be installed in one of the six 313 MW machines at Dinorwig Pumped Storage Power Station, also in North Wales, in 1998. The paper is an illustration of close co-operation between contractor and end user working together on the development of a new type of hydrogenerator bearing technology.

Introduction

Most hydrogenerator thrust bearings employ babbitt (whitemetal) as the working surface for the bearing and this has remained the world's preferred choice as the facing material for most heavy duty hydrodynamic bearing applications. The strengths and weaknesses of the material are well known. In particular, babbitt provides a dimensionally stable surface which is easily repaired or replaced. The material is forgiving in the sense of being able to absorb into its surface hard bits of detritus without causing further damage. On the other hand babbitt has a relatively low melting point which imposes an upper limit on its operating temperature. If this temperature is exceeded, catastrophic failure of the bearing is likely to ensue within a very short period of time. The effect of the babbitt temperature limit is to restrict the maximum duty (expressed as a combination of speed and load) permissible in any particular bearing. As a further consideration, it can be noted that the main constituent of babbitt is tin, an expensive commodity which has often been in limited availability in many parts of the world.

According to engineers in both the former Soviet Union and China, babbitted bearings operated well until pressure to increase generating capacity caused duties to increase, and this led in turn to a series of bearing failures. Coupled to this were associated failures of the high pressure oil lubrication (jacking) system used to stop and start the machines. As a consequence of the problems in both these countries PTFE is now being used widely in hydrogenerator bearing design as the facing material. However very few developments have taken place in the west using PTFE.

Why PTFE ?

As an engineering material the benefits of PTFE are well known: an extremely low coefficient of friction when paired with steel (0.04~0.09); unique chemical stability; excellent dielectric properties; and good mechanical strength. A negative feature of PTFE is that its mechanical properties are highly temperature dependent. Thus, a temperature rise from 20 °C to 80 °C leads to a decrease in compressive strength by a factor of three. Even more significant, PTFE is subject to excessive creep, i.e. deformation under load, even at low temperatures. These latter properties prevent PTFE being used as a bearing facing material in an unmodified form.

The design of the PTFE bearing, which has evolved because of these limitations, involves the application of a sheet of 3 mm thick PTFE to a 7 mm thick liner made from copper/bronze wire coils. The PTFE is applied under pressure which causes it to flow into gaps in the wire coil to a depth of 1~1.5 mm. In this way a firm bond is formed between the PTFE facing material and the wire coil under-layer. The composite PTFE/wire layer is then soft soldered to the steel backing plate of the thrust pad. The PTFE partial penetration of the wire coils allows the pad to retain its resilience. This reduces surface contact stresses and ensures a uniform load over the full thrust face, even in the presence of thrust collar face waviness.

Reported experiences with this type of thrust pad all indicate satisfactory operation and clear advantages deriving from the use of PTFE faced bearings. In particular, significantly higher specific start up and operating loads, in the range 5~6.5 MPa, are reported which compare very advantageously to the 3.5 MPa specific load (in operation) typical for babbitted bearings. Furthermore the need for high pressure forced lubrication at start up and shut down is removed with considerable cost savings.

The greater permitted specific operating loads lead to smaller pad areas for given loads and in turn savings in the energy losses incurred by the bearings. It can be demonstrated that energy loss reduction of 20~30 % is easily achieved by the use of PTFE faced thrust bearing. The classic wipe of babbitt which is often followed by a catastrophic failure is well known. In the case of PTFE lined bearings localised contact can still take place, but the resulting frictional heating is much lower. PTFE has a much higher working temperature than babbitt, and therefore the catastrophic failure does not occur. Instead the mode of failure, revealed by experimental work described later, is a very gradual one associated with progressive wear.

One evident concern with the use of PTFE is that of surface wear. However extensive evidence is available to show that PTFE wear is not a major concern even given the fact that these bearings are operating at much higher specific loads, in addition to the absence of high pressure forced lubrication at start up and shut down. Conscious of the fact that minimal wear will always be a requirement, more recent developments have looked at the use of filled grades of PTFE. Fillers such as carbon black, glass fibre, and graphite are all possible candidates to help improve wear resistance.

Given the obvious advantages of PTFE, the authors began a program of development in 1995 aimed at producing a bearing which would operate at duties typical in hydrogenerator applications. Such duties are at their most arduous in the Dinorwig Pumped Storage Power Station in North Wales, UK. The remainder of this paper describes the evolution of such a bearing.