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

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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 babbit. 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 babbit (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, babbit
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 babbit 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 babbit 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 babbit 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.

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