# ‘PTFE Bearing Technology for Thrust and Journal Applications’

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## Abstract

*Michell Bearings has developed PTFE bearing technology for thrust and journal applications. The paper describes this type of bearing together with the key advantages of the product compared with babbitt. The advantages will be demonstrated by two case studies; one involving the retrofit of problematic babbitt bearings with PTFE and the other concerning the design of PTFE thrust blocks for a water jet propelled ferry application. A detailed description of Michell naval thrust block testing facility will be described. The latter being based on an ex-UK submarine thrust block which has been retrofitted with PTFE thrust pads.*

## Introduction

In 1839 an American by the name of Isaac Babbitt invented a bearing alloy that was to later bear his name – Babbitt Metal. More generally known in other parts of the world as whitemetal, the material is an alloy of tin (sometimes lead), copper, and antimony. Tin based whitemetals have been the predominant material for a wide variety of hydrodynamic bearings for many years. Their use for thrust surfaces, such as in the multi-collar thrust blocks of the early steam ships, pre-dates the invention of the tilting pad bearing at the start of the last century. The strengths and weaknesses of the material are well known [1]. In particular, whitemetal provides a dimensionally stable surface that is easily repaired or replaced. The material is forgiving in the sense of being able to absorb into its surface hard particles of detritus without causing further damage. On the other hand whitemetal has a relatively low melting point and this leads to an upper limit on the temperatures possible during hydrodynamic bearing operation. 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 whitemetal 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 whitemetal, namely tin, is an expensive commodity which has often been in limited availability in many parts of the world.

With the development of the tilting pad and taper-land hydrodynamic thrust bearing at the beginning of the twentieth century it was natural for engineers to continue to work with the material they knew. Although other materials have been developed for hydrodynamic bearing surfaces, including, for example, copper-lead alloys, whitemetal has remained the world’s preferred choice for most industrial applications.

Almost one hundred years after the invention of whitemetal another significant bearing material was to emerge. In 1938, Dr Roy Plunkett, a worker at the DuPont research laboratories (Jackson Laboratory in New Jersey), was working with gases related to Freon refrigerants when upon checking a frozen, compressed sample of tetrafluoroethylene, he and his associates discovered that the sample had polymerized spontaneously into a white, waxy solid to form polytetrafluoroethylene or PTFE. The material these days is better known throughout the world by its DuPont tradename of Teflon.

## PTFE and Hydrodynamic Bearings

Whilst PTFE has been around for some time now, and is well associated with bearing technology, its use as a hydrodynamic bearing lining is relatively recent. Originating in Russia and China for use in hydrogenerator power plant, their use is extensive and is attracting much attention in other parts of the world.

The construction of the bearing is similar in many respects to conventional tilting pad bearings. Fig. 1 shows a cross section through a typical PTFE faced thrust pad. 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.

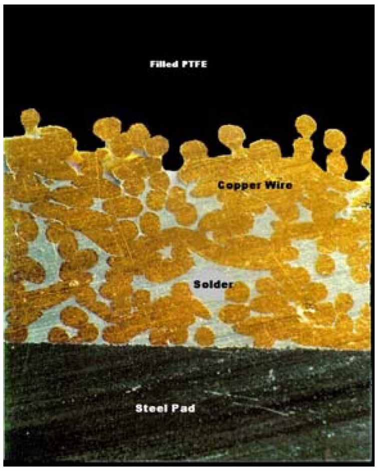


Fig. 1, Cross section through a PTFE faced pad

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 the tin or lead based alloy is metallurgically 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 (350 lbf/in$^2$).

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 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 supports for example, would rapidly fail at the joint due to the differential expansion rates encountered at the sliding speeds typical of hydrodynamic bearings.

What makes this type of bearing so attractive, however, is the significantly higher specific loadings that are possible [2]. The reason for this are the mechanical, thermal, and frictional properties of the PTFE. These in turn confer 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 housings, smaller lubrication systems, and a smaller cooler. The foregoing also result in significant weight savings. 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. Finally when combined with a PTFE faced journal bearing, the complete bearing is electrically insulated.

## Case Study

A dramatic example of how a PTFE faced thrust bearing can out perform a babbitt bearing can be seen in the following case study [3].
In this case three newly installed turbine bearings as part of a 384 MW pumped storage project all experienced similar bearing failures during commissioning. In each case, at the first attempt to commence reverse rotation, serious damage to the whitemetal surface occurred 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 rotating collar that forms part of the rotating assembly. Later analysis was to show that the principal cause of failure was excessive deformation of the rotating support structure under this load. Interestingly, all the machinery at the site was based on well established designs, but incorporated a number of minor design changes compared with predecessor plant intended to reduce the cost of manufacture. 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.
The damage to all the pads was similar, extending from the inner diameter to a point 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 babbitt 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 failed pad is shown in Fig. 2

Fig. 2, Misalignment damage to a babbitted thrust pad

The investigation into the failure which followed revealed that the pads were operating under less than ideal conditions. It was felt that the reliability of the units could be substantially increased by changing to PTFE faced thrust pads. The increased thrust capacity afforded by PTFE would result in a bearing which would be more forgiving to those conditions which normally give rise to

problems associated with babbitt faced bearings: overload, misalignment, and marginal oil film thickness.
Accordingly, the bearing in one of the units was converted to PTFE. The modification consisted only the removal of the whitemetal and replacement by a layer of the PTFE/wire composite previously described. The original steel of the pad was used and since PTFE pads do not require high pressure oil injection this was omitted. It should be noted that the original cause of the problem, the deformation of the rotating parts of the machine, remained uncorrected.
After 500 hours of operation, including both directions of rotation, the PTFE pads were inspected. Fig. 3 shows the pads
Examination of the PTFE surface of two diametrically opposite pads showed them to be in excellent condition. Virtually all of the original "as manufactured" surface of the PTFE was still visible. The marks produced by the final grinding operation could still be clearly seen. Only near the inner diameter were there any signs of marking in the form of three fine scratch marks. These were produced either by dirt particles passing through the oil film, or by corresponding marks on the mating thrust collar runner. The surface condition of the two thrust pads was identical. Most importantly there was no evidence of any localised loading as a result of the misaligned collar. Two more examinations took place at 1000 and 1500 hours and eventually the remaining two units were also converted to PTFE faced thrust pads. At the last report in December 2001 all three units had each accumulated 8500 hours of operation and there has been no reported problems since the conversion to PTFE. The bearings are continuing to perform satisfactorily.
This example clearly demonstrated the forgiving nature of PTFE and its ability to operate in conditions which previously had destroyed a babbitt bearing.

Fig. 3, The same pad as Fig. 2 converted to PTFE faced after 1500 hrs of operation.