Size-for-size Comparisons of PTFE-faced Thrust Bearings in Two Applications, With Correlation Against Analysis

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Abstract

According to published data, some 80% of hydro generator bearings in Russia and associated countries have been fitted with PTFE-faced pads. This bearing material is finding increasing use in North America. Some advantages claimed include higher specific loading, lower power loss and the omission of oil-lift facilities. Also it is claimed that repeated starts and stops can be made under load without damage to the pads or rotor, and with a wear rate that is acceptable.

There is strong interest in the Industry concerning this material, but limited data are available on actual performance. In this paper example results are given from extensive testing of PTFE-faced pads, in two sizes of pad. PTFE and babbitt-faced pads are compared directly, size-for-size. The power losses for the two types of bearing were found to be almost identical. Some of the effects observed during testing are described and discussed, including the effect of creep. The test results are compared with predictions using the GENMAT analysis software. Some new developments in material composition and construction methods are discussed.

Introduction

PTFE–faced thrust bearings were developed in the 1970's in the former Soviet Union, as a consequence of a nation-wide program to increase the power output from hydro facilities. Prior to this (according to Alexandrov [1] and Shen [2]), the usual type of bearing had disk-supported babbitt-faced pads, which were quite lightly loaded as judged by modern standards.

Shen [2] gives an interesting account of the problems that occurred in China when this upgrade was implemented, for example 'break-down occurred in almost every hydroelectric unit through the 1970's'. The upgrade called for an increase of PV from (typically) less than 50 MPa.m/s to 55 – 91.

According to numerous reports (many of which are not formally published) the replacement with PTFE-faced pads 'completely eliminated the wiping-out problem' and allowed the development of bearings of 3000 – 4000 tonnes capacity. It is reported that at present over 80% of hydro generators in the former Soviet Union have this type of bearing, and at least 400 units in the PRC. These developments have attracted strong interest in the Industry in Europe and the Americas but few data are available. Some units in the UK and Ontario have been retrofitted with PTFE-faced thrust bearings, as described by Simmons *et al.* [3], Knox [4], and Mohino *et al.* [5]. However few direct comparisons have been made between PTFE-faced and babbitt-faced bearings. This paper gives size-for-size comparisons for two bearing assemblies with pads of approximately 130 mm x 140 mm size and 306 mm x 260 mm size. The PTFE and babbitt bearings were tested in sequence in the same test machines.

Advantages claimed for PTFE-faced bearings

In publications such as [1,2] and others, the advantages over conventional babbitt- faced bearings are described as:

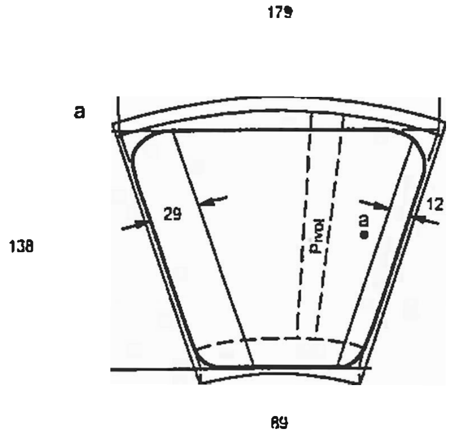
1. Reliable operation to specific pressures of 10 MPa and above
2. Reduced power loss
3. Reduced thermal crowning of the pad, so that features used to reduce thermal deflection in babbitt-faced pads need not be applied
4. Reduced oil-film temperature. (As claimed in some publications)
5. No requirement for an oil-lift (jacking) system during starting and stopping
6. No scoring damage to the runner surface in the event of a failure
7. No dwell time required before re-starting
8. More relaxed tolerances on pad thickness and flatness

Bearings tested

Size	*Bearing #1*	*Bearing #2*
Mean pitch diameter, mm	464	912
Pad size: circum., on mean radius, mm	133	306
radial, mm	140	260
Thickness of PTFE, mm	5	2
Overall thickness of pad, mm	40	38.1
Number of pads	8, also tested with 4 removed	as for #1
Support system	Offset radial line	Set of 25 springs, offset
Test conditions		
Sliding speed, m/s	to 41 m/s	8 pads,24 m/s; 4 pads,28 m/s
Specific loading, MPa	to 10.2 (4 pads)	8 pads,5 MPa;4 pads,10 MPa
Lubricant, ISO	32	32
Bath temperature, °C	40 - 70	70
Suppliers	Electrosilia, Russia	Liao Yuan Scientific Institute, China
Principal references for test facilities	Simmons *et al.* [3] Horner *et al.* [6]	Yuan *et al.* [7]

Table 1 Bearing size and test conditions

Bonding method used for thrust pads



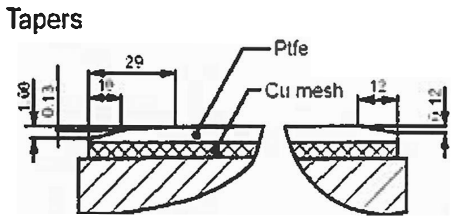


Fig 1. Pads in bearing #1 *Tapers on the lead and trail edges*

A 5 mm plate of pure PTFE is clamped against a matrix of copper wire matting and the assembly is heated. PTFE is extruded into the matrix for about 1.0 – 1.5 mm giving a mechanical bond when cooled. The matrix is then soldered to the steel backing. The face of the finished assembly is ground and the tapers are added at the leading and trailing edges. More recent techniques of production (Knox, [4]) use a thinner layer of carbon-filled PTFE, with the matrix being almost filled with solder

The size of bearing #1 is typical of a medium-large pump, and is smaller than a significant hydro application. The pads were too small to show the thermal deformation problems associated with large thrust pads, but were convenient for initial tests. The pads were initially tested as a set of eight, and later as a set of four to extend the range of specific load. Thermocouples were installed in the PTFE about 3 mm from the surface, but as will be shown, these gave no indication of the temperature in the oil film. Later in the test program some of the thermocouple holes were drilled straight through to the surface, with the beads of the thermocouples positioned about 3 mm from the surface. These were found to give a more representative measure of film temperature.

The pads were supplied with extensive tapers on the lead and trail edges (Fig 1). These are much larger than would normally be considered necessary and are thought to assist in the formation of a film, especially at start-up. With babbitt pads it is usual to only 'radius' the pad edges. The trailing edge taper appears to perform a useful function in supporting the trailing edge, as is discussed later. The tolerance on dimensions and flatness of the PTFE pads of both bearings appeared to be much looser than for babbitt bearings.

The babbitt-faced pads used for comparison were made to identical dimensions, with identical features on the surface. As with the PTFE pads, when calculating the specific pressure, the trailing taper and the first section of the double leading taper were neglected. The power loss was calculated from the flow and temperature rise of the oil supply, and includes losses in the support and reaction bearings. About 85% of the overall losses can be assigned to the test bearings.

Analysis model

The computed results were obtained using the GENMAT software described in references [8,9]. Some of the features included are:

1. An integrated treatment of heat transfer in the film, pads and rotor in three dimensions, which included the presence of the PTFE and copper-matrix layers
2. Thermo elastic deflection of the pads and deformation of the surface layer.
3. Super-laminar and turbulence effects in the film
4. The inclusion of a hydrostatic oil lift of any general plan shape.
5. Hard support of the pads, for example on line or disk supports, or on an arbitrary arrangement of springs (as for bearing #2).
6. "Carry-over" of hot oil between pads is allowed for by solving the turbulent boundary layer equations in the grooves between pads
7. Thermal bowing of the rotor is included