Like for like performance comparison of PEEK and PTFE thrust bearings for use in vertical pump and motor applications
Comparaison à l'identique des performances de paliers de butée en PEEK et PTFE destinés aux applications de pompes et de moteurs verticaux.

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Over the past two decades polymer lined hydrodynamic bearings have received much publicity and been shown to offer advantages over whitemetal (Babbitt) lined bearings in a number of circumstances. In particular, both PTFE and PEEK have demonstrated their ability to sustain higher loads than whitemetal, which in turn results in more compact designs and therefore lower associated power losses. More recently PEEK has been publicised as having superior material properties to PTFE with the implication therefore that it must yield superior performance. However there has been very little work undertaken to directly compare the like for like performance of the two materials.

This paper details test work performed with sets of 80mm PEEK and PTFE lined thrust pads, both with identical geometry. Each set was tested at a range of duties typically experienced in vertical pump and motor applications, with sliding speeds between 2.5m/s and 21.2m/s, and specific loads up to 7MPa. The results indicate that within the duty ranges tested PEEK pads can experience operating difficulties, whereas PTFE pads are unaffected and continue to perform as expected.

Au cours des deux dernières décennies, les paliers hydrodynamiques rechargés en polymères ont connu une large publicité et ont démontré qu'ils présentaient des avantages par rapport aux paliers recouverts de métal blanc (régule ou Babbitt) dans un certain nombre de circonstances. En particulier, le PTFE et le PEEK ont démontré leur capacité à supporter des charges plus élevées que le métal blanc, ce qui permet des conceptions plus compactes et donc des puissances absorbées plus faibles. Plus récemment, il a été affirmé que le PEEK possédait des propriétés en tant que matériau supérieures à celles du PTFE, ce qui impliquait donc des performances supérieures. Cependant, très peu de travaux ont été entrepris pour comparer directement les performances des deux matériaux dans des conditions identiques.

Ce document détaille les essais effectués avec des ensembles de butées de 80 mm en PEEK et PTFE, tous deux de géométrie identique. Chaque ensemble a été testé pour différentes conditions généralement rencontrées dans les applications de pompes et de moteurs verticaux, avec des vitesses de glissement comprises entre 2,5 m / s et 21,2 m / s et des pressions spécifiques pouvant atteindre 7MPa. Les résultats indiquent que, dans les limites des plages de charge testées, les patins avec PEEK peuvent rencontrer des difficultés de fonctionnement, alors que les patins avec PTFE ne sont pas affectés et continuent de fonctionner comme prévu.

1 Introduction

Over the past two decades polymer lined hydrodynamic bearings have received much publicity and been shown to offer advantages over whitemetal (Babbitt) lined bearings in a number of circumstances. PTFE (Polytetrafluoroethylene) is now well established in the hydro industry having been developed as a thrust bearing lining material in the 1970's [1] to overcome persistent hydrogenerator thrust bearing failures in the former Soviet Union. By 1990 the vast majority of hydro-electric power stations in Russia had been fitted with PTFE lined thrust bearings [2]. Since then much work has been undertaken [3, 4, 5, 6, 7] to understand the performance of PTFE thrust pads. Today, the current performance and reliability of PTFE technology is such that many large machines have been designed and built with PTFE faced pads as the first choice.

The advantages of using PTFE linings in large thrust pad applications include:

- Higher load carrying capability: Specific loads in excess of 10MPa are cited [6, 7] and certainly Michell Bearings has thrust pads operating in service at 6.3MPa.
- Reduced thermal crowning: PTFE is an insulator, so the thermal gradient through the thickness of the pad is lower, leading to a reduction in distortion and resulting in a flatter operating surface [6, 7].
- Higher starting load capability: Michell Bearings has tested the breakaway capability of PTFE thrust pads under specific loads of 7MPa [8] and supplied bearings for Pelton turbine applications with starting loads of up to 6.2 MPa.
- Durability: PTFE lined thrust pads have proven successful in highly misaligned conditions where whitemetal lined pads have previously failed [5]. In addition, service life of more than 20 years for a single set of pads is reported [8], with the pads undergoing 12-13 start/stops per day.
- Reduced coefficient of friction: PTFE has a much reduced coefficient of friction compared to whitemetal. Tests have shown that PTFE has a breakout coefficient as low as 0.06 compared to 0.18 for whitemetal [8].
- Reduced power loss: Higher load carrying capacity enables a reduction in bearing size to be realised, resulting in power loss savings typically in the order of 20-30% [9]. On several occasions the author's company has been able to reduce thrust surface areas allowing air cooled rather than water cooled bearings to be used.

In contrast, the development of PEEK (Polyetheretherketone) as a tilting pad lining material for hydro applications originated in Japan in the early 2000's, but only a few installations have subsequently been reported [10,11]. Other PEEK applications have included special process fluid lubricated bearings and oil lubricated bearings for high speed turbomachinery using small thrust pads [12]. Like PTFE, PEEK has the same claimed advantages when compared to whitemetal, but the material properties of the two polymers have been shown to differ significantly [13, 14]. Compared to PTFE, PEEK exhibits higher strength, stiffness, dimensional stability with temperature and resistance to creep. The implication therefore is that PEEK with its superior material properties must yield superior performance. However, there has been very little work undertaken to directly compare the like for like performance of the two materials in commercially available bearings routinely installed in typical industrial applications.

PTFE thrust pads have been shown to offer advantages over whitemetal not only for large hydrogenerator sized pads, but also for typical reversing vertical pump applications with small (80 mm) thrust pads [15]. In pump applications it is normal to have a requirement for the bearings to sustain short duration reversals unless an anti-rotational backstop is fitted. Hence, unlike the majority of hydro-generators, the bearing thrust pads must be capable of accepting such rotation reversals and, in many cases it is specified that the bearing must be capable of accepting full load during these periods of reverse operation [16].

Although either offset or centre pivot thrust pads can be used for reverse rotations, the advantage of using offset pivot pads in pump applications has long been recognised by leading pump manufacturers. That is the safety and reliability of the thicker and cooler working oil film generated by an offset pivot is utilised during the longer periods of normal forward rotation, with the much shorter durations of reverse rotation (e.g. pump head run-down) being accommodated with acceptance of a slight performance penalty. Whilst it is well established that whitemetal and PTFE lined thrust pads are able to tolerate rotation reversals with offset positioned pivots [5, 6, 8, 15], this is not the case for PEEK lined pads, with no published work known to the authors.

This paper reports the results of a test programme in which PEEK lined 80mm sized offset pivoted thrust pads were tested in forward and reverse rotations. The thrust pads were tested in a mid-range frame size of vertical bearing commonly used in pump and pump motor applications. The test duties replicated those applied to a set of identically sized PTFE lined thrust pads tested previously [15]. The range of test speeds matched those typically experienced in pump applications, but at specific loads significantly higher than those established for whitemetal thrust pads. The results for the PEEK lined pads are compared to those published for the identical PTFE lined pads [15] to determine whether the 'superior' properties of PEEK would translate into superior performance.

2 Test bearing and equipment

The test bearing and loading arrangement is shown in Figure 1 and is identical to that used in the previous PTFE tests [15]. Oil is supplied to the test bearing from an external source and is drawn through the working elements via the pumping action of the rotating thrust collar, which is attached to the shaft. The oil then flows to drain over a weir, which ensures that the test pads are fully submerged with oil. The loading module uses hydraulic pistons to force the shaft downwards against the test thrust pads, which are situated beneath the thrust collar. Forward rotation is defined as clockwise rotation when viewing the shaft and test bearing from above.

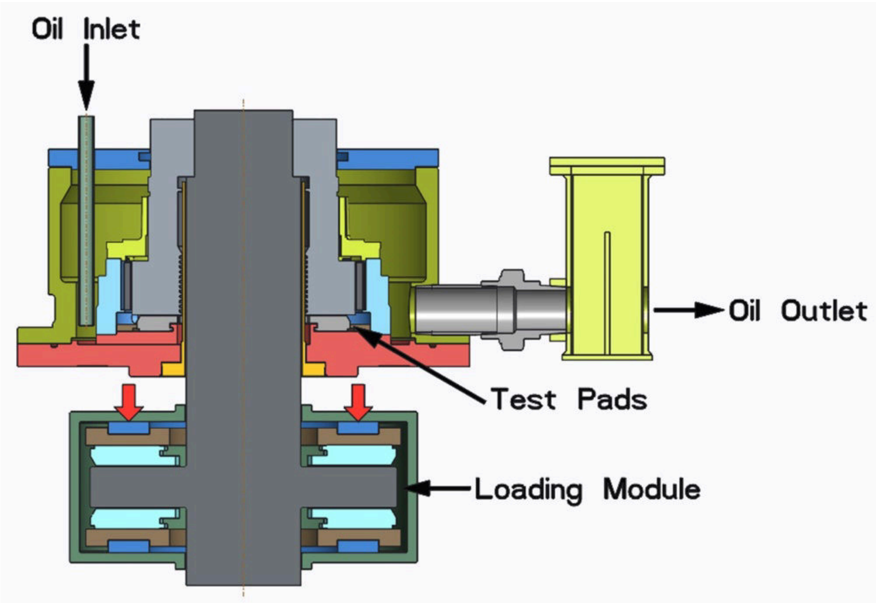

Figure 1 – Test bearing and loading arrangement

The grade of PEEK used was reinforced with 30% carbon fibre, graphite and PTFE. Four of the eight thrust pads contained miniature thermocouples to measure pad temperatures in the same manner used for the PTFE tests. The thermocouples were embedded into the steel backing in both the leading and trailing outer quadrants of the thrust pads. Small holes were drilled through the PEEK surface to meet up with the tips of the thermocouples, hence ensuring that the thermocouples were measuring the oil temperature in the oil film itself. The position of the thermocouple for forward rotation is shown in Figure 2 and the dimensions of the test pads are shown in Table 1. In addition to fitting thermocouples into the thrust pads, probes were also appropriately positioned to measure oil inlet, oil outlet and oil bath temperatures.

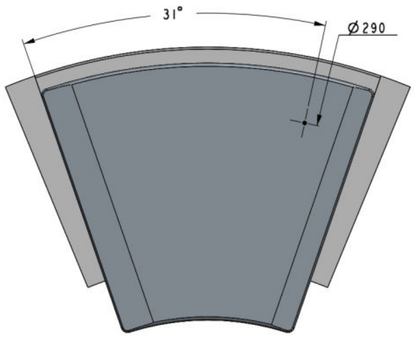

Figure 2 – Test thrust pad showing thermocouple position

Number of thrust pads	8
Outside diameter (mm)	321
Inside diameter (mm)	161
Mean pressure diameter (mm)	254
Thrust pad radial width (mm)	80
Pad angle (degrees)	38
Pivot position (% of pad angle)	60%

Table 1 – Test pad dimensions

3 Test programme

The objective of the test programme was to subject the PEEK thrust pads to identical test duties previously applied to the equivalent sized PTFE pads [15]. Hence, specific loads of 2 to 7MPa would be applied, in both forward and reverse rotation directions, over a speed range of 190 to 1600 rev/min (2.5 to 21.2m/s sliding speeds measured at the mean pressure diameter of the pad). Like the PTFE pads, the PEEK pads were to experience the maximum loading at both the maximum and minimum speed in both directions of rotation. Several cycles of testing were planned with the direction of rotation being reversed between each cycle. The minimum duration of testing at any single duty point was to be 1 hour and the maximum 8 hours. This duration would depended upon the severity of the particular duty in question. The most arduous duties, namely the highest loads at either highest or lowest speeds would be tested for the longest periods whilst less time was to be spent on more moderate cases. Temperature readings were taken once temperature equilibrium conditions were established. Throughout the test, the bearing was fed with ISO VG 32 turbine grade mineral oil at a constant flow of 25 litres/min. The oil inlet temperature was 42°C (±1°C).