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„Effect of PTFE retainer on friction coefficient in polymer thrust bearings under dry contact“

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Effect of PTFE retainer on friction coefficient in polymer thrust bearings under dry contact

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Abstract.
Polyetheretherketone (PEEK) is a tough semi-crystalline thermoplastic polymer with excellent mechanical properties. While abilities of polyphenylenesulfide (PPS) are similar to PEEK, former material cost was lower than later. Polytetrafluoroethylene (PTFE) is well known because of its low friction coefficient and self lubrication ability. The objective of this study is to observe the friction coefficient of hybrid bearings, PTFE retainer sandwiched with PPS-races or PEEK-races. Rolling contact fatigue tests were performed and in situ friction forces wear measured. It is concluded that the PTFE retainer reduced friction coefficient.

Introduction

A wide range of materials are presently used for the production of bearings: high carbon chromium bearing steels, carburized steels, ceramics, and polymers. Among these materials, polymers are chosen for applications, where light weight, nonmagnetic and high corrosion resistance are required.

Polyetheretherketone (PEEK) is a tough semi-crystalline thermoplastic polymer with excellent mechanical properties [1-4]. While abilities of polyphenylenesulfide (PPS) are similar to PEEK, former material cost was lower than later [5-8]. Polytetrafluoroethylene (PTFE) is well known because of its low friction coefficient and self lubrication ability [9].

Excellent mechanical properties, high corrosion resistance and self-lubrication ability is what makes both PPS and PTFE adequate materials to be employed in dry, corrosive (chemical), erosive (electrical) and abrasive environments [10]. Due to the above mentioned properties, bearings manufactured from these materials are expected to provide excellent performance in functions, such as sliding bearings [11] or joint replacements [12].

Rolling contact fatigue (RCF) behavior of PEEK bearings was investigated under dry conditions [13-18] and it was concluded that wear loss is strongly related with the friction coefficient. Therefore, decreasing the friction coefficient is crucial to decrease the wear loss and hence extend the life of bearing components.

In our previous works [19, 20] polymer bearing specimens were rolling contact fatigue (RCF) tested under dry contact. PEEK-race, PPS-race, PEEK-retainer, PPS-retainer, and PTFE retainer were used. Based on wear loss measurement and roughness observation on wear track, wear loss originating from PTFE retainer was lower than others because the wear debris from PTFE retainer adhered wear surface [20].

In the present study, the effect of wear debris originating from PTFE retainer on friction coefficient was investigated. RCF tests were performed to measure friction coefficients under dry contact.

Test method

Specimens. The geometry of the bearing specimens was designed based on the JIS B 1513 #51305 standard. The outer diameter was 52mm, the inner diameter was 25mm and the pitch circle diameter was 38.5mm.

Figure 1(a) is a photo of unreinforced PEEK race (VICTREXc450G) and Fig. 1(b) is for unreinforced PPS (TECHTRON® PPS). Fig. 1(c) and (d) show the PEEK retainer and the PPS retainer (material equal to that of the races). Fig. 1(e) is for PTFE retainer made of composite PTFE (Du Pont-Mitsui Fluorochemicals), containing 25% carbon graphite and 75 % pure PTFE. Each retainer held nine 9.525 mm (3/8") diameter Al_2O_3 balls. The physical and mechanical properties of the material are shown in Table 1.

All thrust bearing sets used in this study consisted of two races and a retainer. The specimens comprising PTFE retainers will be thereinafter referred to as "Hybrid PEEK" or "Hybrid PPS" bearings. Specimens comprising only PEEK or PPS elements will be referred to as "PEEK" or "PPS" bearings, was respectively.

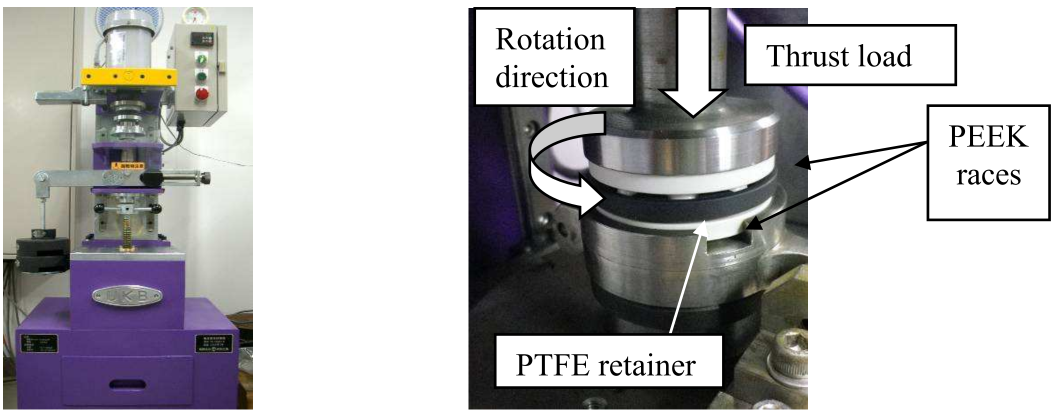
Rolling contact fatigue test. All specimens were cleaned in an ultrasonic bath, in ethanol prior to testing. The RCF tests were conducted using a thrust type machine shown in Fig. 2(a). All tests were performed under dry conditions, as shown in Fig. 2(b). The rotation speed of the machine was 900rpm. The total number of rotating cycles was 2.88×10^5.

(a) PEEK race. (b)PPS race. (c) PEEK retainer. (b)PPS retainer. (e)PTFE retainer.

Fig. 1 Bearing sample elements.

Table 1 Test material properties.

	PEEK	PPS	PTFE
Melting point, °C	334	278	327
Glass transition point, °C	143	90	130
Specific density, g/cm^3	1.32	1.35	2.10
Tensile strength, MPa	97	83	18
Bending strength, MPa	156	142	9.41
Bending elastic modulus, MPa	4100	3900	1166



(a) Photograph of the device. (b) sample holder detail.

Fig. 2 RCF test machine.

Friction coefficient measurement. Figure 3 shows the friction measurement method. As the bearing rotates, the lever connected to the sample holder applies a pressure to the load cell. The friction coefficient was calculated based on the following equation:

$$\mu = \frac{F \cdot R}{L \cdot r} \tag{1}$$

where F is the load applied to the load cell (N), R is the distance from the center of bearing to load cell (mm), L is the thrust load (N), and r is the pitch radius (mm).

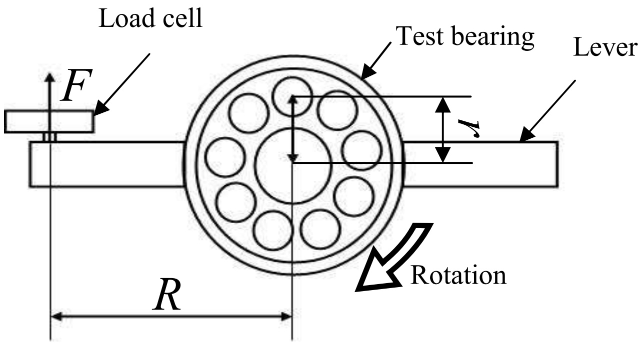


Fig. 3 Schematic illustration of friction coefficient measurement method.

Results and discussions

Friction coefficient. Figure 4 shows the relationship between the number of cycles and the friction coefficient in PPS-races bearings. The friction coefficient increased at the beginning of the test and stabilized after $8{\times}10^4$ cycles. For the PPS samples tested at 600 rpm and 200N, it reached 0.05, the highest value for these conditions.

Figure 5 shows the relationship between the number of cycles and the friction coefficient in PEEK-races bearings. The friction coefficient decreased at the beginning of test and stabilized after 10^3 cycles. The friction coefficient of hybrid bearings was lower than that of PEEK bearings. This feature was similar to PPS-race's bearings. This indicated that PTFE retainers reduce friction coefficient in the present conditions.

The time when the peak stabilized was shorter than that of PPS-races. The friction coefficient of PPS bearings was higher than that of PEEK bearings. This means that the lifetime of PEEK was lower than that of PPS [19, 20].

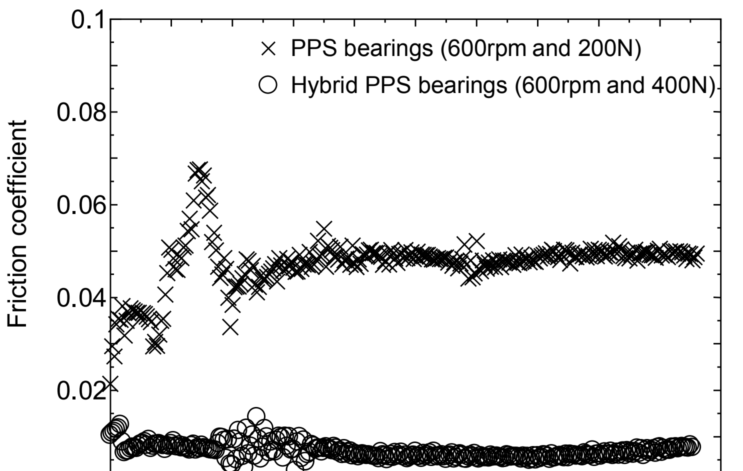


Fig. 4 Relationship between number of cycles and friction coefficient in PPS-races.

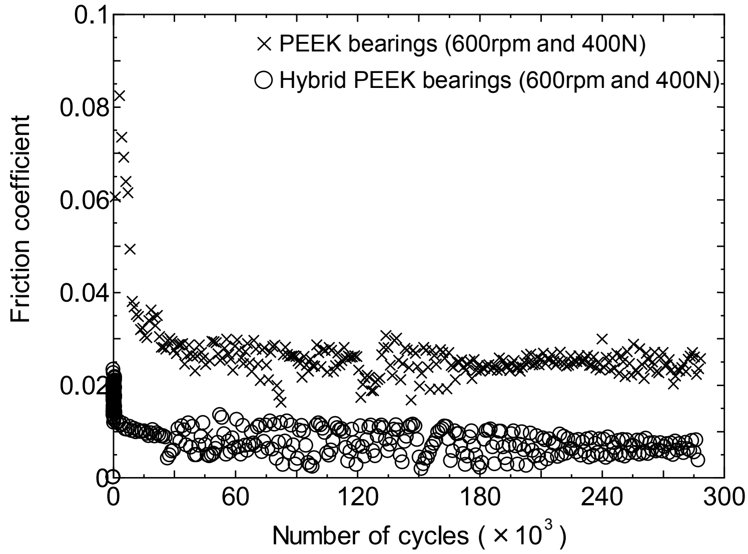


Fig. 5 Relationship between number of cycles and friction coefficient in PEEK-races.

Conclusions

Rolling contact fatigue tests under dry condition were performed in order to investigate the effect of wear debris originating from PTFE retainer on friction coefficient. From the performed tests the followings conclusions were drawn:

(1) The friction coefficient in the PTFE retainer element was lower than that in other retainer element.

(2) The friction coefficient of PPS bearings was higher than that of PEEK bearings.

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