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On dry sliding friction and wear behavior of PPESK filled with PTFE and graphite

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Abstract

Novel poly(phthalazinone ether sulfone ketone) (PPESK) resins have become of great interest in applications such as bearing and slider materials. In this paper, dry sliding wear of polytetrafluoroethylene (PTFE) and graphite-filled PPESK composites against polished steel counterparts were investigated on a block-on-ring apparatus at the same sliding velocities and different loads. The results indicated that the addition of 5–25 wt% PTFE and 5–30 wt% graphite contribute to an obvious improvement of tribological performance of PPESK at room temperature. Worn surfaces were investigated using a scanning electron microscope (SEM). As a result, the friction coefficient and wear rate of the PPESK composites decreased gradually with addition of fillers. A moderately low friction coefficient and specific wear rate were reached when the filler contents were above 20 wt%. The mechanical properties of PPESK composites were also investigated. The tensile and impact strength of PPESK composites decrease slightly as the addition of fillers contents were below 15 wt%.

Keywords: Poly(phthalazinone ether sulfone ketone) (PPESK); Graphite; Polytetrafluoroethylene (PTFE); Friction and wear

1. Introduction

Polymer can be considered to be one of competitive materials for tribological applications because of their low friction values against steel counterparts, good damping properties, and self-lubricating abilities. In order to meet the special need of tribological application, e.g. concerning one or several measurable material properties, polymer composites can be designed by selecting the correct composition and choosing the appropriate manufacturing process. Polymer composites containing different fillers and/or reinforcements are frequently used for these purposes.

As is known to all, the matrix of the tribological material should have high-temperature resistance and high cohesive strength. There are many high-performance materials that can be used as matrixes, such as poly(ether ether ketone) (PEEK), polyimide (PI) and polyethersulfone (PES). A number of their composites have been prepared for tribological materials and their tribological properties were also investigated in recent years [1–8]. In order to reduce the friction coefficient, internal lubricants such as PTFE, graphite, short glass fibers and carbon fibers were utilized individually or incorporated frequently. PTFE and graphite are almost the most important and promising solid lubricants in controlling friction, wear or both in polymer composites. PTFE and graphite-filled polymeric materials have been discussed in the tribological studies in many articles published recently [9–14].

A novel polymeric material, poly(phthalazinone ether sulfone ketone) (PPESK) [15,16], has extremely high glass transition temperature (T_g is in the range 263–365 °C), thermo-oxidative stability and superior mechanical properties. In the last few years, much attention have been paid to achieve either by chemical modification via direct synthesis using different monomers or physical modification via blending process to improve their manufacture ability. However, to our knowledge, few systematic studies on the

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preparation and tribo-properties of PPESK composites have been reported.

In this work, we studied the influence of the PTFE and graphite contents in PPESK composites on mechanical properties and tribo-performance. Moreover, the friction and wear mechanism of PPESK composites were also discussed.

2. Experimental

2.1. Material and manufacturing

The PPESK resins (grand 8020) were provided by Dalian University of Technology (Liaoning Province, China); Mw was 75,000 g/mol and the melt viscosity was 8×10^3 Pa s (shear rate: 14.4 s^{-1}). PTFE and graphite were selected as traditional fillers to enhance the friction and wear resistance of PPESK matrix. The particle size of PTFE was about 4 μm ($\ngtr$5 μm) and for the graphite around 20 (10–25 μm).

The fillers (PTFE and graphite) and PPESK were kept in an oven at 120 °C for 4 h before the mixing process. After premixing of the powders for 5 min in a high-speed powder mixer, the composites of PPESK/PTFE and PPESK/graphite with different filler ratio were prepared by a two-screw extruder in the temperature range 300–340 °C. Finally, all the test specimens were manufactured using an injection molding machine and cut for the three-dimensional size $12 \times 10 \times 4\,mm^3$.

2.2. Mechanical properties

A pendulum-type charpy impact machine tester (CHARPY XCJ-4) was applied to investigate the unnotched impact testing according to ASTM D256. The dimensions of unnotched specimens were $50 \times 6 \times 4\,mm^3$. Tensile tests were carried out at a speed of 10 mm/min on a SHIMADZU Autograph testing machine (AG-2000A) according to ASTM D638. All mechanical tests were performed at room temperature.

2.3. Friction and wear testing

In order to determine the tribological properties of PPESK composites, dry sliding wear tests were carried out on a block-on-ring apparatus (MM-200). The main parts of the apparatus are shown schematically in Fig. 1.

The composite specimens were rotated against a 45# Cr6 steel ring and lasted for 60 min. Different pressures (50 and 500 N) and the same sliding velocities (0.419 m/s) were applied. The contact surface of the composite block and the carbon steel ring were pre-worn with 800# grinding paper and washed using acetone. The mass loss of the specimens after experiments, Δm, was measured, and the specific wear rate (ω) of the material was calculated by the following equation

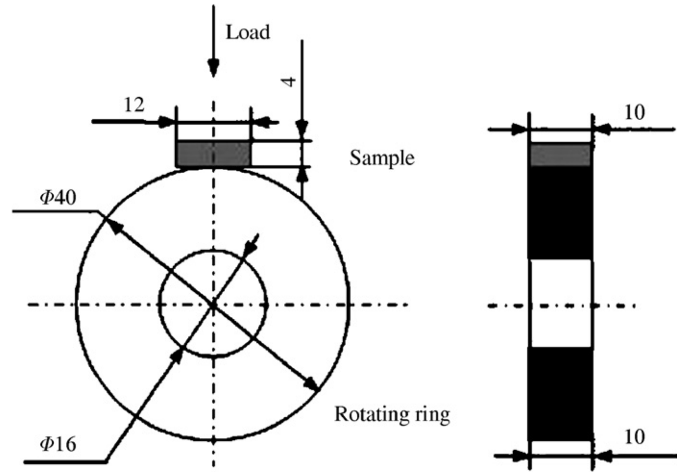

Fig. 1. The contact schematic diagram for the frictional couple.

$$\omega = \frac{\Delta V}{F_N L} = \frac{\Delta m}{\rho F_N 2\pi R t r} \quad (mm^3/N\,m), \tag{1}$$

in which ΔV is loss in volume, F_N the normal load, L the sliding distance, ρ the density of the specimen, R the radius, t the testing time and r the rotation rate.

2.4. Scanning electron microscope (SEM)

An SEM (JEOL-JSM-5600) was used to analyze the worn surfaces of PPESK composites.

3. Results and discussions

3.1. Mechanical properties

Table 1 shows that both the tensile strength and unnotched charpy impact of PPESK filled with PTFE or graphite decrease gradually with increase in filler concentrations. The tensile strength of PPESK/PTFE decreased slightly when the PTFE content was below 15 wt%, and then decreased sharply with the addition of PTFE beyond 15 wt%. The similar tendency was also observed for graphite/PPESK composites. It was mainly attributed to the weak interface interaction between PPESK and fillers, and PTFE or graphite aggregate easily as the filler concentrations increase over 15 wt%.

3.2. Effect of PTFE in PPESK

The sliding time dependence of friction coefficient of the PPESK/PTFE composite was shown in Fig. 2. At the beginning of the sliding stage the friction coefficient decreased remarkably and fluctuated slightly after sliding duration of 15 min. Neat PPESK showed very high friction coefficient (about 0.63) under the lower testing load 50 N. This phenomenon became more obvious as a higher testing load 500 N was applied. In this case, it was in 5 min that the neat PPESK specimens were seriously worn. The composite