Preparation of CF/PEEK and Study on Friction Performance

Pengyuan Gao, Yanjun Wang†, Dezhang Meng, Xin Zhou and Lei Liu

School of Mechanical Engineering, University of Jinan, Jinan, China

†Corresponding author: yanjunwang@ujn.edu.cn

Abstract. Vacuum sintering technology is used to prepare PEEK composite materials. The friction and wear test of polyether ether ketone (PEEK) and its composite materials under different temperature and dry friction conditions was carried out using a ball-disk friction and wear test machine. Scanning electron microscope and white light total three-dimensional profiler were used to observe the surface morphology of the material before and after wear, and compare the material surface before and after the experiment, Study the effect of carbon fibre content and temperature on the tribology properties of materials. At the same time, the wear mechanism of the material is studied.

1. Introduction

With the development of contemporary society, Due to its excellent performance, composite materials have been widely used as anti-wear and wear-resistant materials in many occasions instead of traditional metals, PEEK is one of them. The coefficient of friction of PEEK at room temperature is 0.34, and its glass transition temperature is about 143 °C and melting point is about 343 °C. PEEK has a series of excellent properties, such as high temperature resistance, corrosion resistance, fatigue resistance, high mechanical strength, excellent fluidity, easy processing, etc., and also has good dimensional stability, flame retardant and insulation.

The research results of Chu Tingting and others [1] showed that PEEK can reduce the friction coefficient of PEEK and has excellent comprehensive performance. Cai Zhenjie [2] found through experiments that when PTFE fine powder is added, the amount of wear of the material under oil lubrication shows a decreasing trend, and under water lubrication shows an increasing trend. Zhang Zhiyi [3] preliminarily studied the effect of carbon fibre on the friction and wear performance of PEEK and studied its wear mechanism. Wu Xinxin [4] found that PEEK material has outstanding tribology characteristics, especially can maintain excellent wear resistance and low friction coefficient at high temperature of 250°C. Wang Wancheng [5] and others have shown that PEEK has a low coefficient of friction under water lubrication conditions, which can effectively extend the service life of the material. Xiao Bowen [6] proved through experiments that PEEK and its composite materials with the increase of PV value, the more obvious the difference in wear rate. The research of Tharajak J [7] shows that the wear rate of PEEK is low under the conditions of 100 degrees and 200 degrees, and the effect of boron nitride content is not significant. PEEK is considered to be an ideal polymer wear-resistant material, and is widely used in electrical and electronic engineering, automotive engineering, packaging and paper processing machinery, transportation technology, chemical engineering, aerospace and other fields.

With the development of society, a single polymer material can no longer fully meet the requirements of the wearer on the wear resistance of the material, therefore, doping with PEEK and other materials to reduce its friction coefficient and wear rate to make it exhibit more excellent wear resistance has become
an important research direction. In order to meet the needs under actual working conditions, PEEK is often blended, filled and fibre-reinforced to obtain more excellent composite materials. Sasuga T and other [8] experiments have shown that adding glass fibre or carbon fibre to PEEK resin can greatly improve the rigidity, dimensional stability, impact strength, tensile strength and bending strength of the material. Both CF and GF can make the load thermal deformation temperature exceed 300 ℃, and at the same time, the tensile strength and friction performance are greatly improved. Experiments by Yi Meng et al. [9] showed that pure PEEK has the largest wear volume under dry friction, and the wear of composite materials can be improved after adding GF, CF, and PTFE.

In this paper, the tribological characteristics of three kinds of PEEK with different carbon fiber content are studied to analyze the tribological behavior of the material and the effect of carbon fiber content on the friction and wear characteristics of PEEK. To provide experimental basis for improving PEEK composites friction and wear characteristics.

2. Materials and methods

2.1. Sample preparation

The PEEK-based composite material is prepared by vacuum hot pressing sintering method. First, the powder is ball milled, dried and then loaded into a mould. A hydraulic press is used to apply 30MPa pressure to reduce the air in the powder and then placed in the sintering furnace. Before heating, the pressure of the sintering furnace is lowered to less than 10⁻¹Pa, the temperature is raised to 240℃ for 30min, and the pressure is slowly applied to 10MPa, and finally the temperature is raised to 300℃ for 40min to ensure the bonding degree of the PEEK composite material, so that the composite material has better overall performance.

2.2. Experimental method

Cut PEEK and its composite materials into 10mm × 10mm × 5mm samples, Pre-grind and polish one surface of the three sample blocks with a metallographic test pre-grinding machine. The hardness of the three specimens was measured using a micro Vickers hardness tester. The samples were cleaned ultrasonically before and after the experiment, and the quality of the samples before and after wear was measured. Affiliations of authors should be typed in 9-point Times. They should be preceded by a numerical superscript corresponding to the same superscript after the name of the author concerned. Please ensure that affiliations are as full and complete as possible and include the country.

The friction and wear test was carried out on the RTEC MFT-50 friction and wear test machine, and the friction and wear experiments were carried out on the sample block using GCr15 ball, PEEK ball, zirconia ceramic ball and silicon nitride ceramic ball, The performance of the four types of grinding balls is shown in Table 1. The experimental load is set to 30N, the reciprocating frequency of the test machine spindle is 2Hz, the spindle stroke is 4.5mm, the wear time is set to 30min, and the experiment is conducted at room temperature. The change curve of friction coefficient with time is directly obtained from the test machine, and the change curve is fitted with Origin. Ultrasonic ethanol was used to clean and dry the abraded surface of the sample block, and then the three-dimensional morphology of the surface of the three sample blocks after abrasion was observed with the USP-Sigma test machine. After spraying gold on the surface of the three specimens, the surface morphology of the three specimens before and after abrasion was observed with a scanning electron microscope, impact and wear mechanism for carbon fibre PEEK tribology properties.

| material | GCr15 | PEEK | ZrO₂ | Si₃N₄ |
|----------|-------|------|------|-------|
| Hardness (HV) | 750   | 50   | 1100 | 1500  |
| Diameter(mm)   | 6.5   | 6.35 | 6.0  | 6.0   |
3. Results and discussion

3.1. Mechanical properties

Table 2 shows the test results of the hardness of the three materials. It can be seen from the table that the carbon fibre content has little effect on the hardness of PEEK. The hardness of carbon fibre is higher than that of PEEK, but the addition of carbon fibre does not affect the hardness of PEEK.

| material          | PEEK | 10%CF/PEEK | 30%CF/PEEK |
|-------------------|------|------------|------------|
| Hardness (HV)     | 25.21| 27.22      | 30.83      |

3.2. Tribology properties

Figure 1 is a line chart of the average friction coefficient of the three materials under different pairs of grinding balls. As can be seen from Figure 3, the addition of carbon fibre reduces the friction coefficient of the material. Carbon fibre replaces the matrix and directly bears the external load, reducing the interaction between PEEK resin and the surface of the abrasive. Carbon fibre plays a better role in lubricating, and makes the composite material have less friction and friction coefficient. The friction coefficient between 10% CF / PEEK and 30% CF / PEEK is not large, the increase has been reduced.

Fig 1. Average friction coefficient of three materials

Figure 2 is the change curve of friction coefficient of three materials under different conditions of grinding balls. Figures (a), (b) and (c) are PEEK, 10% CF / PEEK and 30% CF/PEEK in four As can be seen from the figure, the change curve of friction coefficient under the condition of grinding ball, it can be seen that when the materials of the grinding balls are ZrO2, GCr15, Si3N4, the friction coefficients increase first and then tend to stabilize. In the early stage of wear, the friction coefficient between the GCr15 ball and the material increased the fastest, followed by Si3N4, and ZrO2 the slowest. The friction coefficient of the three materials on the grinding ball eventually tends to the same value, and the three materials have little effect on the friction coefficient of the grinding ball.
3.3. Surface Topography Analysis

In figure 3 (a), (b) and (c) are PEEK, after 10%CF/PEEK and 30%CF/PEEK wear microscopic three-dimensional surface topography. It can be seen from the figure that the depth of the PEEK wear scar is
0.21mm, and the wear is the most serious. The depth of the CF/PEEK wear scar is relatively shallow, indicating that carbon fibre can improve the friction and wear performance.

**Fig.3.** Microscopic three-dimensional topography of the surface after wear

Figure 4 is the surface morphology of the material before friction. It can be seen from the figure that the surfaces of the three materials are relatively smooth, 10% CF / PEEK and 30% CF / PEEK are darker in colour, which is due to the addition of carbon fibre.
Figure 5 is the surface morphology of the material after wear. It can be seen from figure 5 that after the wear of the PEEK surface, there are some debris and wrinkles generated by the wear on the surface, and no obvious furrows and pits appear. PEEK produces a transfer film on the surface in the process of friction and wear, which can play an important role in the process of friction and wear. 10% CF/PEEK surface did not show debris from wear, and there were no obvious scratches. This is due to the low carbon fibre content. The carbon fibre can be better dispersed in PEEK, which is conducive to the reunion of fibre and PEEK. The wear performance of the material makes the material have a lower friction coefficient and reduces the wear volume. 30% CF/PEEK wear surface produced abrasive debris and more obvious scratches, which may be due to the high carbon fibre content, carbon fibre cannot be completely dispersed in PEEK, so in the process of friction and wear, carbon fibre is ground, Exists in the friction pair and produces abrasive wear, resulting in more obvious scratches.

4. Conclusions
The hardness of CF / PEEK increases with the increase of carbon fibre content. When the grinding ball material is ZrO2, GCr15, Si3N4, the friction coefficient is increased first and then tends to be stable, while when grinding with the PEEK ball friction coefficient has been rising in a short time, and the friction coefficient finally stabilized High value, more abrasive debris is generated during the wear process, causing visible wear marks. In actual working conditions, try to avoid using the same materials to contact and wear each other.

The presence of carbon fiber can improve the friction and wear performance of the material. This is because the wear debris generated by the carbon fiber during friction and wear plays a certain lubricating role, but the enhancement effect of carbon fiber on the friction and wear performance of PEEK is not with the increase of the carbon fiber content the proportion increases, but there is an optimal content. After exceeding the optimal content, carbon fiber will adversely affect the friction and wear performance of the material.

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