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Tribological study of PEEK reinforced with SiC particles: a comparative approach to the Micro-Nano effect

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More efficient, sustainable and environmentally friendly materials are a crucial issue for society. For high-performance applications, composite materials are increasingly used. Previous studies show that the addition of particles, especially silicon carbide (SiC), improves tribological properties, but the causes of these upgrades are often phenomenological. Introducing this charge into PEEK enhances its mechanical properties in volume and surface area. Our research presents the tribological properties of this composite material. Monitoring the evolution of morphological and chemical changes highlights the influence of particle size and rate on tribological properties.

Keywords: Tribology, Wear, PEEK, silicon carbide

1. Introduction

Polyetheretheretherketone (PEEK) is a thermoplastic widely employed in high-performance applications. It reveals excellent mechanical properties, resistance to chemical attack and thermal stability. The addition of SiC particles in PEEK improves its intrinsic and tribological properties. We provide a study that shows how the content and size of the filler affect the tribological behavior of PEEK matrix composites.

2. Materials

PEEK is mixed at 380 °C with nano- and micrometer-sized SiC particles, noted n-SiC and µ-SiC, each. Their dimensions are around 50 nm and 2 µm, respectively. The specimens are then prepared by thermocompression. For each batch, five samples are formulated with 0, 2.5, 5, 7.5 and 10% Vol of SiC. 9.5 mm diameter 100Cr6 balls are used for the tribological tests.

3. Methods

For each sample, the glass transition temperatures (T_g) and the crystallinity rate (χ_c) are determined by differential scanning calorimetry (DSC). The storage (E') and loss (E'') moduli were measured with dynamic mechanical analysis (DMA). The tribological tests were carried out on a ball-on-plane tribometer with a 5 Hz reciprocal translation motion during 1500 s without lubrication and in ambient air. The normal load was 25 N. The track is 10 mm long. The experiments are interrupted every 300 s to observe the evolution of the wear track. The ratio between the normal load and tangential force is used to calculate the coefficient of friction (COF).

4. Results

The presence of SiC charges lowers the T_g and limit crystallization: from 152.5 °C (PEEK) to 149.9 °C with 10% vol. n-SiC or 148.3 °C with 10% vol. µ-SiC. χ_c decrease from 35.6% for neat PEEK to 26.3% (10% vol. n-SiC) and 24.2% (10% vol. µ-SiC). The DMA revealed both the increase in chain mobility and the reduction in interracial adhesion between SiC and PEEK when the SiC rate increases. The COF is 0.37 for neat PEEK. With 2.5% vol. n-SiC, the COF is 0.34. It jumps to 0.39 with 10% vol. n-SiC. With µ-SiC all COF values are higher and grow with the SiC rate: 0.52 with 10% vol. µ-SiC. After 1500 s, wear tracks show different morphologies. Schallamach waves appears (Fig.1). There wavelength increases with the SiC rate. Abrasive wear and debris are observed with high SiC content composites.

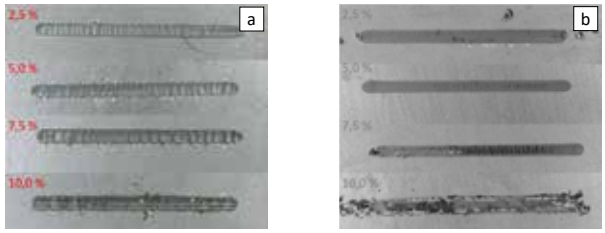

Figure 1: Wear tracks after 1500 s for PEEK filled with (a) n-SiC and (b) µ-SiC.

5. Discussion

The chain mobility increasing and interfacial adhesion lowering between SiC and PEEK are directly associated with the two tribological mechanisms highlighted in the wear tracks: the appearance of Schallamach waves and abrasive wear. On the one hand, the more the mobility of the chains increases with the SiC rate, the spacer the Schallamach waves are. On the other hand, the lower the SiC/PEEK adhesion, the greater the debris generated by the composite. Although the tribological behavior is linked to multi-physical parameters, these two characteristics, polymer chain mobility and charge/matrix interaction, seem controlled deformation and debris production in this tribosystem. The tribofilm circulate ineffectively in the wear track with high SiC content. So the tribological performances are weakened. A rate of n-SiC between 2.5 and 5% in PEEK gives optimised results for our tribological conditions.