

THE EFFECT OF ZIRCONIUM TUNGSTATE (ZT) PARTICLES ON THE STRUCTURE AND TRIBOLOGICAL BEHAVIOR OF POLYETHERIMIDE/POLYTETRAFLUOROETHYLENE MATRIX COMPOSITES

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Polyetherimide (PEI) is a transparent amorphous material with high strength and stiffness. It is resistant to long-term use temperature exposures up to 170 °C [1]. As one of the high-performance engineering polymers, polyetherimide (PEI) is characterized by high thermal stability and outstanding mechanical properties, making it suitable for demanding applications such as structural parts of airliners' nacelles and handles of medical devices, etc.[2].

Compared with metals or ceramics, neat PEI cannot meet the requirements of high wear resistance in many situations. The incorporation of solid lubricants such as polytetrafluoroethylene (PTFE) powder can improve the tribological properties of the neat polymer. PTFE is capable of forming a self-lubrication tribochemical films which reduces the coefficient of friction and wear rate of the composite on the friction interface [3].

However, especially when sliding at high temperatures, the difference in the coefficients of thermal expansion of PTFE and PEI may affect the stability of the film. By blending with Negative Thermal Expansion (NTE) particles with PTFE, the loss of bonding of PTFE to the matrix due to differences in thermal expansion can be minimized. These NTE particles can also be used to reinforce transfer films.

In this work, PTFE particles and zirconium tungstate particles with negative coefficient of thermal expansion were introduced into PEI matrix to enhance the tribological properties. The introduction of zirconium tungstate particles helps PTFE to form a stable self-lubrication tribochemical film.

The source materials were used such as polyetherimide (PEI) powders with the mean particle size of 16µm ('Solver PEI ROOH'grades, Solver, Jiande, China), Fluralit' PTFE powder ('Fluralit synthesis' LLC, Russia) with the mean particle size < 3µm produced via thermal decomposition of the 'F-4' fluoroplastic, and micron-sized ZrW₂O₈ powder manufactured using thermal decomposition ($T = 570^{\circ}\text{C}$) of the ZrW₂O₇(OH)₂·2H₂O precursor, which in turn was synthesized using the hydrothermal conditions at the Nikolaev Institute of Inorganic Chemistry, Siberian Branch of Russian Academy of Sciences, Novosibirsk, Russia.

Tribological properties of composites were tested on the high-temperature tribo-tester 'THT-S-BE-0000' tribometer (CSEM, Neuchâtel, Switzerland) according to the 'ball-on-disk' scheme. The sliding velocity was 0.3 m/s, the load on the sample was 5 N. The sliding distance was 1000 m. The wear track radius was 8 mm. The Ø6mm ball had the surface roughness Ra=0.02µm and was made of the standard quenched and tempered AISI 52100 (GCr15) bearing steel with hardness of 60 HRC. The surface morphology of the specimens after friction testing is analyzed using an Alpha-Step IQ stylus profilometer.

As shown in Figure 1, the composite PEI/10PTFE has the lowest CoF and WR at $T = 23^{\circ}\text{C}$. When the test temperature was raised up to 120°C, the CoF and WR of the composite increased. However, the CoF for sliding friction was lower than that obtained when tested at 180°C. The introduction of 0.5 wt % ZT at 23 °C increased the CoF and WR by a factor of 2.3 and 1.5, respectively. Because of the low level of thermal expansion at this temperature, the effect of ZT is not significant.

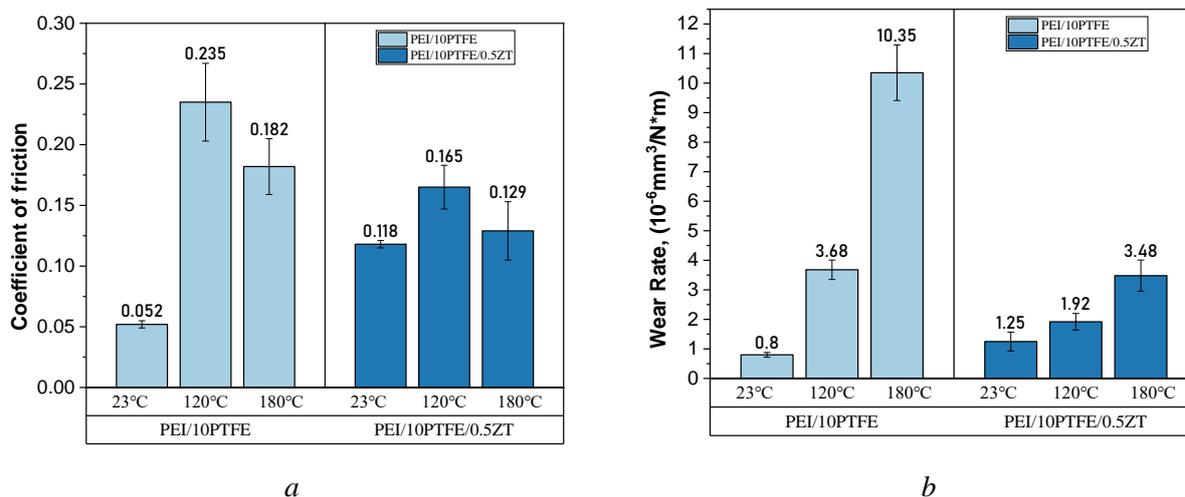


Fig. 1. Tribological properties of PEI/PTFE composites before and after introduction of ZT:
a – Friction coefficient; b – Wear rate

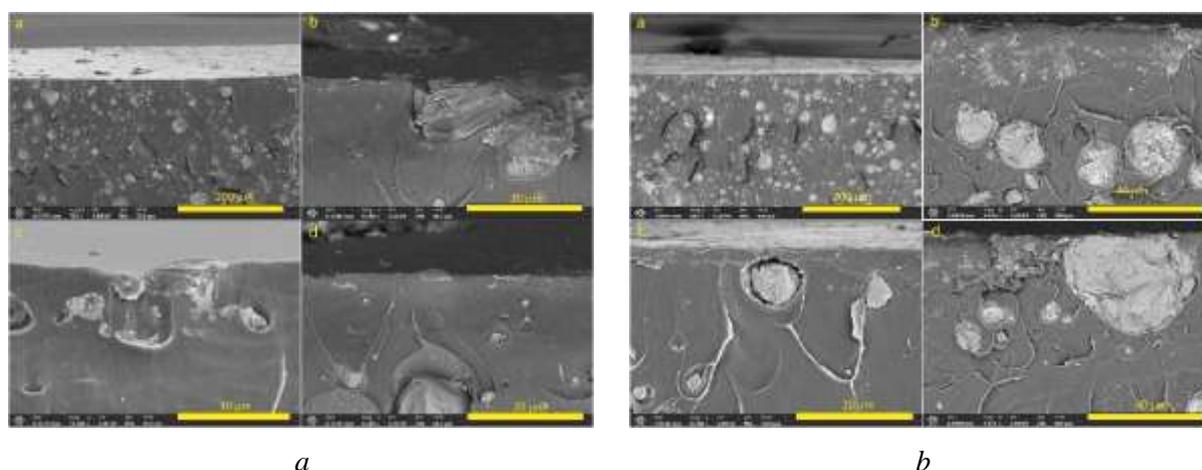


Fig. 2. SEM images of structures below the worn surface of two composites composite at 180 °C:
a – PEI/PTFE; b – PEI/PTFE/ZT

The effect of thermal expansion increases as the test temperature increases. As shown in Fig. 2, the thermal expansion effect has affected the structure of the composite PEI/PTFE at the test condition of 180°C. Due to the different coefficients of thermal expansion of the matrix and PTFE, a significant cavity at the PTFE boundary can be observed (Fig. 2, a). The introduction of ZT, however, significantly mitigated the effect of thermal expansion on its structure, and a significant reduction in the volume of the cavities around the PTFE particles can be observed (Fig. 2, b). This ensured the stable formation of self-lubricating chemical friction film at high temperatures, and accordingly, the introduction of ZT reduced the wear rate of the composite by a factor of 3 at 180 °C.

References

1. Laurence W.M., Effect of Temperature and other Factors on Plastics and Elastomers (Second Edition) // William Andrew Publishing. – 2008. – № 5. – P. 213–241.
2. Chang L., Zhang Z., Zhang H., Friedrich K. Effect of nanoparticles on the tribological behaviour of short carbon fibre reinforced poly(etherimide) composites // Tribology International. – 2005 – Vol. 38. – P. 966–973.
3. Kathryn L.H., Angela A.P. PTFE Tribology and the Role of Mechanochemistry in the Development of Protective Surface Films // Macromolecules. – 2015. – № 48. – P 339–374.