Enhancement of Mechanical and Tribotechnical Properties of Polymer Composites with Thermoplastic UHMWPE and PEEK Matrices by Loading Carbon Nanofibers/Nanotubes

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Ultra-high molecular weight polyethylene (UHMWPE) possesses moderate strength characteristics, as well as a low friction coefficient, high wear and chemical resistance and high impact toughness. This provides its wide application in various areas of engineering, particularly, for fabricating wear resistant components of friction units to operate under harsh conditions, as well as for surgery implants in medicine. Composite materials based on a UHMWPE matrix can substantially increase the wear resistance of components in friction units [1–3].

High-tech structural plastic polyetheretherketone (PEEK) is distinguished by an exclusive and balanced combination of mechanical, physical and chemical properties defining its growing popularity in aerospace engineering and implantology [4]. However, being highly strong and heat-resistant in a wide temperature range, PEEK possesses low wear resistance and a high friction coefficient. Recently, composites based on polyetheretherketone have been developed. The type and size of fillers are determined by the application area, and the environment where the composites are used is mostly restricted by carbon and glass fibers [5–7].

TABLE 1. Mechanical properties of UHMWPE and PEEK based composites loaded with carbon nanofibers (CNF) and carbon nanotubes (CNT)

Filler content, wt %	Density ρ, g/cm³	Shore hardness D	Elastic modulus E, MPa	Ultimate strength σ_U, MPa	Elongation at break, ε, %	Crystallinity χ, %
PEEK	1.31	78.3 ± 1.1	2690 ± 202	109 ± 5.0	23 ± 6	38.75
PEEK + 1 wt % CNT	1.31	79.5 ± 0.4	2447 ± 126	96.2 ± 8.7	5.6 ± 0.7	39.27
PEEK + 1 wt % CNF	1.31	80.2 ± 0.4	–	–	–	33.18
UHMWPE	0.93	57.7 ± 0.5	405 ± 17	36 ± 1.6	482 ± 6	48.6
UHMWPE + 1 wt % CNF	0.93	57.9 ± 0.7	410 ± 4	30 ± 1.7	368 ± 13	42.2
UHMWPE + 1 wt % CNT	0.93	59.2 ± 0.5	532 ± 16	37.8 ± 6.0	417 ± 28	–

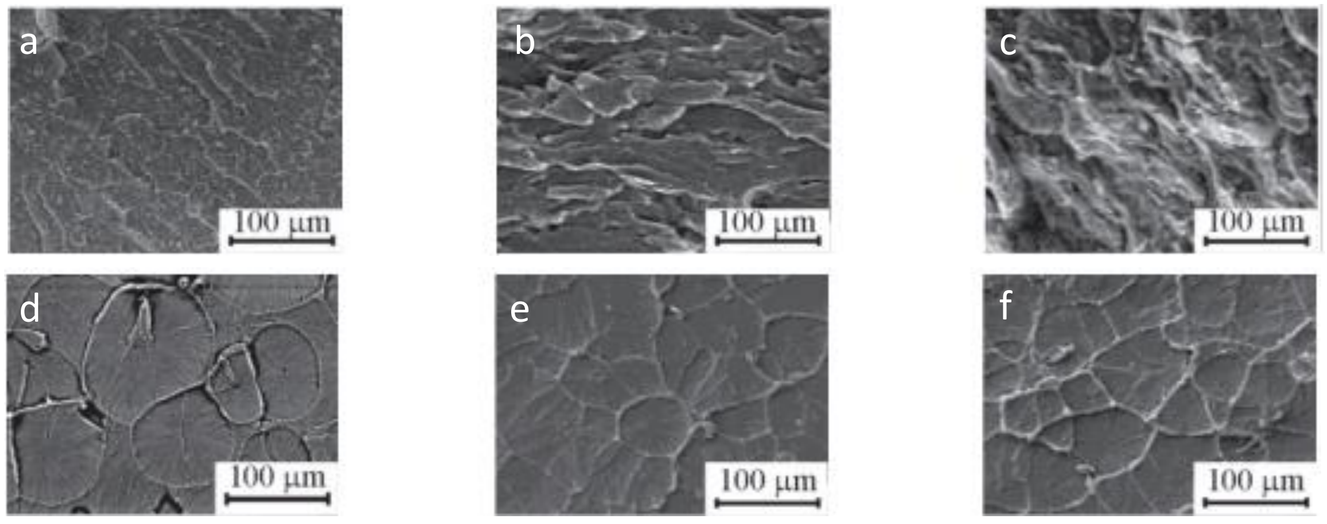

FIGURE 1. SEM-micrographs illustrating permolecular structure of PEEK (a) and its composites PEEK + 1 wt % CNF (b), PEEK + 1 wt % CNT (c); UHMWPE (d), and its composites UHMWPE + 1 wt % CNF (e), UHMWPE + 1 wt % CNT (f)

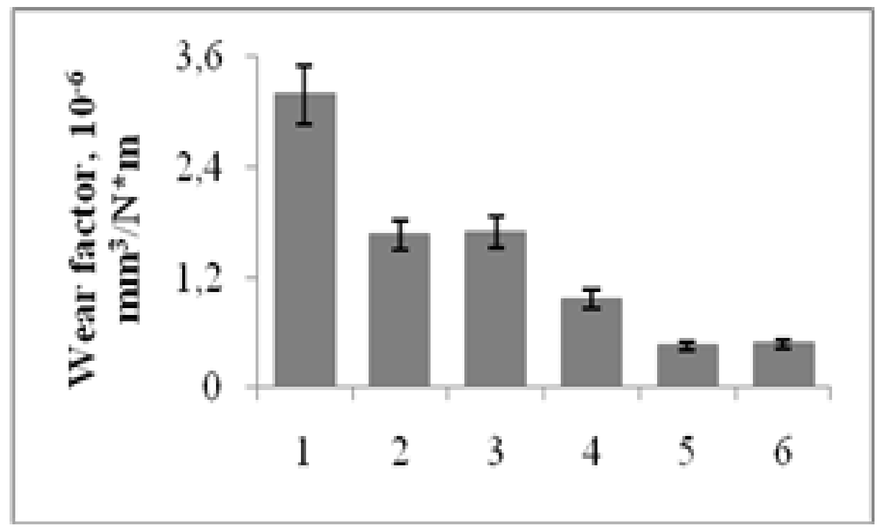

FIGURE 2. Wear factor (10^{-6} mm³/N m) for the composites PEEK (*1*), PEEK + 1 wt % CNF (*2*), PEEK + 1 wt % CNT (*3*), UHMWPE (4), UHMWPE + 1 wt % CNF (*5*), UHMWPE + 1 wt % CNT (*6*) under dry sliding friction at steady state wearing stage

CONCLUSION

It is suggested that carbon nanofibres and nanotubes play the role of the solid lubricant medium in the tribocontact of polymer composites with the various thermoplastic matrices (ultra-high molecular, high-strength) and can provide doubling of their wear resistance under the required operating conditions (low and elevated temperatures, corrosive media, high and medium loads, etc.). UHMWPE nanocomposites with carbon nanofibres/nanotubes possess the highest tribotechnical characteristics at moderate sliding velocities (V = 0.3 m/s) and loads up to P = 60 N. PEEK nanocomposites with carbon nanofibres/nanotubes can be efficiently applied in tribounits with moderate sliding velocities and low loads (not exceeding P = 30 N).

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