Influence of Load and Sliding Velocity on Wear Resistance of Solid-Lubricant Composites of Ultra-High Molecular Weight Polyethylene

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Ultra-high molecular weight polyethylene (UHMWPE) possesses moderate strength characteristics as well as low friction coefficient, high wear and chemical resistance in aggressive media. For these reasons, it is used for manufacturing components of friction units in mechanical engineering and medicine. The above-mentioned unique properties of UHMWPE determine the operating conditions of products made of it (low temperatures, corrosive environment, etc.). Extrudable high-strength and solid lubricant nano- and microcomposites based on ultra-high molecular weight (UHMWPE) matrix are recently being actively developed [1–6].

At the same time, the issues of the wear resistance dependence versus the sliding velocity and loading magnitude of these composites under dry sliding friction are remained to be studied with a view to determine the limits of heir loading operation intervals [7]. In the paper, mechanical and ribotechnical characteristics of UHMWPE composites with solid lubricant fillers (polytetrafluoroethylene, calcium stearate, molybdenum disulphide, colloidal graphite, boron nitride) are studied under the conditions of dry sliding friction at varying load and sliding velocity. Being based on the results of our previous studies, the optimum content of solid lubricants for the composites was taken to be equal to 5 wt %.

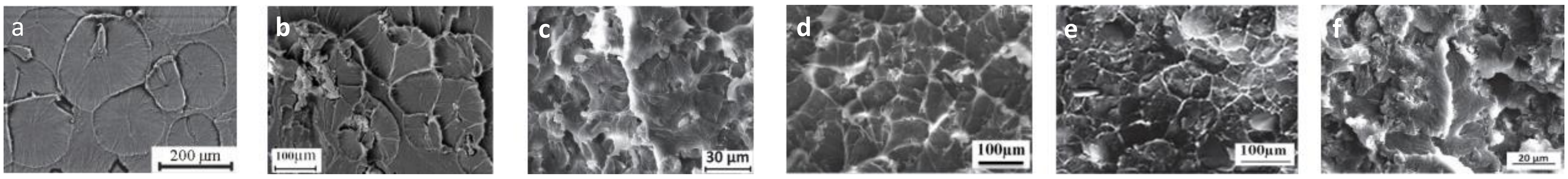
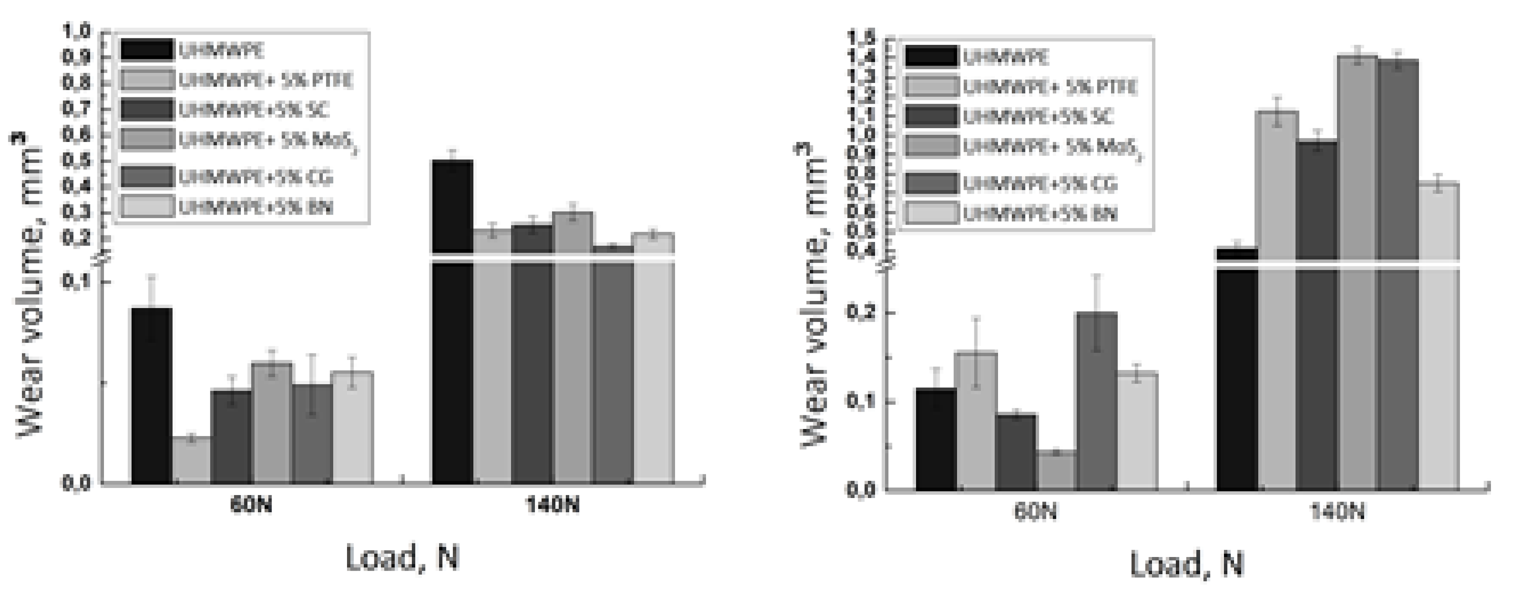


FIGURE 1. Permolecular structure of UHMWPE (a) and its composites with 5 wt% polytetrafluoroethylene (PTFE) (b), 5 wt% calcium stearate (CS) (c), 5 wt% molybdenum disulfide (MoS_2) (d), 5 wt% colloidal graphite (CG) (e) and 5 wt% hexagonal boron nitride (BN) (f)

TABLE 1. Physical-mechanical properties of UHMWPE and its composites

Composition	Density ρ, g/cm^3	Shore hardness D	Ultimate strength σ_U, MPa	Elongation at break ε, %	Crystallinity χ, %	Friction coefficient ƒ
UHMWPE	0.928	55.6 ± 0.2	36 ± 1.6	482 ± 6	56.5	0.12
UHMWPE + 5 wt % PTFE	0.951	54.5 ± 0.6	29.2 ± 1.0	465 ± 23.6	39.5	0.07
UHMWPE + 5 wt % CS	0.913	54.3 ± 0.2	33.1 ± 0.9	411 ± 19.5	41.0	0.11
UHMWPE + 5 wt % MoS_2	0.928	57.4 ± 0.3	28.9 ± 1.6	500 ± 25.3	43.6	0.8
UHMWPE + 5 wt % CG	0.953	56.8 ± 0.3	29.7 ± 1.5	503 ± 25.1	42.1	0.08
UHMWPE + 5 wt % BN	0.955	55.7 ± 0.4	24.1 ± 0.9	360 ± 16.4	41.2	0.08



a b

FIGURE 2. Volumetric wear of UHMWPE and its composites at the steady-state wearing stage.
Sliding velocity 0.3 (a) and 0.5 m/s(b), and loads 60 and 140 N

CONCLUSION

The wear resistance of solid lubricant UHMWPE composites at the moderate sliding velocity (V = 0.3 m/s) and load (P = 60 N) increases by 2–3 times in comparison with pure UHMWPE. However, when increasing the load up to P = 140 N the wear resistance of UHMWPE and its composites is reduced twice. At high sliding velocity and load (up to P = 140 N) the multiple increase in wear of the UHMWPE and all its composites (by the factor of 5–10) occurs. In terms of application in tribounits for mechanical engineering the efficiency of the solid lubricants under study for the high-molecular weight UHMWPE matrix can be summarized as the following. At moderate sliding velocity and load all the fillers possess almost equal efficiency. At high sliding velocity (V = 0.5 m/s) and the moderate load (P = 60 N) the molybdenum disulphide can be recommended as providing highest wear resistance. At the high load (P = 140 N) regardless the sliding velocity none of the studied solid lubricant fillers is recommended for improving wear resistance of UHMWPE. Polytetrafluoroethylene and calcium stearate being bioinert materials can be recommended as solid lubricant fillers for UHMWPE components applied in artificial joints in traumatology and orthopedics.

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