COMPARISON OF STRUCTURE AND TRIBOTECHNICAL PROPERTIES OF EXTRUDABLE UHMWPE COMPOSITES FABRICATED BY ADDITIVE MANUFACTURING TECHNOLOGIES

Panin S.V.[1,2, a)] *, Kornienko L.A.*[1]*, Buslovich D.G.*[1,2]*, Dontsov Yu.V.*[2]*, Alexenko V.O.*[1,2]

[1]Institute of Strength Physics and Materials Sciences SB RAS, Tomsk, Russia
[2]National Research Tomsk Polytechnic University, Tomsk, Russia
[a]e-mail: svp@ispms.tsc.ru

Ultra-high molecular weight polyethylene (UHMWPE) possessing strength characteristics acceptable for polymers as well as low coefficient of friction, high wear and chemical resistance in aggressive media is used for manufacturing friction units for machines and mechanisms. Besides, it has found wide application in medicine as components of orthopedic implants [1]. However, because of the long length of the polymer chains, UHMWPE has a near-zero melt flow index (MFI) [2] which significantly hinders the possibility of its processing by traditional methods (screw extrusion, injection molding, etc.). Therefore, the issues of improving the processability (in terms of extrudability) of UHMWPE and its composites are relevant.

The purpose of this work is to search for commercially available fillers (micropowders) as polymer fillers for adding into the UHMWPE matrix. This will make it possible to fabricate durable and wear-resistant complex shaped products for tribounits using 3D-production technologies.

The polymer-polymeric UHMWPE compositions filled with polypropylene powder grade 21030 were studied. Specimens were prepared by a) hot pressing of two-component powder mixtures and b) by 3D printing from pellets obtained by milling the extrudate after extrusion blending of the same polymer components. The task of the study was to evaluate the influence of the method and modes of superposition on the formation of permolecular structure, mechanical and tribotechnical properties of polymer-polymer composites.

Ultra-high molecular weight polyethylene (UHMWPE) by Ticona (GUR-4120) with a molecular weight of 5.0 million and particle size $d \approx 50$ μm and powder of polypropylene PP21030 with the particle size $d \approx 100 – 200$ μm were used. The granules of the grinded extrudate of the composite blend UHMWPE – PP after extrusion mixing had a size of 3 – 5 mm.

Bulk preforms of polymer composites were produced by: a) compression sintering at a pressure of 10 MPa and a temperature of 200°C with a subsequent cooling rate of 5°C/min; b) FDM method (Fused Deposition Modeling) plates with the size of 65 × 70 × 10 mm were printed from pellets of the same polymer components. Studies of tribotechnical properties of polymer-polymeric compositions of UHMWPE were carried out under different loads P and sliding velocities V (60 N × 0.3 m/s, 60 N × 0.5 m/s, 140 N × 0.3 m/s, 140 H × 0.5 m/s).

It is shown that the wear characteristics (Fig. 1) of the investigated UHMWPE composites fabricated by hot pressing at moderate sliding velocities (V = 0.3 m/s) and loads (P = 60 N) remain at the level of neat UHMWPE (I_V = 0.08 mm^3/h). At the same time, for composites obtained by 3D-printing wear resistance decreases (I_V = 0.12 mm^3/h).

Under severe testing conditions (V = 0.5 m/s, P = 140 N), there is a multiple increase in wear as UHMWPE (I_V = 0.71 mm^3/h) and its composites (by 5 – 10 times) regardless of the manufacturing method. In this case, the wear resistance of polymer-polymeric composites of UHMWPE obtained by extrusion mixing with subsequent 3D-printing at a load of P = 140 N and a sliding velocity V = 0.5 m/s are close to those for composites obtained by hot pressing of powder mixtures (I_V = 0.58 mm^3/h and I_V = 0.61 mm^3/h, respectively). Thus, when the content in the UHMWPE matrix is >20 wt. % PP abrasion resistance under severe test conditions (V = 0.5 m/s, P = 140 N) is 15 % higher than for unfilled UHMWPE.

The elastic recovery [3] of composites is slightly less than that of pure UHMWPE (decreases from 46.5 % to 19.6 % at a velocity of 0.3 m/s and a load of 60 N).

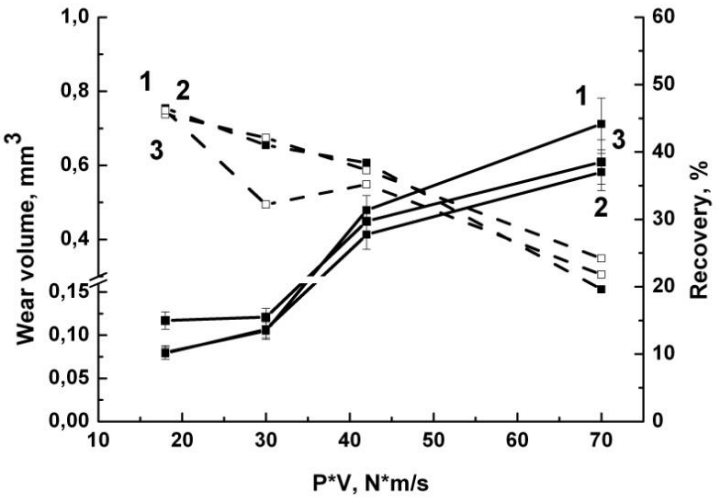

Figure 1. The volume wear (mm^3) and elastic recovery (%) for pure UHMWPE (1) and composites UHMWPE + 20 wt. % PP (powder technology) (2), UHMWPE + 20 wt. % PP (FDM method) (3) under conditions of dry sliding friction at velocities of 0.3 and 0.5 m/s with loads of 60 and 140 N at the steady-state stage of wear

The temperature of the counterbody under triboloading velocity of 0.3 m/s in the composite with polymer filler practically does not exceed T = 28 ± 2°C. When the velocity is increased up to 0.5 m/s there are beads and folds on the wear track surface of the neat UHMWPE. With an increase in the load up to 140 N the temperature for all composites increases to 51 ± 2°C.

The acceptable conditions of triboloading (velocity, load) for materials from extrudable polymer-polymer mixtures based on ultrahigh-molecular weight polyethylene for mechanical engineering and medicine have been determined.

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