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STRUCTURE AND TRIBOMECHANICAL PROPERTIES OF EXTRUDABLE ULTRA-HIGH MOLECULAR WEIGHT POLYETHYLENE COMPOSITES FABRICATED BY 3D-PRINTING

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Currently, the world scientific community intensively deals with development of topical issues of additive manufacturing for polymer and polymer-based composite materials and products that are widely used in many industries (aircraft, ship-building, mechanical engineering, medicine, etc.). Thermoplastic polymers with high melt flow index (ABS, PA, PVB, PVC, PU, PPS, PEEK, PI) are conventionally used as feedstocks. Their composites are of high strength, but possess large value of friction coefficient and insufficiently high wear resistance to be used as antifriction materials in metal–polymer systems. Polyolefins (in particular, UHMWPE) are practically not employed to develop feedstocks in additive manufacturing technologies. Meanwhile, UHMWPE possesses a number of unique properties (wear resistance, low friction coefficient, bioinertness, etc.) that determines its exclusive fields of application. Ultra-high molecular weight polyethylene (UHMWPE) having sufficiently high strength properties, and also a low value of friction coefficient, high wear and chemical resistance in aggressive media is used in friction units of machines and mechanisms, as well as in medicine for manufacturing parts of orthopedic implants. However, due to the long polymer chains UHMWPE has nearly zero melt flow rate (MFR) that significantly limits its processability by traditional and advanced technologies: screw extrusion, injection molding, layer-by-layer extrusion (Fused Deposition Modeling), etc. For this reason, improving the manufacturability of UHMWPE in terms of extrudability as well as its composites is of relevance.

The structural–functional analysis has been conducted for antifriction UHMWPE based composites aimed at development feedstocks for additive manufacturing of complex shape friction units for operation in harsh conditions (low temperatures, aggressive media, high sliding velocities and loads). In order to improve the extrudability of UHMWPE the problem of the optimal choice of polymer plasticizers from the industrially produced thermoplastics was solved. In order to efficiently accelerate the development of extrudable UHMWPE based composites with a minimum amount of experimental data an algorithm is proposed to determine control parameters (recipes). The latter gives the required (restrictive) values to the effective characteristics of multicomponent polymer-polymer composites. This allows achieving their predescribed tribological, mechanical and technological properties. In order to determine the effective characteristics depending on the values of the control parameters the analysis of experimental data is carried out to construct the corresponding response surfaces in the space of states. The surfaces obtained make it possible to reveal the range of values of the control parameters providing achievement of the specified characteristics of the tribomechanical and technological properties of multicomponent composites.

With the use of this algorithm, the optimal content of a three-component mixture ″UHMWPE + 17 wt. % HDPE-g-SMA + 12 wt. % PP" was revealed with tribomechanical properties being equal to unfilled UHMWPE while at melt flow index being appropriate for 3D–printing by the Fused Deposition Modeling (FDM). A comparative analysis of the structure, mechanical and tribological properties of the multicomponent composition ″UHMWPE + 17 wt. % HDPE-g-SMA + 12 wt. % PP″ fabricated by means of the FDM and hot pressing was carried out. It is shown that extrudable 3D printed UHMWPE based composites over their tribomechanical properties (wear resistance, friction coefficient, elastic modulus, yield strength, tensile strength, elongation) exceed similar characteristics of compression sintered composites. The latter is associated with the formation of a more uniform permolecular structure with increased crystallinity. Extrudable composites with UHMWPE matrix at optimal content of plasticizing fillers (″UHMWPE + 17 wt. % HDPE-g-SMA + 12 wt. % PP″) as well as composites with solid lubricant fillers (nanohydroxyapatite, carbon nanofibers) were fabricated and investigated. The tribotechnical properties of 3D–printed composites were studied under various triboloading conditions ($P * V$). It is shown that extrudable UHMWPE based composites fabricated by the FDM can be used in friction units operating in a wide range of velocities and loads.

The use of extrudable UHMWPE based composites in additive manufacturing technologies will reduce the time and energy costs of production as well as expand the range of wear-resistant products of complex shape for friction units in mechanical engineering and medicine.