

Секция 3. Перспективные материалы и технологии

THE EFFECT OF PARTICLE SIZE OF POLYTETRAFLUORETHYLENE ON PROPERTIES OF COMPOSITES BASED ON ULTRA-HIGH MOLECULAR WEIGHT POLYETHYLENE

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ВЛИЯНИЕ РАЗМЕРА ЧАСТИЦ ПОЛИТЕТРАФТОРЭТИЛЕНА НА СВОЙСТВА КОМПОЗИТОВ НА ОСНОВЕ СВЕРХВЫСОКОМОЛЕКУЛЯРНОГО ПОЛИЭТИЛЕНА

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***Аннотация.** С целью исследования влияния дисперсности наполнителя на структуру, механические и триботехнические свойства композиционных материалов на основе сверхвысокомолекулярного полиэтилена (СВМПЭ), был использован политетрафторэтилен (ПТФЭ) с различными размерами. Экспериментальные результаты показали, что при добавлении маленького наполнителя (\varnothing 10 мкм) структура композитов более однородная, механические свойства снижаются меньше и износостойкость при сухом трении скольжения выше в 2 раза, чем при добавлении большого наполнителя (\varnothing 100-180 мкм). Указано оптимальное содержание наполнителя для повышения износостойкости композитов на основе СВМПЭ. Полученные результаты обсуждались чтобы преодолеть ограничения структуры и относительного удлинения, предел прочности при растяжении композитов.*

INTRODUCTION

Ultra-high molecular weight Polyethylene (UHMWPE) holds an important place in the group of polymeric materials because of special properties, such as low friction coefficient, high abrasion resistance, good chemical corrosion resistance, large plastic impact indicators, often used in the machine building, machine parts manufacturing and machine structures. Composite materials based on UHMWPE allows for increased the abrasion resistance of the details frequent heavy loads [1-3]. The basic problem of processing UHMWPE is low capable of adhesion molecules between the substrate and filler in composite structure [4-5].

Polytetrafluoroethylene (PTFE) is a perfluorinated, straight chain, high molecular weight synthetic polymer [6]. In contrast to most inorganic functional filler, PTFE is an organic filler having a unique combination of high heat and chemical resistance together with the lowest friction coefficient of any known internal lubricant, high purity, and dielectric properties. The features and benefits of PTFE include excellent slip, antiblocking, improved stability against polishing, and improved abrasion, scratch, mar, and scuff resistances [7].

In [8] the author has shown that the addition of 10% PTFE (F-4PN) (\varnothing 100-180 μ m) wear resistance under dry sliding friction increased 1.6 times, but the elongation and tensile strength reduced to 40 %, the molecular structure of composites unbalanced greater than UHMWPE. In this paper were investigated the effect of the size of PTFE filler with different weight content on the structure and properties of UHMWPE.

RESEARCH METHODOLOGIES

We used the powder UHMWPE (GUR-2122 by company Ticona) with the molecular weight of 4.0 million carbon units and particle size of 5-15 μ m, the powder Polytetrafluoroethylene (F-4PN20 - \varnothing 14 μ m) and Polytetrafluoroethylene F-4PN (\varnothing 100 -

180 μm). Samples of the polymer-polymeric composites were prepared by hot pressing at pressure of 10 MPa and temperature of 200°C with rate of the subsequent cooling of 4°C/min.

Wear resistance of materials under dry friction was determined on a "shaft-tree" scheme at a load of 68.8 N per sample and the speed of rotation of 100 min⁻¹ in accordance with ASTM G99 on friction machine SMT-1 (slip speed 0.32 m/s). The size of samples was $H \times W \times L = 7 \times 7 \times 10$ mm. A counterbody diameter of steel ShKh15 was 62 mm. The area of friction track was determined by the software «Rhino Ceros 3.0» by manual selection of contour of abrasion surface (friction track) and then automatically calculation of its area. Tribotechnical characteristics were evaluated by averaging the four samples.

Structural investigations were carried out by the scanning electron microscope LEO EVO 50 at an accelerating voltage of 20 kV on the notched cleavage surfaces of samples destroyed mechanically after exposure to liquid nitrogen. Structural studies were carried out with the use of scanning electron microscope LEO EVO 50 at the accelerating voltage of 20 kV. Cleavage surfaces were obtained by mechanical fracture at fast bending of specimens preliminary cooled in liquid nitrogen. The degree of crystallinity was measured with the use of STD Q600 installation. Mechanical characteristics were determined under tensile tests at electromechanical testing machine Instron 5582. Testing coupons were dog-bone shaped with the number of specimens of each type not less than 5 (according to Russian state standard - GOST 11262-80).

RESULTS AND DISCUSSION

In this work were investigated the structure and properties of composites based on UHMWPE with addition of PTFE particles (5, 10, 20, 40 wt. %). Table 1 shows mechanical properties and friction coefficient of "UHMWPE-PTFE" compositions.

Table 1 - Mechanical properties and friction coefficient of UHMWPE-PTFE compositions with the small (1) and the large (2) size of the filler powder.

Filler content wt. %	Density g/cm^3	Shore D hardness	Tensile strength σ_U , MPa	Elongation ε , %	Cryst. χ , %	Friction coef. f
0	0,93	59,5±0,6	32,3±0,9	485±23	44,8	0,12
5(1)	0,97	59,8±0,5	29,2±1,0	465±23	39,5	0,067
10 (1)	1,00	59,6±0,6	27,0±1,2	428±25	35,8	0,067
20 (1)	1,06	59,7±0,6	24,7±1,3	406±24	35,0	0,068
40 (1)	1,22	59,8±0,6	20,2±1,0	217±23	26,0	0,075
5(2)	0,97	59,5±0,5	28,5±1,0	438±25	36,5	0,089
10 (2)	0,99	59,8±0,4	25,1±1,2	384±24	34,3	0,098
20 (2)	1,01	59,6±0,6	22,6±1,3	332±23	32,8	0,098
40 (2)	1,12	59,9±0,5	18,1±1,0	289±23	20,6	0,099

It can be seen from table 1 that the density of composites UHMWPE-PTFE increase, the hardness does not change significantly and mechanical properties (tensile strength and value of elongation to failure) gradually reduce with the increasing of content PTFE. The powder size of particles PTFE determines the uniformity of its distribution in the matrix and by doing so homogeneity and crystallization of the permolecular structure formed (the crystallinity reduces by the weight content of the filler). Furthermore also it

shows that mechanical properties of composites based on UHMWPE when adding filler PTFE with the small size of particles better than with the large size.

Dry sliding friction: As is followed from Fig. 1, a the wear rate of “UHMWPE-PTFE” compositions depends on the weight fraction of the filler and its size (the wear rate is reduced more than twice in the composition with smaller size filler). If this takes place the lowest wear rate is characteristic for the composition of “UHMWPE + 10 wt. % PTFE” (column 3). Wear track surface roughness of the composition “UHMWPE + 10 wt. % PTFE” is also the lowest (Fig. 1, b). Thus, despite a slight decrease in tensile strength, “UHMWPE-PTFE” composite is characterized by more than double increase in wear resistance under dry sliding friction. The subsequent increase of the PTFE weight fraction above 10 wt. % is not effective from the improving wear resistance point of view. By doing so, the friction coefficient is also reduced (Table 1).

To clarify the relationship between nature of wear (under dry sliding friction), the structure, wear track surface topography as a function of size and weight fraction of the PTFE in UHMWPE based composites were studied (after end of testing). Also the counterface surface and permolecular structure of the “UHMWPE-PTFE” compositions with different size of the filler were examined (Fig. 2, 3).

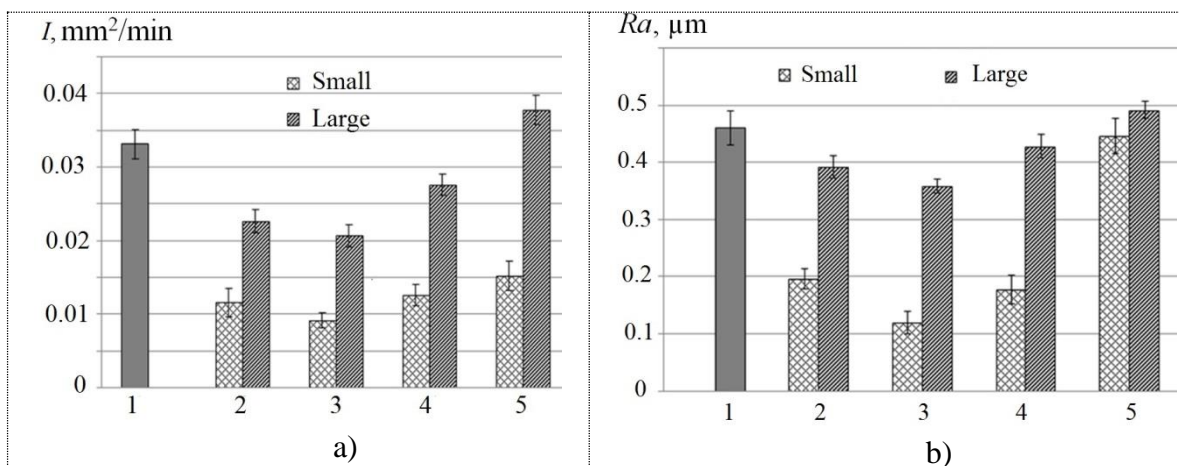


Fig. 1. Wear rate (I) (a) and surface roughness of the wear tracks (Ra) (b) of UHMWPE and UHMWPE-PTFE compositions: pure UHMWPE (1) UHMWPE + 5 wt.% PTFE (2) UHMWPE + 10 wt.% PTFE (3) UHMWPE + 20 wt.% PTFE (4) and UHMWPE + 40 wt.% PTFE (5) under dry sliding friction

In dry powder form, particles PTFE are effective lubricants due to their lamellar structures. Such lamellar structures are even able to prevent contact between highly loaded stationary surfaces. In the direction of motion, the lamellae easily shear over each other resulting in low friction. As a result, micro-groves that are characteristic feature for the wear track surface of pure UHMWPE and composite “UHMWPE-PTFE” with large particles, are practically not observed in compositions with smaller particles of PTFE, which indicates that small PTFE particles added in the UHMWPE play a good self-lubrication effect under dry sliding friction. In “UHMWPE-PTFE” compositions the most smooth wear track surface is observed when weight fraction of the PTFE makes 10 wt. % PTFE (Fig. 6, c). This is in a good agreement with data on the wear rate (Fig. 1, a).

As is followed from Fig. 3 the increasing of weight fraction of the PTFE in the blends gives rise to a gradual change in the permolecular structure pattern: with the in-

crease of PTFE content to 10 wt.% there observed refinement of spherulitic structure elements (fig. 3, b, c), then it becomes less uniform, while after, formation of spherulitic structure is suppressed (at 20 wt. % of PTFE – Fig. 3, d). It is seen from the figure that the adhesion between the filler and the matrix is quite satisfactory. Increasing of the PTFE particle size gives rise to formation of very non-uniform per molecular structure. In compositions with the small PTFE particles uniform small-size spherulitic structure is formed with the higher crystallinity in contrast with one at use of large polymeric filler particles. On the other hand, the PTFE particles being toughly "pressed" into the UHMWPE matrix play a role damping inclusions that although increase the wear, but do not lead to the decrease in overall wear resistance. Therefore small PTFE particles are preferable when choosing a polymer-polymeric composition (UHMWPE-PTFE) for further design of solid nanocomposites on its basis.

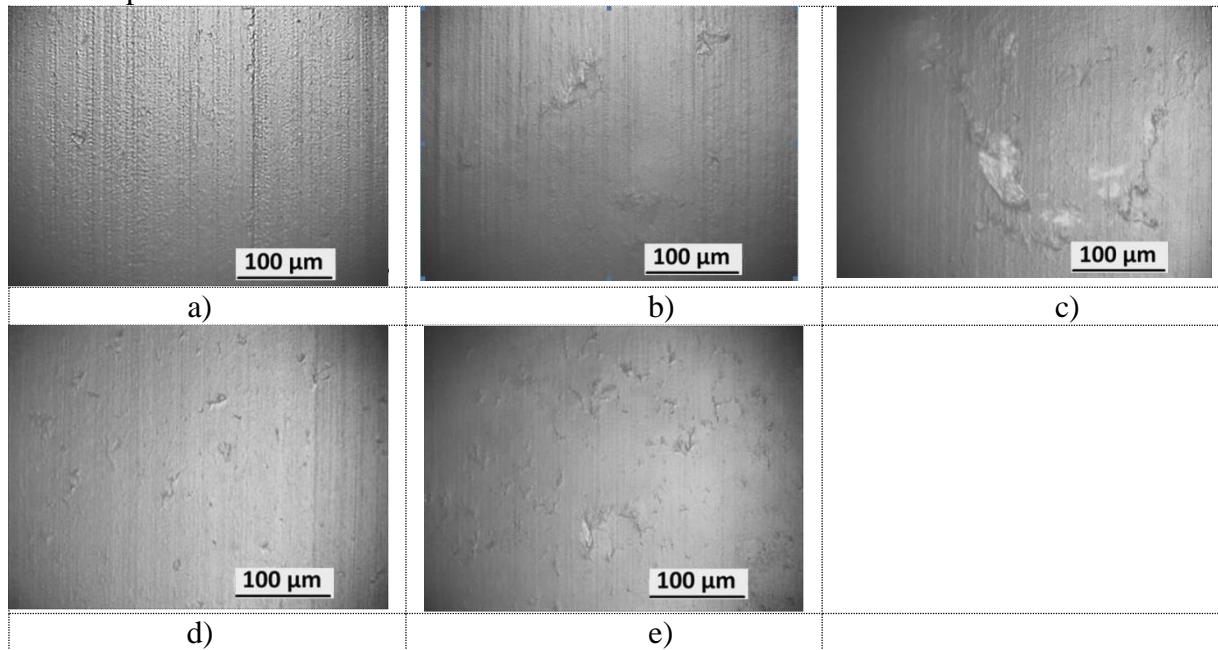
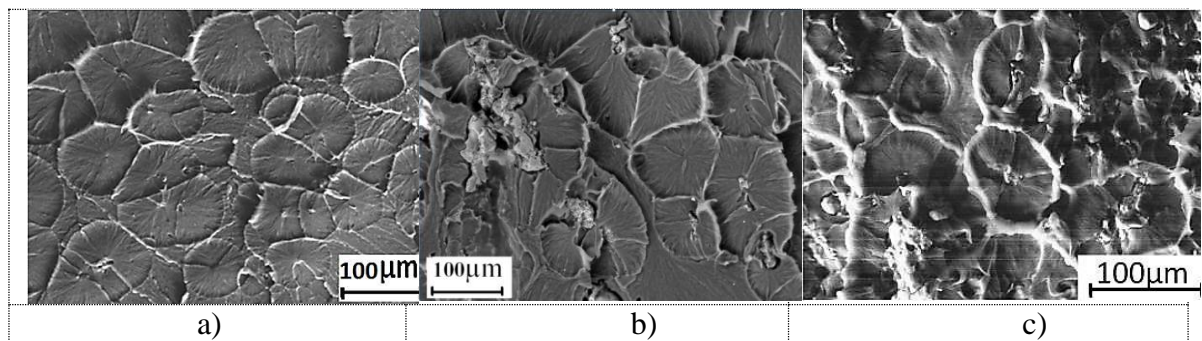
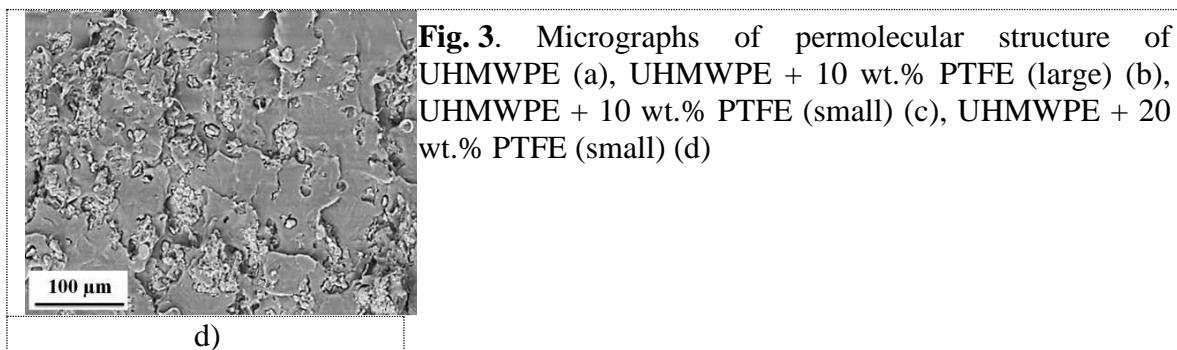


Fig. 2. Micrographs of wear track surfaces of UHMWPE (a), UHMWPE + 10 wt.% PTFE (large) (b), UHMWPE + 20 wt.% PTFE (large) (c), UHMWPE + 10 wt.% PTFE (small) (d) and UHMWPE + 20 wt.% PTFE (small) (e) under dry sliding friction





Thus, reducing the size of filler suit the size of UHMWPE particles help to improve the structure and mechanical properties of composites based on UHMWPE. But because the melting temperature of PTFE is higher than prepared temperature of composites ($330^{\circ}\text{C} \leftrightarrow 200^{\circ}\text{C}$) should structure still not very homogeneous. To overcome this problem, the author has used a different type of fillers, satisfy the necessary requirements. The results of that experiment will be introduced in the next paper.

CONCLUSION

The dispersion of filler greatly affect the structure and properties of composites “Ultra-high molecular weight Polyethylene - Polytetrafluoroethylene” (UHMWPE + PTFE):

+ When adding PTFE with small size of particles ($\varnothing 14 \mu\text{m}$) structure of composites were more homogeneous, mechanical properties decreased less than adding filler with large size ($\varnothing 100\text{-}180 \mu\text{m}$);

+ The wear resistance of composites “UHMWPE + PTFE (small)” higher 2 times than composites “UHMWPE + PTFE (large)” and 3.5 times compared with pure UHMWPE (the best content of PTFE – 10 wt.%).

References

1. Kozlova S.P. Transfer tekhnologiy iz transportnoy otrasli v gorodskoye khozyaystvo po sozdaniyu izdeliy, obladayushchikh antiobledenitel'nyimi i antikorroziionnymi svoystvami i sposobnykh rabotat' v agressivnoy srede / «Polimernyy klaster Sankt-Peterburga», 2012 [Russian language]
2. Harley L. Stein. Ultra high molecular weight polyethylene (UHMWPE) // Engineered Materials Handbook.-1999, Vol.2: Engineering Plastics.
3. Okhlopkova A.A., Sokolova O.V., Shits Ye.YU. Polimernyye kompozitsionnyye materialy na osnove sverkhvysokomolekulyarnogo polietilena i ul'tradispersnykh soyedineniy // Treniye i iznos.- 2004(25), № 2, 202-206 [Russian language].
4. Galetz M.C., Blar T., Ruckdaschel H., Sandler K.W., Alstadt V. Carbon Nano-fibre-Reinforced Ultrahigh Molecular Weight Polyethylene for Tribological Applications // Journal of Applied Polymer Science.- 2007, Vol.104, 4173-4181.
5. Mashkov YU.K., Ovchar Z.N., Baybaratskaya M.YU., Mamayev O.A. Polimernyye kompozitsionnyye materialy v tribotekhnike. – M.: OOO «Nedra-Biznessentr», 2004 [Russian language].
6. Gapi Group, Virgin PTFE at www.gapigroup.com/ptfe2.HTM.
7. Rohr, F E. (2003) Paint Coat. Ind., Defining and Predicting Performance of Surface Modifiers in Coatings, 19 (10), 110, accessed at www.pcimag.com.

8. Nguyen Xuan Thuc. Effect of adding Polytetrafluoroethylene on properties of Ultra-high molecular weight polyethylene // Journal of Natural Science of Hue University. – T110, S.11 (2015) [Vietnamese language]
9. Marino Xanthos. Functional Fillers for Plastics / Marino Xanthos, - 2nd Edition, updated and enlarged, 2010. – 531 p.

ИЗМЕНЕНИЕ СТРУКТУРЫ СПЕЧЕННОЙ АЛЮМИНИЕВОЙ БРОНЗЫ ПОСЛЕ ОБРАБОТКИ МЕТОДАМИ ИНТЕНСИВНОЙ ПЛАСТИЧЕСКОЙ ДЕФОРМАЦИИ

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CHANGES IN THE STRUCTURE OF THE SINTERED ALUMINUM BRONZE AFTER PROCESSING BY A METHOD OF SEVERE PLASTIC DEFORMATION

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Annotation. The purpose of this work is to study the structure and the mechanical properties of sintered aluminum bronze after high plastic deformation. Pressure with changing of deformation axis was used. Porosity, after deformation, was reduced. Microhardness was increased.

Введение. Для спеченных материалов характерно наличие остаточной пористости и неоднородное распределением легирующих компонентов [1], что обуславливает снижение их механических свойств. Данная работа направлена на изучение возможности применения методов интенсивной пластической деформации (ИПД) для изменения структуры и улучшения механических свойств спеченных с переменной порошковых материалов на примере системы Cu-Al.

Целью данной работы является исследование возможности модифицирования структуры спеченных высоколегированных сплавов системы Cu – Al методами интенсивной пластической деформации для улучшения их механических свойств путем создания субмикро- и нанокристаллической структуры материала.

Материалы и методика эксперимента

В качестве объектов исследования использовались спеченные при 950°C прессовки кубической формы из смесей порошков меди марки ПМС-1 и алюминия марки ПА-4 в соотношении соответствующему двухфазному ($\alpha+\gamma$)–составу (24 ат. % Al) согласно диаграмме фазового равновесия системы Cu-Al. Пористость исследуемых спеченных образцов составляла 17 -25 %, средний размер зерен: α -фазы составил 30-60 мкм, γ -фазы в виде пластин со средней толщиной 2-3 мкм. Одноосное сжатие образцов для определения предельно допустимых значений деформации осуществляли на установке МС-500 при комнатной температуре и после предвари-