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INFLUENCE OF GRAPHITED DUST ON THE ABRASION PROCESSES OF COMPOSITE MATERIAL BASED ON POLYTETRAFLUOROETHYLENE

Purpose. *Study of the influence of graphitized dust on abrasive wear of polytetrafluoroethylene-based composites.*

Research methods. *Experimental studies were performed using modern methods of physical and mechanical tests, which ensures the reliability of the results. A laboratory mixer with a rotating electromagnetic field and a hydraulic table press TU 10003 TORIN were used for the production of samples. Weighing of samples for experiments was carried out on a VLR-200 scale, abrasion assessment was carried out on a HECKERT machine. The friction surfaces were studied using a BIOLAM-M microscope.*

Results. *The conducted studies showed that the index of abrasive wear of the composite with a polytetrafluoroethylene matrix decreases from 2.974 mm*^{3}*/m to 2.539 mm*^{3}*/m with a content of 10 % of graphitized dust. This helps to increase the service life of parts, which will reduce the frequency of their replacement, as well as reduce production costs.*

Given that graphitized dust is a waste of metallurgical production, its secondary use as a filler for composite materials allows to partially solve the environmental problem of disposal of production waste.

Scientific novelty. *Today, the production of products from composite materials is one of the promising directions of production, because the combination of a polymer matrix with various fillers makes it possible to obtain more economically profitable materials, forming the necessary physical properties. The possibility of using production waste as a filler allows solving the current problem of recycling and disposal of environmentally harmful substances. Therefore, the conducted research opens up new ways to solve a complex of environmental and economic problems.*

Practical value. *The obtained results are important in the further process of manufacturing composite materials. The ability to increase the resistance of the material to abrasive abrasion allows the production of parts that work in friction conditions.*

Key words: *composite, filler, F4 fluoroplastic, graphitized dust, abrasive wear.*

Introduction

Polytetrafluoroethylene (F4 fluoroplastic) is valued for certain properties: it has a low coefficient of friction and high chemical resistance, strength, dielectric properties that do not lose even at high temperatures [6, p. 23]. The shortage of this material determines its high price. Because of this, polytetrafluoroethylene is almost never used in its pure form, but various impurities are added to it. Graphitized dust is a waste of metallurgical production, so its use as a filler in parts with polytetrafluoroethylene will reduce their price and increase the environmental friendliness of enterprises whose production by-product is graphitized dust.

Analysis of research and publications

Composites are materials obtained from two or more components, between which there is a clear interface [8, p. 7]. A matrix is a substance that allows binding particles of the filler and transmitting the action of forces between them [8, p. 15]. And fillers serve to change the characteristics of composite materials, usually increasing their strength [8, p. 7]. Due to the addition of fillers with certain properties to composites, the scope of their application is quite large: medical, nuclear, optics, etc. [8, p. 30-37].

The most important stage of composite production is the selection of materials, which is based on the experience of scientific research, the use of reference information, and the practical experience of researchers. At the very beginning, you need to choose and analyze the properties of the matrix and choose the main fillers, based on such parameters as the compatibility of components. In the future, the composite forming technology is chosen by equipment productivity and material properties [8, p. 15].

There is a large number of composite materials and because of this there was a need to classify them. The main features are the number of components, the nature of the matrix and filler, the shape of the reinforcing components, the volume content of the filler, properties, the formed structure, the method of manufacture and purpose [8, p. 38–40].

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Polytetrafluoroethylene (nCF_2CF_2) is the chemical name, and F4 fluoroplastic is the technical name of this material, which is used in Ukraine and some other countries. It looks like a white powder with a bulk density of 0.2...0.3g/cm^3 and is intended for the manufacture of products by sintering or pressing [4, p. 5]. The density of the material in the finished products is within 2.18...2.24g/cm^3. It is classified as a thermoplastic matrix [5]. It is used in certain fields, such as mechanical engineering, aerospace, robotics, and others. It is characterized by a low coefficient of friction (up to 0.02), chemical inertness, dielectric properties, resistance to elevated temperatures, high resistance to radiation, low thermal conductivity, non-flammability, low smoke generation, resistance to aggressive environmental factors, frost resistance, hydrophobicity, high antifriction properties. Many of them are due to the structure of F4 fluoroplastic, namely strong bonds between F–C molecules [1].

Disadvantages are a high degree of abrasion of the surface during friction, insufficient mechanical strength when exposed to high temperatures, a high coefficient of linear temperature expansion, a tendency to residual deformation and recrystallization, the impossibility of obtaining products by casting, and cost. Therefore, fillers are usually added to it, which eliminate these shortcomings without worsening the properties [6, p. 24]. Graphite and metal powders are popular among them [8, p. 63], which makes graphitized dust a suitable filler.

Graphitized dust is a byproduct of the production of steel from pig iron by the oxygen converter process, in which molten liquid iron is poured into a horizontally positioned converter and steel scrap is added. Then it is returned to a vertical position and an oxygen nozzle is introduced. With its help, oxygen purging is carried out: it is needed to oxidize cast iron impurities. After that, steel is released from the converter [10, p. 55–57]. Graphitized dust is thrown out during blowing and collected in the mixer. In the process, water is added to it (to facilitate collection), dried and sent to storage or disposal.

Given that graphitized dust is a production waste, secondary use is very relevant. Graphitized dust can be classified as fillers that are inorganic in origin and dispersed in form.

Presentation of the main material and analysis of the results obtained

Production of composites for the study of their mechanical properties was carried out using standard methods. As a result, we received samples of the composite of a cylindrical shape with a diameter and height of 15 mm with a content of graphitized dust of 10...50 wt.%. The properties of graphitized dust and the theoretical values of the density of the obtained composites are presented in the table 1 and fig. 1. According to the graph, the density of the obtained composites should belong to the interval between the minimum and maximum theoretical density values.

Table 1 – Properties of graphitized dust

Indicator	Value
Density, ρ, g/sm^3	1,658…2,084
Chemical composition, %	FeO (40,6), C (31,4), Fe_2O_3 (17,47), SiO_2 (7,1), CaO (2,65), MnO (0,47), S (0,15)
Particle size, m	<10^{-5}

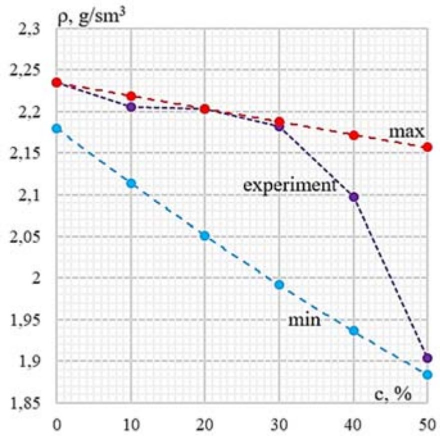

Figure 1. Theoretical and experimental values of the density of the obtained composites depending on the content of graphitized dust

When making composites, the dispersed matrix and filler are mixed using devices with a rotating body [8, p.110]. In a special laboratory device, when an electric current flows, a rotating electromagnetic field (0.12 T) is generated, which affects the ferromagnetic particles previously added to the mixture in such a way that they move in the flask, mixing and grinding fluoroplastic F4 and graphitized dust. After that, the ferromagnetic particles were removed by the method of magnetic separation.

To form the products, the prepared dry mixture was poured into the mold. The top and bottom are closed with punches, they are used to evenly distribute the load on the materials. With the help of hydraulic table press TU 10003 TORIN, a pressure of 60 MPa was applied. The method of hydraulic pressing was chosen due to the possibility of changing the composition and producing 6 samples at the same time. However, this method is characterized by uneven compaction and possible workpiece defects [9, p. 203]. All processes were carried out at room temperature of 12 ºC (285 K). The resulting tablets were heated to 370 ºC (643K) under a constant load of 60 MPa. Subsequently, the samples were cooled to 150 ºC (423 K) under the same load. The manufactured composites were pressed out of the mold. After cooling the samples, the fog was removed by a mechanical method [7]. The same molding technique was used to make a sample of pure F4 fluoroplastic. In fig. 2. manufactured samples are shown.

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Figure 2. Made samples of fluoroplastic F4 and composites with graphitized dust

The density of the finished samples was determined by the hydrostatic method. In fig. 1 (experiment) shows the change in the density of composites depending on the content of graphitized dust. It can be seen that the obtained values are within the limits of theoretical calculations. It can be seen from the graph (see Fig. 1) that with an increase in the content of graphitized dust in the composite material, the average density of the sample decreases. At 10 % and 20 %, the density is almost the same, but the addition of 30 % and more filler greatly reduces it. This may be due to the presence of pores due to uneven compaction during sample formation.

To determine the index of abrasive abrasion of composites, a HECKERT machine was used, on which there was a grinding wheel with rigidly fixed abrasive particles with a dispersion of 100 µm. Samples are fixed in a replaceable holder, which is then installed to the chuck of the machine. At the same time, the sample specially protrudes 3±0.5 mm beyond the edge of the holder. During the experiment, a constant load of 10 ± 0.2 N is applied to it. During the experiment, the sample moves at a constant speed of 10 ± 1 mm during one complete revolution of the machine drum along the updated sanding pad. The complete path of friction that the composite passes is 40 m. After the test is completed, the wear products and dust are removed from the surface of the sample and the tested material is weighed on scales. In fig. 3 shows the dependence of the index of abrasive wear of composites on the content of graphitized dust. It can be seen from the figure that the addition of 10% of graphitized dust improved the surface abrasion value by reducing it from 2.974 mm3/m to 2.539 mm3/m, but a further increase in the filler content leads to a deterioration of this indicator.

At the next stage, we studied the friction surfaces of samples of pure F4 fluoroplastic and composites based on it. The research was carried out on a BIOLAM-M experimental binocular microscope in reflected incident light, which is equipped with a TREK digital camera (DCM1300, resolution 1.3 megapixels) and connected to a PC.

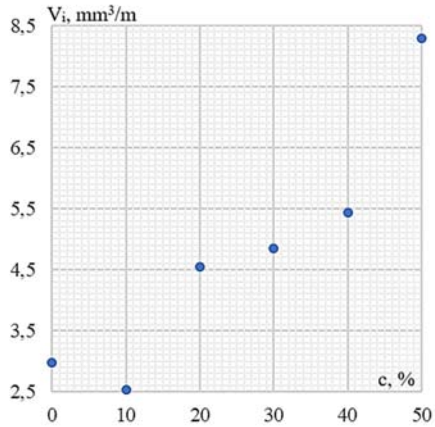

Figure 3. Graph of the dependence of the index of abrasive wear of composites on the content of graphitized dust

Photos of the friction surfaces of the samples obtained by the optical method are presented in fig. 4. In the photo of friction for samples of pure fluoroplastic F4 (see Fig. 4*a*) and a composite based on it with a content of 10 % graphitized dust (see Fig. 4*b*), clear lines from abrasive particles are observed.

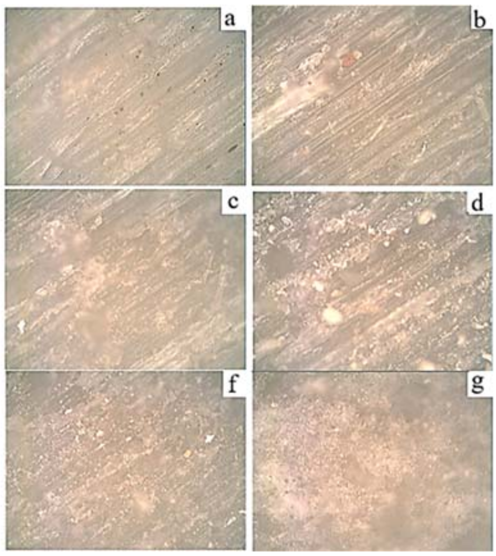

Figure 4. Photo of the friction surfaces of samples of pure F4 fluoroplastic (*a*) and composites based on it with a graphitized dust content of 10 % (*b*), 20 % (*c*), 30 % (*d*), 40 % (*f*), and 50 % (*g*)

Composite materials that contain more than 10% graphitized dust (see Fig. 4*c*-*g*) are characterized by surface defects, which is associated with the presence of pores and voids at the place of particles of graphitized dust that broke out from the surface during tests on friction. These photos are blurry and the image is not clear. This indicates poor adhesion [8, p. 43] between graphitized dust and F4 fluoroplastic. So, the friction surfaces showed that the increase in the indicator in composites with a content of graphitized dust more than 10 % was due to poor adhesion between the matrix and a large number of filler particles.

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Conclusions

As a result of the study, it was established that the use of 10 % of graphitized dust in the production of the composite leads to a reduction in the cost of materials by 10 % compared to pure fluoroplastic F4. Such results are of great importance in conditions of mass production of parts.

Testing of the abrasive wear rate revealed a decrease from 2.974 mm^3/m to 2.539 mm^3/m when using 10 % graphitized dust. This contributes to a significant increase in the service life of parts, which will reduce the frequency of their replacement and also allow to reduce production costs.

As already mentioned, graphitized dust is waste and the majority of it is subject to disposal. This process also has a negative impact on the environment due to harmful emissions. So, in addition to reducing the cost and increasing the service life of parts, the use of such a filler allows you to partially solve the problem of recycling ecology.

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ВПЛИВ ГРАФІТИЗОВАНОГО ПИЛУ НА ПРОЦЕСИ СТИРАННЯ КОМПОЗИТНОГО МАТЕРІАЛУ НА ОСНОВІ ПОЛІТЕТРАФТОРЕТИЛЕНУ

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Мета роботи. *Дослідження впливу графітизованого пилу на абразивне стирання композитів на основі політетрафторетилену.*

Методи дослідження. *Експериментальні дослідження виконані із застосуванням сучасних методів фізичних та механічних випробувань, що забезпечує достовірність отриманих результатів. Для виготовлення зразків використано лабораторний змішувач з обертальним електромагнітним полем та гідравлічний настільний прес ТУ 10003 TORIN. Зважування зразків для дослідів проведено на вагах ВЛР-200, оцінка стирання – на машині HECKERT. Вивчення поверхонь тертя проведено за допомогою мікроскопу БІОЛАМ-М.*

Отримані результати. *Проведені дослідження показали, що показник абразивного стирання композиту з матрицею політетрафторетилену зменшується з 2,974 мм^3/м до 2,539 мм^3/м при вмісту 10 % графітизованого пилу. Це сприяє збільшенню терміну служби деталей, що знизить частоту їх заміни, а також дозволить знизити витрати виробництва.*

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Враховуючи, що графітизований пил є відходом металургійного виробництва, вторинне його використання в якості наповнювача для композитних матеріалів дозволяє частково вирішити екологічну проблему утилізації відходів виробництва.

Наукова новизна. *На сьогодні виготовлення виробів із композитних матеріалів є одними із перспективних напрямків виробництва, адже поєднання полімерної матриці з різними наповнювачами дає можливість отримувати більш економічно вигідні матеріали, формуючи необхідні фізичні властивості. Можливість використання в якості наповнювача відходів виробництва дозволяє вирішити актуальну проблему сьогодення щодо вторинної переробки та утилізації шкідливих для екології речовин. Тому проведені дослідження відкривають нові шляхи до вирішення комплексу екологічних та економічних проблем.*

Практична цінність*. Одержані результати мають важливе значення в подальшому процесі виробництва композитних матеріалів. Можливість підвищення стійкості матеріалу до абразивного стирання дозволяє виготовляти деталі, які працюють в умовах тертя.*

Ключові слова: *композит, наповнювач, фторопласт Ф4, графітизований пил, абразивне стирання.*

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