Investigation of the effect of tungsten carbide nanopowder additives on the strength properties of fiberglass, based on LAVESAN glass fabric and EPR 320 epoxy resin

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Abstract. The paper presents the results of tests for modulus of elasticity and tensile strength of fiberglass samples consisting of glass fiber Lavesan (Italy) and epoxy resin binder EPR 320 with hardener EPH 162, modified with WC tungsten carbide nanopowder, obtained from carbide waste. The positive effect of WC nanopowder on tensile strength and modulus of elasticity is shown. With the addition of nanoadditives in the mass concentration of 1 ... 4% of the resin mass, the increase in tensile strength was more than 1.5 ... 2.5 times, with no significant change in material elasticity.

Keywords: GRP, epoxy, nanopowder, tungsten carbide, tensile strength, modulus of elasticity.

1. Introduction
Fiberglass is one of the most commonly used polymer materials in modern industry. This material has a number of characteristics that provide improved performance of the final product. Objectively increases the need to improve the characteristics of this material due to its high demand.

One of the directions to improve the physical characteristics of polymer materials is the addition of nanoscale structures to the matrix. Works [1-13] study the effects of various modifiers on the mechanical characteristics of fiberglass and carbons. Nanoscale oxides of titanium, silicon, aluminum and graphene nanotubes are used as modifiers. The results of work [1-4, 6-7] indicate a significant change in the mechanical characteristics of the tested materials.

Wide application of nanomodifiers is limited by their high cost and small production volumes. To solve this problem, the authors [14] propose the use of nanopowders of metals and their compounds obtained by the technology of production of nanopowders from carbide wastes [13]. This method provides mass production of nanoscale powders, which will make it possible to modify composite materials at low cost.

Previous studies [14] have shown the effectiveness of using refractory metal nanopowders and their compounds obtained by technology [13] as an additive to epoxy resin, increasing its strength characteristics.

2. Materials and research methods
An experimental study of the effect of WC nanopowder on changes in the strength characteristics of nanocomposites was carried out. Characteristics of the initial materials: glass fabric Lavesan (Italy) with a density of 162 g/m², woven twill 2x2, thickness 0.16 mm, binder - epoxy resin EPR 320 Momentive (Netherlands) and hardener EPH 162 (Netherlands).

WC tungsten carbide nanopowder, obtained by technology [13] from carbide wastes, was used as a modifier of GRP. The nano-additive is mainly nanoplates with sizes from 40 to 200 nm, larger particles are agglomerates.

In to study the effect of tungsten carbide nanopowder on the tensile strength and modulus of elasticity at transverse bending of fiberglass plastics, samples were made using the lamination technology. The binder
was prepared according to the manufacturer’s recommendation. Nanopowders were injected directly into the hardener by mechanical stirring for three minutes. The content of nanopowder in the samples is 0...10% of the mass of epoxy resin, in steps of 1%.

For tests on the tensile strength and transverse bending elasticity, samples are made in the form of plates 150x30x1 mm and 60x20x1.25 mm respectively, consisting of three layers of structural glass fabric. For each type of testing 44 samples were made, 4 samples for each concentration. Endurance of samples until the moment of their testing was carried out within five days at a temperature of 24 °C and relative humidity of 66%. Tensile strength tests were carried out on the universal testing machine TRM - 500 “Tochline”. At breakage tests the loading speed was 10 mm/min. Transverse bending strength tests were performed at a loading speed of 5 mm/min.

3. Analysis of results

In order to study the influence of tungsten carbide nanopowder on changes in GRP performance, we carried out tests on the tensile strength (Fig 1) and transverse flexural modulus (Fig 2).

![Figure 1. Changes in GRP tensile strength as a function of WC nanopowder content.](image1.png)

![Figure 2. Changes in modulus of elasticity at transverse bending of GRP as a function of WC nanopowder content.](image2.png)

The obtained results (Fig. 1) show positive influence of WC nanomodifier obtained from carbide scrap on GRP strength characteristics. As can be seen from the graph (Fig. 1-a), when the concentration of nanopowder in GRP is 1% of the epoxy mass, the strength limit increases more than 2.5 times compared to the control sample (without adding powder). The maximum tensile strength is observed at a concentration of nanopowder WC 4 wt%, an increase in strength of more than 3.5 times compared with the control sample. Such a significant increase in strength can be explained by an increase in the contact area of individual layers of glass fabric, due to the distribution of nanoparticles in the volume of epoxy resin, between these layers. With further increase of WC 4...8 mass. % nanopowder concentration, the breaking strength decreases, the minimum value at 7 mass. %, but despite this, the value of strength at this point is 117% higher than the value of the control sample (without addition of nanopowder).

Changes in modulus of elasticity at transverse bending (Fig. 2) as a result of increased content of additives are wave-like. At the concentration of nanopowder of 1 wt% increase in modulus of elasticity at transverse bending by more than 8% compared to the control sample, then at the concentration increase up to 3% the index does not change significantly. At concentration of nanopowder WC 4 ... 7 wt % decrease of values of measured parameter occurs. Decrease in test strength for specimens can be explained by matrix embrittlement and, as a result, loss of strength properties of the specimen in transverse direction. The maximum increase in modulus of elasticity by more than 40% is observed with the content of nanopowder in GRP of 10 wt %.

A comparative diagram of the relative change in modulus of elasticity in transverse bending (%) and tensile strength (%) is shown in Figure 2.
As it can be seen from the obtained results, a significant increase in tensile strength is 150...250%, at a concentration of 1-6%, the increase in elasticity changes by 6...8% at a concentration of 1...3 wt%. At a concentration of 8-10% there is an increase in strength, maximum values are observed, strength - more than 250%, elasticity - more than 40% at 10 wt% of nanopowder. The wave-like nature of the graph can be explained by the dependence of measured parameters on the distribution of nanoparticles and their agglomerates in the volume of the binding agent.

In terms of technical and economic characteristics, optimal concentrations of additives are 2-3%. A small amount of nano additives provides a significant increase in tensile strength, as well as a small increase (within 10%) in the elasticity of the material.

4. Conclusions
As a result of the study it was found that the addition of nanomodifier WC in the fiberglass matrix has a positive effect on the strength characteristics:
- Modification of GRP nanopowder tungsten carbide in the concentration of 1-4% leads to a significant increase in the tensile strength of the material, up to 250%.
- From the technical and economic point of view, the optimal concentration of the additive is 2-3%.
- The maximum growth of the investigated characteristics is observed at the concentration of 10%, for the ultimate strength is more than 250%, for the modulus of simplicity at transverse bending is more than 40%.

Potentially important direction for further studies is to study the distribution of nanoparticles and agglomerates in the volume of the matrix, as well as the effect of this distribution on the final characteristics of the material.

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