Polymer composite material based on titanium hydride

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Abstract. The article discusses the possibility of synthesizing highly filled polymer composites based on polystyrene and titanium hydride. The composites were prepared by solid-phase compaction at high specific pressure. For uniform distribution, titanium hydride was preliminarily milled in a jet-vortex mill. The particle size of titanium hydride after grinding is in the range from 0.1 to 107 μm. The modal particle diameter is 35.41 μm, and the specific surface area of the particles is 15279 cm² / cm³. The titanium hydride content in the composites did not exceed 60 wt%. The article presents data on the density and microhardness of the obtained composites. It was found that the introduction of titanium hydride increases the physicomechanical characteristics of the composites. The Vickers microhardness of a pure polystyrene sample is 19.87 ± 0.20 HV, and a sample containing 60 wt% titanium hydride is 36.17 ± 0.78 HV (at a load of 200 g).

1. Introduction
Polymer materials are widely used in various fields of industry, including construction, automotive, nuclear, and others. [1-2] The use of polymers is due to their low cost, ease of processing and high physical and mechanical properties. The introduction of various fillers into polymers makes it possible to expand the field of application, to create functional materials with desired properties [3]. The introduction of radiation shielding fillers into cement and polymer matrices makes it possible to create composites that can be used in the nuclear and space industries [4-5]. It is known that the use of materials containing hydrogen significantly increases the protection against neutron radiation. Hydrogen is a very good neutron moderator and is the main constituent in most materials used for neutron shielding. The nucleus of a hydrogen atom - a proton has, with a good degree of accuracy, the same mass as a neutron, therefore, with each act of elastic scattering on a hydrogen nucleus, a neutron loses about half of its initial energy. A neutron barrier made of hydrogen has the best shielding properties per unit mass of shielding.

Of particular interest for radiation protection are metal hydrides, for example, titanium hydride [6-10]. In this work, the possibility of creating polymer composites based on titanium hydride and a thermoplastic polystyrene matrix is investigated. It is known that the main problem of creating effective radiation-protective composite materials is the uniform distribution of the filler in the matrix [11-15]. The work [16] studied the possibility of creating a hydrophobic radiation-protective filler for...
introduction into a non-polar polymer matrix. In [17], data are presented on the modification of the surface of mineral fillers with organic particles for further introduction into a composite material. In this work, the possibility of preliminary grinding of the titanium hydride filler to improve the homogeneity of the components in the finished composite is considered.

2. Materials and methods
Amorphous impact-resistant polystyrene (UPS-803E) was used as a matrix. The structural structure of the used polystyrene is shown in Figure 1.

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\text{CH}_2 - \text{CH} - \text{CH}_2 - \text{CH} - \text{CH}_2 - \text{CH}
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*Figure 1. Structural structure of polystyrene.*

The initial titanium hydride was spherical granules (shot) with a diameter of 1-4 mm. The true density of titanium hydride granules is 3800 kg/m³, bulk density is 2526 kg/m³, hydrogen content is 3.55 wt%. The elemental composition of titanium hydride is shown in Table 1.

| Element | Ti   | H    | Al   | Fe   | O    | Si   | C    | N    |
|---------|------|------|------|------|------|------|------|------|
| wt%     | 95.63| 3.50 | 0.40 | 0.20 | 0.10 | 0.08 | 0.05 | 0.04 |

Table 1. Elemental composition of titanium hydride.

The grinding of titanium hydride shot to a powdery state was carried out in a jet-vortex mill for 15 minutes. The composites were synthesized by hot pressing at a polystyrene softening temperature of 180 °C and a pressure of 80 MPa. To carry out pressing, the powdery components of polystyrene and titanium hydride were previously mixed and the mixture was placed in a mold.

The dispersion of the powders was monitored on a «Microsizer 201C» laser particle analyzer. The Vickers microhardness of the obtained samples was investigated on a NEXUS 4504 device at the same load of 200 g.

3. Results and discussion
Figure 2 shows the data on the granulometry of titanium hydride after grinding the shot in a jet-vortex mill for 15 minutes.

*Figure 2. Fractional composition of titanium hydride powder.*
Analysis of the data on the granulometry of the titanium hydride powder after grinding showed that the particle sizes are in the range from 0.1 to 107 µm (Fig. 2), with most of the particles in the range from 10 to 70 µm. The modal particle diameter is 35.41 µm, and the specific surface area of the particles is 15279 cm²/cm³. The use of titanium hydride powder with high dispersion is a necessary condition for obtaining homogeneous polymer composites. The use of preliminary grinding of titanium hydride shot will significantly improve the physical and mechanical characteristics of the final composites.

Ground titanium hydride was used to synthesize polymer composites. Composites with different filler contents up to 60 wt% were manufactured. The introduction of a filler of more than 60 wt% was not possible. With a small amount of polymer, the filler does not bind into a single composite, which leads to low physical and mechanical characteristics and destruction of the composite.

Table 2 presents data on the density of the obtained composites based on polystyrene, depending on the content of titanium hydride.

| Titanium hydride content, wt% | 0.99 | 1.21 | 1.47 | 1.71 |
|-------------------------------|------|------|------|------|
| Density, g/cm³                |      |      |      |      |

As expected, the addition of titanium hydride increases the density of the samples. A sample containing 60 wt% titanium hydride has the highest density of 1.71 g/cm³, and a sample of polystyrene without filler has the lowest density.

One of the characteristics of the near-surface layers of the material is the Vickers microhardness (HV), which makes it possible to assess the nature of changes in the micromechanical properties and the degree of mechanical heterogeneity in composites. To assess the Vickers microhardness, a pyramidal diamond indenter was pressed into the surface of polystyrene composites under load for at least 15 seconds. The load in all measurements was the same - 200 g. Table 3 presents data on the microhardness by the Vickers method of polystyrene composites with different titanium hydride content. Figure 3 shows the obtained prints of a tetrahedral pyramid on the studied composites.

| Titanium hydride content, wt% | 19.87± | 24.42± | 29.26± | 36.17± |
|-------------------------------|--------|--------|--------|--------|
| Vickers microhardness (HV)     | 0.20   | 0.56   | 0.63   | 0.78   |

Analysis of the data in Table 3 showed that the introduction of the proposed filler titanium hydride significantly increases the microhardness of composites, the higher the filler content, the higher the Vickers microhardness. An increase in the Vickers microhardness with an increase in the filler content is explained by the fact that the introduced filler titanium hydride has a higher hardness. The hardness of titanium compounds on the Mohs scale is 4-5, while the hardness on the Mohs scale for polymers, including polystyrene, is only 1 [18]. It is known that the introduction of inorganic particles significantly increases the mechanical characteristics of composites, including microhardness [19].
To calculate the hardness, the dimensions of the resulting print are measured. The size of the print is measured optically, for which the sample is unloaded and the indenter is removed. During these actions, elastic deformation is restored in the polymer material, as a result of which the size of the indentation differs from the true one achieved when the indenter was inserted. Perhaps, in this case, the true microhardness values are less than those calculated from the measurement results.

4. Summary

The work has established the possibility of synthesizing polymer composites based on thermoplastic polystyrene and ground titanium hydride. It has been established that grinding titanium hydride shot in a jet-vortex mill effectively grinds titanium hydride to a powdery state. The particle size of titanium hydride after grinding is in the range from 0.1 to 107 μm. The modal particle diameter is 35.41 μm, and the specific surface area of the particles is 15279 cm²/cm³.

Composite samples were obtained with different contents of titanium hydride filler: 20, 40, and 60 wt%. Samples containing more than 60 wt. % had low mechanical characteristics. After pressing, these samples did not form a single composite due to the lack of a binder, which led to low mechanical characteristics.

The introduction of titanium hydride increased the density of the samples. The sample containing 60 wt% titanium hydride has the highest density of 1.71 g/cm³, and the sample of polystyrene without filler has the lowest density (0.99 g/cm³).

The introduction of the proposed filler titanium hydride also significantly increases the microhardness of the composites, the higher the filler content, the higher the Vickers microhardness. The Vickers microhardness of a pure polystyrene specimen is 19.87 ± 0.20 HV, and a sample containing 60 wt% titanium hydride - 36.17 ± 0.78 HV (at a load of 200 g).

It was found in the work that the introduction of titanium hydride increases the physicomechanical characteristics of the composites. Further research will be aimed at studying the radiation-protective properties of the developed composites. The effect of neutron radiation on composites will be studied for the possibility of their use in biological protection of transport nuclear power plants.

5. References

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