STUDY OF PHYSICAL-MECHANICAL AND THERMAL PROPERTIES OF FILLED POLYVINYL CHLORIDE

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Abstract.
Background of the problem. At present, many scientific results are being achieved in our country on the use of local mineral fillers in the field of composite materials production. To date, the use of mineral products for the protection of polymeric materials and building horse fires and various aggressive environments is one of the urgent tasks.
Goal. The purpose of the work is to obtain heat-resistant and mechanically strong thermoplastic composite materials by filling polyvinyl chloride with basalt mineral.
Methodology. The physical and mechanical properties of filled polyvinyl chloride (PVC) composites were studied, the melt flow index was determined by the viscometric method, the bending strength was determined by the double-sided bending method, and the impact strength was determined by the Charpy method.
Scientific novelty. The physico-mechanical and thermophysical properties of polyvinyl chloride filled with basalt-containing mineral have been studied.
Obtained data .To obtain a composite material based on PVC, the content of fillers was changed from 1 mass to 5 mass parts. An assessment of the rheological properties of filled composites showed that with an increase in the basalt content, the fluidity of the compositions decreases, however, the resulting compositions can be processed by injection molding. The data obtained show that the optimal compositions are those containing: 5 wt.h. basalt fillers.
The developed materials were studied for flammability by the oxygen index method, and thermophysical properties by the DTGA method.
Key words: polyvinyl chloride, basalt fibers, atomic force microscopy, physicochemical and mechanical properties.

Features. Improvement of physical-mechanical and thermal properties of polymer composite materials based on basalt-containing fillers.

Introduction. Today, the modern development of the economy increases the demand for thermoplastic polymeric materials, but manufacturers cannot satisfy the needs of consumers in polymeric materials used in various fields [1]. By introducing various mineral additives into the composition of polymers, it is possible to significantly improve the quality of polymers and the properties of composite materials based on them, which makes it possible to expand their range and scope. [2-5].

Currently, there are various types of mineral fillers for polymers, and their number is increasing every year, which makes it possible to expand the scope of polymeric materials.

The development of the modern economy requires the production of polymer composite materials not only with high properties, but also with low prices. Therefore, to

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improve the properties of composite materials, it is advisable to use basalt and basalt fibers, which are cheap and effective fillers.

One of the unique properties of basalt is that it is refractory and can withstand temperatures up to 900^0C-1400^0C, resistant to chemical and mechanical stress, has high thermal insulation properties, biological stability, and chemical neutrality - resistant. to aggressive acidic and alkaline environments, does not accumulate radiation. Basalt minerals are an environmentally friendly material, harmless to humans and animals [6].

Methods and materials. The object of study was a thermoplastic composite material based on polyvinyl chloride. The melt flow index was determined according to GOST 11645-73 at a load of 2.16 kg and a temperature of 463 and 503 K. To determine the melt flow index, an IIRT-M brand viscometer with a capillary length and diameter of 8 and 2.09 mm, respectively, was used. the bending was determined by the two-pore bending method according to GOST 6806-73.

Results and discussion. In this work, the problem of improving the mechanical properties of composite materials based on polyvinyl chloride filled with basalt-containing fillers was solved.

The aim of the work is to obtain composite materials based on polyvinyl chloride filled with basalt-containing fillers and to study their physical and mechanical properties [8].

Development of studies of the obtained materials based on polyvinyl chloride containing nanoscale modifiers that affect the supramolecular structure of polymer macromolecules and thus its physical and mechanical characteristics.

Experimental part. Chemical modification by introducing new functional groups into the polyvinyl chloride macromolecule and the study of their physico-mechanical and chemical properties from a scientific and practical point of view are of great importance [9].

We used basalt from the Asmansay deposit in the Jizzakh region, the composition of which is given in Table 1.

The development of basalt rocks from the Asmansay deposit in the Jizzakh region fully meets the republic's need for mineral fiber and exports it abroad [7].

Table 1.

Chemical composition of basalt from the Asmansay deposit

Component	Content, % wt.
	basalt
Silicon oxide SiO_2	47,0
Magnesium oxide, MgO	16,3
Aluminum oxide Al_2O_3	11,2
Iron oxide Fe_2O_3	10,3
Calcium oxide, CaO	8,94
Sodium oxide, Na_2O	1,53
Potassium oxide, K_2O	0,33
Iron oxide FeO	0,16
Titanium oxide TiO_2	0,57
Manganese oxide MnO	0,19
Sulfur oxide, SO_3	less 0,05
Other rock impurities	2,04

To obtain a composite material, the basalt mineral was crushed in a ball mill for 5 hours to 140 μm, and polyvinyl chloride (PVC) was used as a binder.

When choosing the optimal filler particle size, basalt minerals were used in the composition of PVC-based composite materials with particle sizes of 125 and 315 μm, and their physical and mechanical properties were studied.

The amount of dispersed fillers in the polymer matrix was 40%. This amount is the optimal composition for composite materials based on basalt mineral and polyvinyl chloride [8].

The rheological properties of composite materials obtained on the basis of basalt mineral and polyvinyl chloride were determined by the melt flow index (MFR). With an increase in the amount of basalt in the composition of PCM, the melt flow decreases (Table 2), but these composites can be processed by injection molding

Table 2.

Change in the melt flow index of the composition at 200^0C depending on its composition (particle size ≤140 μm)

The composition of the composition, wt.h., per 100 wt.h. PVC	PVC PTR, g/10min,
PVC	5,36
PVC+30basalt	3,22
PVC+40basalt	2,78
PVC+50basalt	2,15

Determination of the physico-mechanical properties of composite materials showed that as a result of the inclusion of up to 40% basalt-containing fillers in the composition, all the physico-mechanical properties of the PVC-based polymer composite material are improved (Table 3). At the same time, it was noted that an increase in tensile strength leads to a decrease in relative elongation.

Table 3

Comparative characteristics of the physical and mechanical properties of the developed PVC

The composition of the composition, wt.h., per 100 wt.h. PVC	impact strength kJ\m2	Elongation at break, %	Tensile strength, MPa
PVC	29	1245	9,12
PVC+30 basalt (BT)	41,2	96,6	9,9
PVC+40 basalt (BT)	62,6	35,4	11,6
PVC+50 basalt (BT)	54,9	12	10,9

The inclusion of dispersed basalt in the polymer composition affects the combustibility of PCM, reducing the self-combustion time of the composite material by 2 times compared to the original polyvinyl chloride, and also reducing the mass loss during ignition in air by 50% (Table 4).).

All indicators of the flammability of the polymer composite material indicate that the basalt mineral used as a filler has the ability to reduce flammability.

Table 4

The influence of the amount of basalt on the flammability of polyvinyl chloride

The composition of the composition, wt.h., per 100 wt.h. PVC	Weight loss upon ignition in air, %	Self-burning time, sec.
PVC	55	236
PVC+40 basalt(BT)	23	123
PVC+50 basalt(BT)	21	112

Atomic force microscopy (AFM) is widely used to study the topography and microstructure of various materials. This method makes it possible to form the surface of a sample obtained in the nanoscale range on a three-dimensional surface. The results obtained show a change in the size, shape, surface of particles and mechanical properties of particles on the surface of a polymer composite material [13].

Using this method, the effect of modified filler particles on the polymer surface morphology was studied. The study and analysis of the surface of the modified polyvinyl chloride shows the distribution of dispersed basalt between polymer macromolecules and the features of their interaction. [14-15].

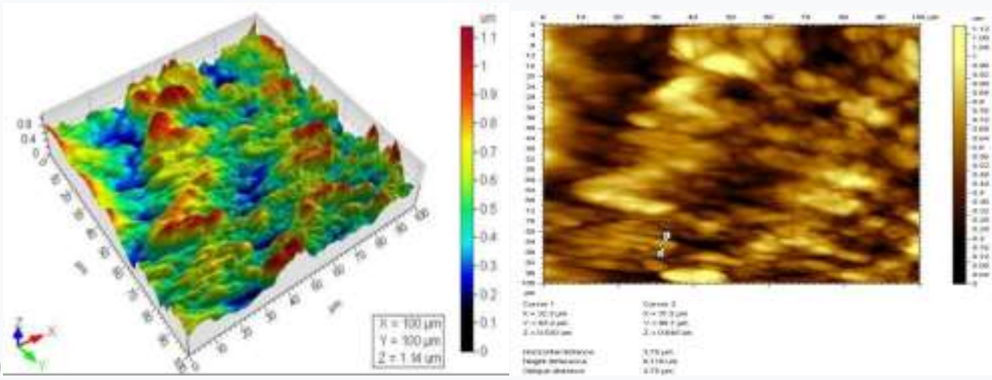
a)  б)

Figure 1. PVC + 40%BT: A) - three-dimensional image, B) - two-dimensional image.

The size of the scanning range was 1-50 μm. On fig. Figure 1 shows the surface of a composite material containing PVC + 40% BT modified with dispersed basalt.

The results show that the surface roughness of the original PVC is 100 nm, and the surface roughness of the PVC + 40% BT composite is 210 nm [16].

Thermal-oxidative properties of composite materials have been studied on the basis of thermoanalytical studies.

It is known that polymer composite materials filled with basalt minerals decompose at a higher temperature than unfilled polymers, and this decomposition is characterized by the formation of an ash residue. This indicates the thermal stability of the obtained composite materials. The complex physical and mechanical properties of composite materials are determined on the basis of chemical changes during the processing of polymers. such as melting point change and heat resistance.

These processes take place at high temperatures. In this work, the thermal and thermophysical properties of polymer composite materials, such as the change in melting temperature and heat resistance, were studied.

The melting temperature and degree of crystallization of polymer composite materials were determined by differential scanning calorimetry (DSC). The results obtained are presented in table. 5.

Table 5. Thermodynamic properties of composite materials based on PVC + 40% BT

The composition of the composition	Start melting, T° C	melting peak я, T°C	Enthalpy, ΔH, Дж/г	Degree of crystallinity α, %
PVC	160	224	188	55
PVC+30% BT	186	243	198	61
PVC+40% BT	197	245	204	59
PVC+550% BT	209	246	210	58

To determine the range of operating temperatures of polymer composite materials by differential scanning calorimetry (DSC), thermograms of the samples were taken.

A comparative analysis of the diffraction spectra of composite materials on fillers showed that the greater the interlayer distance of the modified fillers and the higher the filler concentration, the higher the diffusion rate of the filler included in the composition. Also, the degree of dispersion of fillers in the polymer depends on the duration of mixing of the components and the viscosity of the solution.

Accurate results can be obtained by experimental study of the size and shape of particles by X-ray phase analysis (Debye-Scherrer method). The size of coherent distribution zones (CZR) (the size of nanocrystals) is determined by the Debye-Scherrer formula:

$Dp = K \lambda / (B \cos \theta)$

Dp is the average crystal size (nm) K-Scherrer constant. K varies from 0.68 to 2.08. For spherical crystals with cubic symmetry K = 0.94.

Wavelength l λ -beams Cu Ka = 1.54178 Å.

B is the integral length of the reflections in the FWHM diffractometer (full width at half maximum). cosθ - cosine angle of X-ray diffraction.

Table 6. Results of calculating the size of composite nanoparticles based on PVC + 40% BT according to the Debye-Scherrer formula

№	2theta-Scan Angle	FWHM-integral reflection width	Dp (nm) average crystallite size	Dp (nm) average
1	8.3	0.5	17.42	15.61
2	8.7	0.6	14.61	
3	21.4	0.65	15.12	
4	24.5	0.64	15.70	
5	26.4	0.66	15.23	

According to the results of X-ray phase analysis, it was found that the particle size in the obtained composite materials is nanosized.

Thus, the maximum amount of basalt mineral added as a filler to improve the physical and mechanical properties of polymer composite materials based on polyvinyl chloride was 40%.

All the obtained results showed that the addition of 40% dispersed basalt to polymers increases the strength and thermal stability of polymers.

Conclusion. Thus, an increase in the physical, mechanical and thermophysical properties of polyvinyl chloride filled with dispersed basalts is most effective when using PVC + 40% BT.

Composite materials based on polyvinyl chloride with mineral fillers and surfactants can be widely used as effective heat-resistant polymeric materials.

The phase structure of polyvinyl chloride modified with dispersed basalts can be explained by strong adhesion between the polymer base and fillers.

Modification of the polymer with mineral fillers leads to an increase in their fire resistance.

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