Study of structure formation processes in matrices of mixed components with reinforcing natural fillers

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Abstract. The article presents the results of a study on the development of compositions of heterocomposite materials based on natural dispersed and reinforcing fillers. Using the mechano-chemical modification method, structures were obtained that ensure the compatibility of elements of heterocomposites at the interfacial level at the interface of complex phases where components of different nature and composition are present. By studying the wetting process of the reinforcing filler - spruce fiber obtained from waste, the concentration of the chemical modifier was selected. It has been established that the activity of charged particles of mineral dispersed filler mechanically activated by an unconventional method, crushed with natural stones, lasts for 10-12 hours, which makes it possible to provide time for the maximum use of activity in the formation of stable structures.

1 Introduction

In modern engineering materials science, a trend is developing to maximize the use of local raw materials and waste from various industries, as well as waste from waste products [1]. A wide range of composite materials being developed for those used in various industries gives a choice according to the method of their preparation and modification [2-6]. The list of materials with various performance properties is being updated more and more and will be expanded, of course, with special attention to the resource base and economic issues of the country.

The qualitative characteristics of heterocomposite materials are directly dependent on the compatibility of the components and the production technology. In mixtures of heterocomposite materials, there are components of various physical states, both liquid and solid mineral components that perform the function of enhancing the physical and mechanical characteristics of composite materials [3,4]. In order to enhance the properties of heterocomposite materials, it is advisable to include a reinforcing filler in the composition of the material as components of receptive and absorbers of external stresses that arise during operation. There are various types of reinforcing fillers used in composite

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materials, the most commonly used of them are glass fiber, basalt fiber, carbon fibers, etc. Depending on the internal structure and structure of the fillers, heterocomposites can be divided into layered, fibrous, dispersed. The binder in heterocomposites ensures the homogeneity of the material, provides interstructural interaction in the interfacial layer filler-binder, while it is possible to provide heat-resistant, refractory, moisture-resistant, chemical and electrically conductive properties of materials [7-9]. The study and development of the composition of materials makes it possible to obtain structures at the nanolevel, while selecting the necessary technologies and methods for their production, it is possible to create materials used in radio electronics and other areas [10-14]. But each component and element of the composition performs its functional purpose. Fiber-reinforced composite materials, despite the difficulty of obtaining products from them, are widely used in mechanical engineering. In addition, the formation of stable bonds at the boundary of the binder with the reinforcing filler ensures the resistance of the material to cracking during operation [9].

For the development and production of reinforced composite polymeric materials for structural purposes, we studied a number of fibrous and dispersed materials. Thermosetting epoxy resin ED-20 was used as a thermosetting binder. Products made from them have a high resistance to the preservation of the structure and, accordingly, have increased durability.

2 Methods and materials

The objects of study for obtaining nanocomposite materials and coatings from them were chosen: cold-curing thermosetting polymer: epoxy resin ED-20, hardener polyethylenepolyamine (PEPA), plasticizer-dibutyl phthalate (DBP) and gassypol resin (GS) in a quantitative ratio of 50:50, and also structure formers in the form of dispersed fillers - kaolins of grades AKF-78, AKS-30, AKT-10, polyethylene polyamine (PEPA) was used as a hardener. The most effective for strengthening polymer composite materials (PCM) are fillers of a fibrous nature that give a reinforcing effect, where the structure and composition of the reinforcing filler play an important role, in this regard, we used a waste of silk processing production as a reinforcing filler - a waste of silk fiber (OS) in in the form of small discrete fibers with a size of 1.5÷2.5 mm, while the fibers were preliminarily modified with a solution of low molecular weight chlorosulfonated polyethylene (CSPE).

Natural minerals, in particular kaolin, refers to compounds whose charged electrons are presumably arranged in a mosaic structure. The electrostatic charges formed in this case do not accumulate but recombine with each other, the influence of this phenomenon cannot be caught in the course of the experiment. In this regard, it is possible for us to find not only the technical nature of grinding, but also the physical nature of the filler-binder in the interfacial layer, which in this case may turn out to be advantageous. To obtain highly dispersed activated fillers from local and secondary raw materials, it is necessary to develop a new combined method that combines various variations of individual methods and, accordingly, the designs of installations for grinding materials, in particular, natural minerals [4]. At the same time, it should be noted that if mechanical activation is carried out by the gravity forces of the balls of a ball mill, then the density of the material (ball) is of great importance.

Based on these considerations, in order to increase the volume of critical filling, which makes it possible to save the consumption of the binder, we have chosen an unconventional method of mechanical activation of the filler with a small change in its geometric particle size (preserving their particle size if possible), with the maximum renewal of the surface of mineral particles in a specially designed mechanical activator consisting of a rotating cylindrical vessel and natural stones approximately 50x50x50 mm in size as a spherical

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element of the mechano activator [15], created in the scientific laboratory of the Department of Development and Operation of Oil and Gas Fields of the Karshi Engineering and Economic Institute.

Studies of the structures of the original and heterocomposite materials were examined using FESEM optical microscopy.

3 Results and Discussion

The ratio between the parts of the combined binder determines the characteristics of the composite material - its physical and mechanical properties. An increase in the amount of resin leads to an increase in the hardness, brittleness, and heat resistance of the material [16–18]. Increasing the amount of plasticizer reduces the hardness and increases the magnitude and stability of the dynamic properties. The use of new types of plasticizers opens up wide opportunities for creating compositions of composite materials with high-strength reinforcement and enhancement of mechanical properties with dispersed mineral fillers.

In order to obtain a reinforced structure in the composition of polymer composite materials, we used waste consisting of short silk fibers.

It has been established that, along with the chemical composition of the filler, the properties of the compositions are significantly affected by the shape and size of its particles [3–6]. Fillers have a significant effect on the strength characteristics of heterocomposite materials [4]. In this regard, we studied the effect of discrete silk fiber, mechanically activated Angren kaolin AKF-78, AKS-30, AKT-10, and their combinations on the strength properties of reinforced composite polymer materials.

In the interstructural layers of composites, there are various kinds of bonds that obey the laws of intermolecular interactions in the polymer-polymer, polymer-filler layers, and in the filler-modifier-polymer layer. In order to study this phenomenon, we carried out studies of interfacial phenomena during the modification of silk fiber with a chemical modifier - low molecular weight polyethylene and a mixture of composite material. These studies can be characterized as studies in matrices of mixed components.

It should be noted that the physical and mechanical characteristics of composite materials depend on the type and size of the fiber. It has been found that the tensile and flexural properties of some glass fiber reinforced thermoplastic composites increase with the size of the inorganic fibers [12], therefore, as mentioned above, the use of reinforcing fillers can reduce the risk of cracking in the material [16].

It is also important to take into account their operational properties, which depend on the operating and contacted environment, when developing the compositions of engineering materials.

Silk fiber after removal of adhesive substances from it has a thickness of 12 - 15 microns. [19]. It is based on high molecular weight polypeptides with active radicals consisting of C=O and N-H bonds along the entire length of the macromolecule, they also form hydrogen bonds.

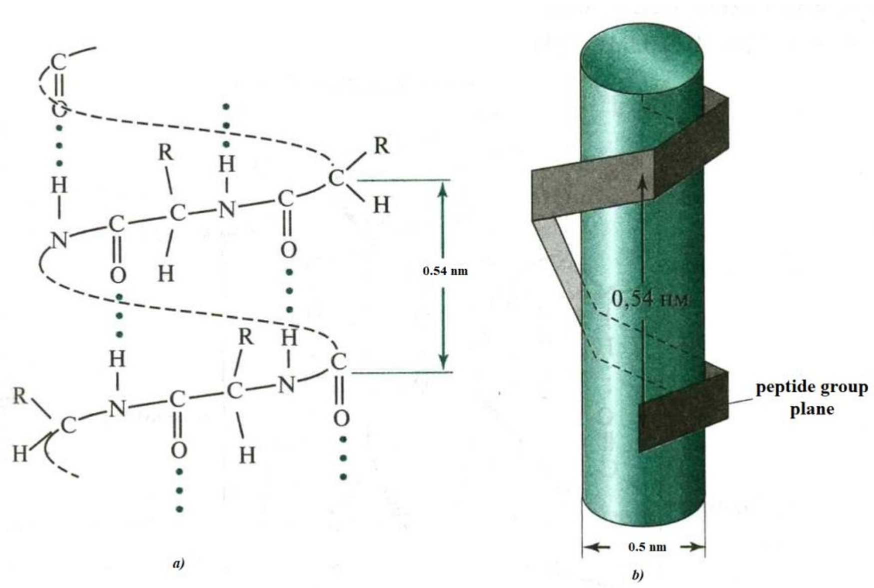

Fig. 1. Chemical (a) and mechanical structure silk fiber [19]

As a wetting agent for the reinforcing filler, in order to improve the contact between the filler-silk fiber and the polymer composition based on ED-20, we chose chlorosulfonated polyethylene (CSPE). When the surface of the silk fiber interacts with the CSPE modifier with the chemical structural formula

$$\left[\left(CH_2-CH_2-CH_2-\underset{\displaystyle Cl}{CH}-CH_2-CH_2-CH_2 \right)_{12} \left(\underset{\displaystyle SO_2Cl}{CH} \right)_{17} \right]_n \quad (1)$$

a filler-binder is formed in the hardened interfacial layer. A micrograph of the modified silk wolf-waste is shown in Fig. 2. It is clearly seen from Fig. 2 that the surface of the silk fiber after the combined modification becomes smoother, while the modifier (CSPE) completely envelops, forming a uniform surface structure, which leads to further formation of stable structures in contact with the binder and interaction with the dispersed filler. This leads to an increase in the wettability of the reinforcing filler with the binder component ED-20 according to the scheme (Figure 3). An analysis of the results obtained by a scanning electron microscope showed that, after mechanochemical modification, bound filler particles are formed on the surface of the alkali fiber, which is apparently associated with the formation of secondary Van der Waals bonds.

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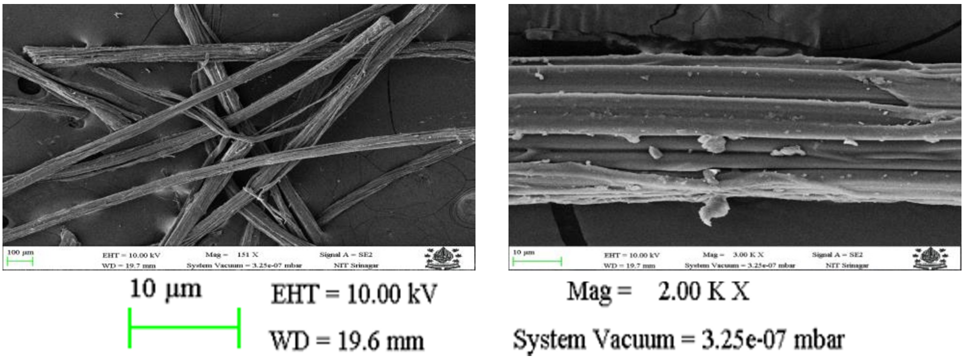


Fig. 2. Micrograph of a silk fiber: a-original; b-modified (bound filler particles are visible on the fiber surface after activation).

The study of the effects of the content of the modifier on the wettability (Fig. 3) shows a significant effect of the modifier on the nature of the wetting angle with modified (a) and unmodified fiber (b).

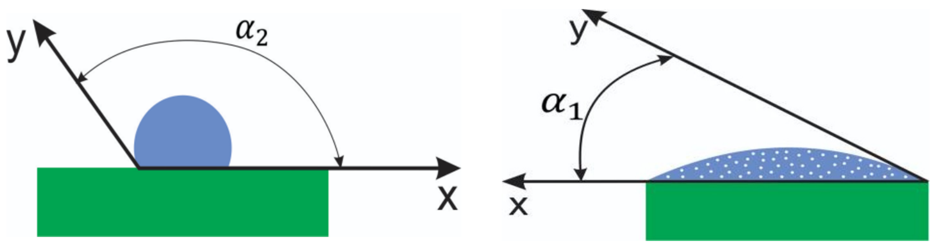


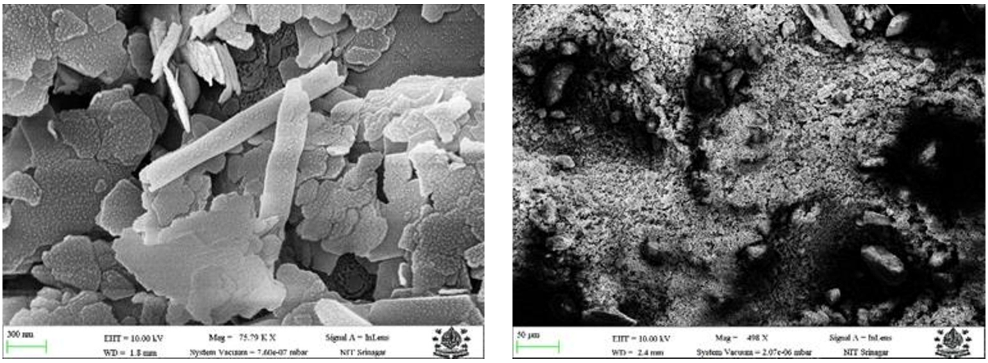
Fig. 3. Photographs of the wetting surface of the silk fiber.

The wetting angle study data show that fiber treatment with 10 and 20% CSPE solution is sufficient to obtain a uniform distribution of the reinforcing filler surface modifier, which is explained by the appearance of stable hydrogen bonds formed by hydrogen atoms of the tertiary amine of the silk fiber polypeptide and conjugated chlorine in the CSPE molecule; a further increase in the amount of modifier leads to deterioration of the process of its uniform distribution on the surface of the filler.

Experimental studies of this process were aimed at obtaining a stable composition with maximum filling with both dispersed fillers and reinforcing ones. In this regard, the next step was to obtain a heterocompound based on ED-20 with finely dispersed kaolin. For this purpose, the optimal composition of the maximum filling of the composition was selected.

It is known that the main purpose of any filler is to reduce the cost, in addition, fillers also contribute to the improvement of some physical and mechanical properties of composite materials. The function of a plasticizer in composite materials is to provide plasticity after hardening, which makes the material durable and resistant to stress. In addition to DBP, the function of a plasticizer is also performed by a reinforcing filler-silk fiber modifier.

The proposed surfactant treated the fiber using an unconventional method of mechanical activation, the concentration of the modifier solution was 9-10%, and the viscosity was controlled using a solvent.



a) *b)*

Fig. 4. Structures of the AKS-30 filler: a) original filler; b) mechanically activated filler.

The results satisfying this theory were obtained by us using the method of combined activation of heterocomposite components, where, according to the results of scanning electron microscopy (Fig. 4.), the structures of the filler of the lamellar structure (Fig. 4.a) are visible, the activity of which increased during mechanical activation (Fig. 4.b), which provided stable bonds in the interstructural space during the formation of a coating on the surface of a structural metal material. One of the observed phenomena during the experiments was that the ion charge during the mechanical activation of the filler was maintained for 10-12 hours, which makes it possible to use this modification method in production conditions, observing all the norms of the technological production mode. The resulting heterocomposite materials had a uniform distribution of the filler throughout the entire volume of the material, which ensured the homogeneity of the material, which is one of the main characteristics that ensure adhesion in the interfacial, which makes it possible to enhance the performance properties of materials.

4 Conclusions

Thus, we have chosen a new composition and method of structure formation of heterocomposite materials and coatings from them based on mixed polyfunctional matrices. The method of combined activation of heterocomposite components was used to study the structures of heterocomposites consisting of dispersed, enhancing mechanical properties, and reinforcing, natural fillers. The use of the combined method of activation of the components of the heterocomposite made it possible to increase the activity of interfacial bonds due to stable bonds in the interstructural space. a method of modification under production conditions in compliance with all norms of the technological mode of production. The resulting heterocomposite materials had a uniform distribution of the filler throughout the entire volume of the material, which ensured the homogeneity of the material, which is one of the main characteristics that ensure adhesion at the interfacial boundary, which improves performance properties materials.

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