The research of polymer composites produced with sclerometric method using magnetic processing

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Abstract. It is shown that the physical and mechanical properties of polymer composite materials can be improved by various activation methods. This article studied the structural changes that occur in polymeric materials under the influence of an electromagnetic field of various strengths. The purpose of the work was to establish the magnetic treatment effect on the physical and mechanical properties of polymer composites based on epoxy binders. In the research tasks, the experiments to study unfilled and filled compositions, the establishment of microhardness indices over the cross section of the samples made under the influence of an electromagnetic field of different strengths, were carried out. The composites based on an epoxy binder grade ED - 20 were considered as an object of research. Polyethylene polyamine served as a curing agent of the composites. Pyrite cinders served as filler in the composites. As a result of the research, the rational modes of the materials’ magnetic processing were established. The improved properties are possessed by the epoxy composites activated at a current of 9 A, lasting 9 hours.

Introduction
A large number of works have been devoted to questions of studying the processes of structure formation, physical and mechanical properties, durability, and the technology of manufacturing polymer composite building materials [1–9]. High physical and mechanical properties of polymer composites are achieved during their manufacture by various activation methods.

This article studied the structural changes of polymeric materials that occur during their processing in a magnetic field. In the previous studies, it was found that by using a magnetic field as a technological device during processing, it is possible to obtain the thermoplastic and thermoset polymer materials of improved quality [10–11]. The improvement of the thermoplastic materials’ properties occurs due to the ordering of the structure by orienting the polymer chains’ links. It was established that the action of a magnetic field also leads to a change in the supramolecular structure of crystalline polymers. The creation of an oriented state in amorphous thermoplastics is accompanied by an increase in their hardness and an increase in the structural state homogeneity. In other works [10, 11, 12, 13] capron was crystallized in a constant magnetic field in a molten film with an open surface with field strength – 8000E to verify the effect of a magnetic field on the crystalline polymers’ supramolecular structure. It has been established that spherulites change their shape, predominant growth occurs in the magnetic...
field direction. The fibrils that make up spherulite grow faster in the field direction than in the perpendicular direction. The ratio of spherulite diameters indicates that the growth rate is 1.5 - 2 times higher in the field direction. At the same time, the overall texturing of the structure in the field direction is observed. Along with the change in the shape of individual spherulites, the development of texture and a predominant growth of spherulitic ribbons in the field direction are observed, which leads to the directional orientation and hardening formation - the microhardness of the treated capron is 38 kgf / mm² and 4 kgf / mm² for the initial one. A magnetic field increases the hardness of the cured composition. The increase in hardness under the influence of a magnetic field strongly depends on the temperature regime of curing and the field strength. After magnetic treatment, a shift in the distribution maximum is observed toward an increase in microhardness. With an increase in the field strength, a decrease in the peak half-width is observed as compared with the initial one, which indicates an increase in the structural state’s homogeneity as a result of magnetic treatment, and with an increase in the magnetic field strength and exposure time, the structural state of the samples becomes more uniform.

In previous studies, we showed that the magnetic field effect improves the physical and mechanical properties of polymer composites [14, 15].

In this work, when studying the effect of electromagnetic fields on the structure of epoxy composites using the sclerometric method, we determined the changes in microhardness along the height of the samples’ cross section.

Materials and methods
Unfilled and filled compositions were considered. As a binder in composites, the ED-20 brand diane epoxy resin was used. The curing agent was polyethylene polyamine, which was introduced in the amount equal to 10 mass parts per 100 mass parts of a synthetic binder. Pyrite cinder was used as filler in the charged compositions - waste from the production of sulfur pyrite firing with a specific surface area of 1300-1500 cm²/g. The filler was introduced in the amount of 100 mass parts per 100 mass parts of binder. Activation was carried out according to the following technology. An electromagnetic field was created using direct electric current of various strengths, passed through a rectangular metal plate, which was the basis of the molds in the samples’ manufacture from the epoxy compositions. To study the effect of electromagnetic fields on the epoxy compositions’ structure, changes in the microhardness along the sample’s cross section height were determined by the sclerometric method.

Discussions and Results
The results of the obtained experimental data on the change in microhardness along the height of the samples’ cross section from the unfilled epoxy compositions resulting from the action of a magnetic field are presented in Figures 1–2.
Figure 1. The changes’ dependence in the samples’ microhardness of the unfilled polymer composites on the current strength and processing time: a) cured within 3 hours; b) cured within 6 hours; c) cured within 9 hours.
Figure 2. The changes’ dependence in the samples’ microhardness indicators of the filled polymer composites on current strength and processing time: a) cured within 3 hours; b) cured within 6 hours; c) cured within 9 hours.

Analyzing the obtained graphs of changes in the microhardness over the cross section, it can be seen that for epoxy compositions without filler cured within 3 hours (Figure 1-a), the highest microhardness is observed for the composition in the electromagnetic field at 9A. At a hardening time of 6 hours (Figure 1-b), the highest microhardness is also characteristic of the composition treated with an electromagnetic field at a current strength of 9A. In the case (Figure 2-c), when the solidification time was the longest (9 hours), the highest microhardness, which is the highest in value among the samples without filler, manifests itself at a current strength of 3A.

For the samples with filler (Fig. 2-a - 2-c), when solidified within 3, 6 and 9 hours, the highest microhardness is observed for the compositions cured in a constant electromagnetic field, with a current strength of 3A.

It follows from the results of the study that, taking the microhardness data of the samples into account, it can be assumed that the most rational magnetic processing modes (processing time and current strength), are: 1. - the longest time (9 hours); 2. - the smallest current strength (9A). The improvement in the epoxy composites properties under this activation mode is apparently due to an increase in structural homogeneity.

Summary
1. It is shown that conducting magnetic processing in the polymer composite building materials’ manufacturing improves their physical and mechanical properties.
2. Rational activation regimes for polymer composites unfilled and filled with pyrite cinders are revealed.
3. The obtained strength indicators are achieved when activated according to the regime conducted at a current strength of 9A for 9 hours.

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