PROPERTIES OF A MECHANOACTIVATED COMPOSITE BASED ON SUPER-HIGH-MOLECULAR POLYETHYLENE FILLED WITH BRONZE POWDER

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ABSTRACT

Peculiarities of the technology to produce a composite material on the basis of super-high-molecular polyethylene (SHMPE) mechanically activated with bronze powder are considered as well as the properties of the produced material. Samples of the press-composition on the basis of SHMPE with 0 up to 97.5% of the bronze powder added were prepared by joint mechanoactivation of super-high-molecular polymer and the bronze powder using planetary mechanoactivator MPF-1 and toroidal vibration mechanoactivator MV-0.05.

Packed density of the press-composition was analyzed as a function of the formula and the mechanoactivation technique used. Bulk samples for the tests were obtained by direct pressing.

The properties of the samples were studied. Dependencies were produced between the density of the material, the physical and mechanical and thermal-physical properties on the one side and the concentration of the bronze powder in the material and the time of mixing of the material in the mechanoactivators on the other side. The way of mechoactivation was assessed as it influenced the properties of the produced material.

INTRODUCITON

Filled polymers are widely implemented in engineering. Practically any polymers can be used as binders, and various in nature and size materials can be used as fillers. As a rule, the fillers are introduced into a polymer to make the composite being produced less expensive and improve its physical mechanical properties [1].

At present, with the development of nanotechnologies new ways of production of filled composite materials have appeared, in particular, the one with implementation of a mechanoactivation method. Mechanoactivation makes it possible to produce nanostructural powders of various materials, and make them in a short enough time; various different materials can be mixed, including polymers, practically at the level of macromolecules. All this results into the upgrading of the properties of the composites on the basis of polymers even at introduction of inconsiderable amounts nanofillers, and this was proved by many authors.

This work describes the properties of the composite material on the basis of super-high molecular polyethylene filled with bronze powder after mutual mechanoactivation using different types of mechanoactivators. The content of the filler in the composition was from 0 up to 97.5 wt. %. It was supposed that introduction of the filler at joint mechanoactivation would provide upgrading of physicomechanical and thermophysical properties of the produced composites, and that would make it possible to make the areas of implementation of the filled polymer materials wider.

USED MATERIALS

The following materials were used to produce the composites. The powder super-high molecular polyethylene (SHMPE) of RUR brand made by Ticona Gmbh (Germany) was used as a polymer binder. The molecular mass of SHMPE was $3–6\times10^6$, the thaw point was 152 ^{0}C.

Bronze powder of BPK brand by Specification 48-08-09-7-85 was used as a filler. The content of Cu in the powder was 82.8 wt%, the content of Sn was 16.5 % wt., the content of additives of Fe was 0.39 % wt, and the content of the lubricant was about 0.3 % wt.

METHODS OF PRODUCTION AND TESTS

The samples of a composite material were produced in the following way: at first using mechanoactivtion the composition was made of a SHMPE powder and a filler in the given concentration, and then this composition was processed by direct pressing into the standard bulk samples to perform further tests.

The technological process to make a composite comprises the following operations:
- making portions of the initial components in compliance with the formula;
- joint mechanoactivation of the components during a certain period of time;
- making portions of the composition for processing;
- pressing of the samples.

Powder composition to produce a composite material were prepared at mechanoactivation of super-high-molecular polymer together with the bronze powder using planetary mechanoactivation MPF-1 and toroidal vibration mechanoactivation MV-0.05. The time of mechanoactivation was selected in such a way that the energy spent to activate a unit of the weight of the material was approximately the same.

Before the pressing the packed density was determined using the method described in [2]. Then the portion of the material to make a billet was supplied into the prepared press-form. The assembled press-form was put onto the plates of the press with electric heating and heated up to the temperature (150 – 160)ºC under the pressure of 25 MPa.

When the press-form reached the specified temperature it was exposed to it during the time calculated from (2.0 – 3.0) min per 1 mm of the thickness of the part; the heating was switched off then and the press-form was cooled down with water. The press-form was disassembled, and the samples were recovered at the temperature not higher than 60ºC.

Before the tests each sample was visually examined and the density was determined. The samples for tests should have even and smooth surface without spallation, cavities or other defects. The density of the samples was determined by hydrostatic weighing by the methods described in [3].

Mechanical tests of the samples were carried out in compliance with the standards valid in the Russian Federation. Not less that 5 samples were taken for each test. They were conditioned before testing during not less than 16 hours at the temperature 296±2K (23±2ºC) and relative humidity of 50±5 %. The tests were performed using test machines by INSTRON Company that provide load measurement with the error of not more than 1% from the measured value.

Measurements of the linear expansion coefficient (LEC) were done with linear dilatometer meant for LEC direct measurement of the plastic materials.

The produced results were statistically processed by the method described in [4].

PRODUCED RESULTS AND THEIR DISCUSSION

The process of mechanoactivation was studied as it influenced the properties of the pure SHMPE, so the powder of SHMPE underwent mechanoactivation during 30 minutes at the planetary mechanoactivator. Then the samples for further stretching tests were pressed out of SHMPE powder after mechanoactivtion and from SHMPE as delivered. The results of the mechanical tests are given in Figure 1.

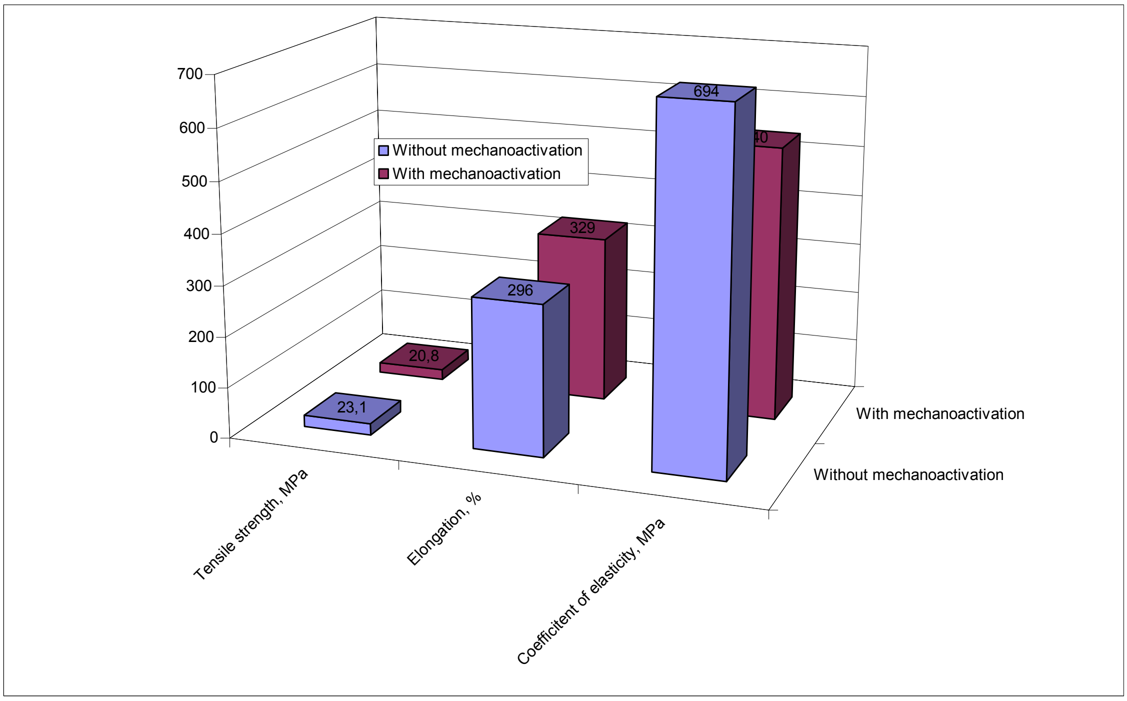

Figure 1: Mechanoactivation as it influences the properties of pure SHMPE at stretching

As it comes from the Figure, mechanoactivation can effect the properties of the polymer, and that most probably is connected to the processes of mechanodestruction that take place in the process of mechanoactivation of the polymer. Mechanoactivation results into the changes in the properties of the polymers: reduction of the molecular mass, reduction of the flow point and specific pressure of the pressing; besides, the destruction processes in the polymer and chemical interaction with the filler are also possible. All this results into the situation when the processing technology for such polymer composite materials can differ from the processing technology for the polymers that did not undergo the mechanoactivation.

So, the samples for tests were pressed in the same moulds, and the volume of portions varied. The dependences of the packed density of the press-composition on the formula, on the way of production and on the time of mechanoactivation and the components in the planetary and vibration mechanoactivator were assessed. The produced functions are given in Figures 2 and 3.

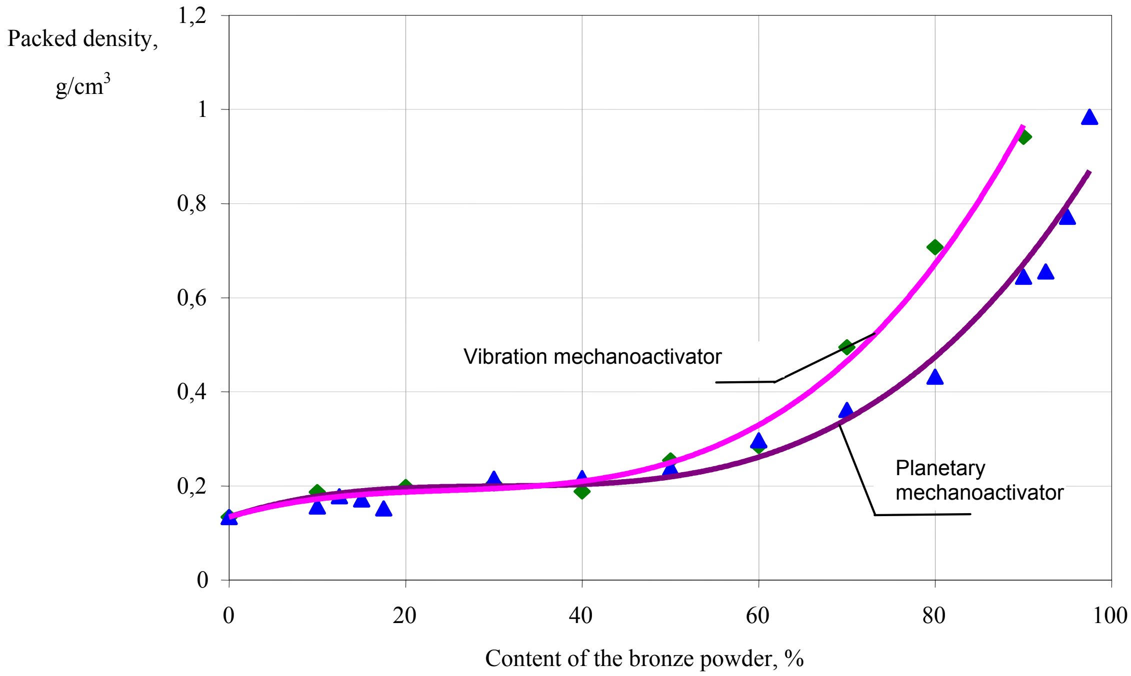

Figure 2: Packed density of the composition on the basis of SHMPE and bronze powder mechanoactivated during 30 minutes in the planetary mill and 24 hours in the vibration mill as a function of the bronze powder content in percent.

It was found out that if the content of the bronze powder is up to 50%wt the packed density practically does not depend on the way of mechanoactivation. When the content of the bronze powder grows higher than 50%, the press-composition produced at the vibration mill has a higher packed density than that of the produced at the planetary mill.

With the growth of the time of mechanoactivation at the planetary mixer the packed density of the material goes down by 2 – 2.5 times, and in about 30 min it reaches the plateau.

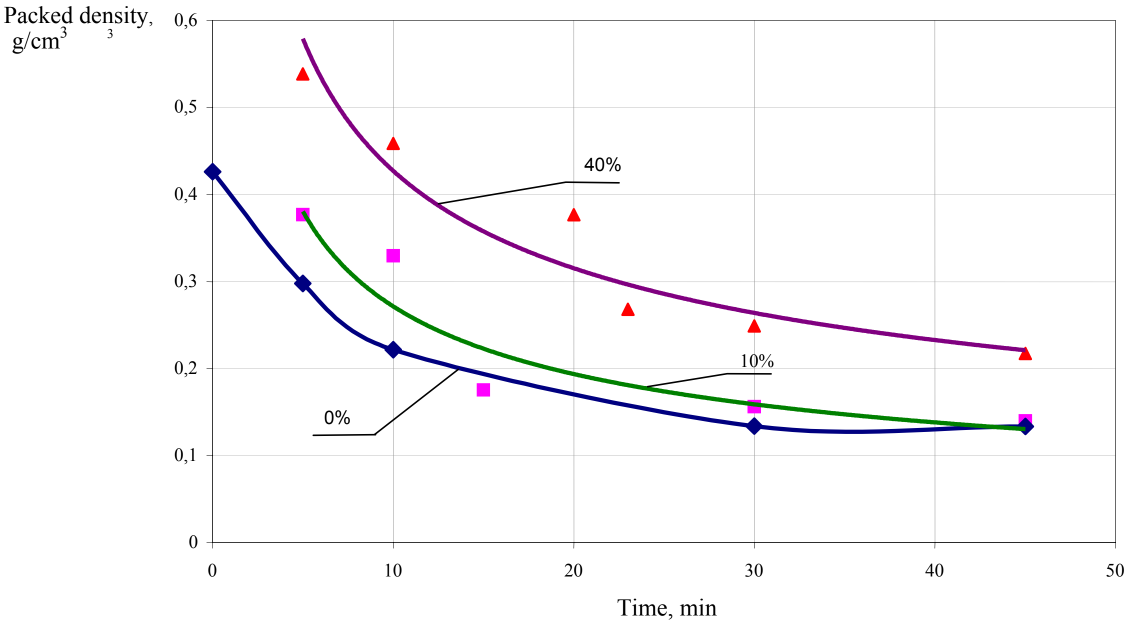

Figure 3: Packed density of the composition with different concentration of the bronze powder (0; 10; 40 % wt.) as a function of time of mechanoactivation at the planetary mixer.

This is the time that practically provides the stable properties of the produced composition. So, mechanoactivation longer than 30 minutes has no sense.
Then, to study the concentration of the bronze powder as it influences the properties of the composites the powder to make the composite material was prepared by mechanoactivtion of the super-high molecular polymer and the bronze powder using planetary mechanoactivator MPF-1 (during 30 min.) and toroidal vibration mechanoactivator MV-0.05 (during 24 hours).
As you can see in Figure 4, the way the material was prepared (30 min at the planetary mill or 24 hours at the vibration mill) does not practically effect the final density of the composite material measured at the samples to determine their stretching properties, as the actual density of the samples is almost identical to the theoretical density of the composite.
In the process of the research on physical and mechanical properties of the material the following parameters were determined:

- failure stress at stretching σ_{pp};
- relative elongation at rupture ε_{pp};
- coefficient of elasticity at stretching E_p;
- failure stress at bending $\sigma_{изг}$;
- linear expansion coefficient α.

It is important to note that despite following the same technology to make the sample to perform the tests and practically identical density of the samples the produced results reveal large enough spread in values, and the destruction of samples could be both brittle and elastic.

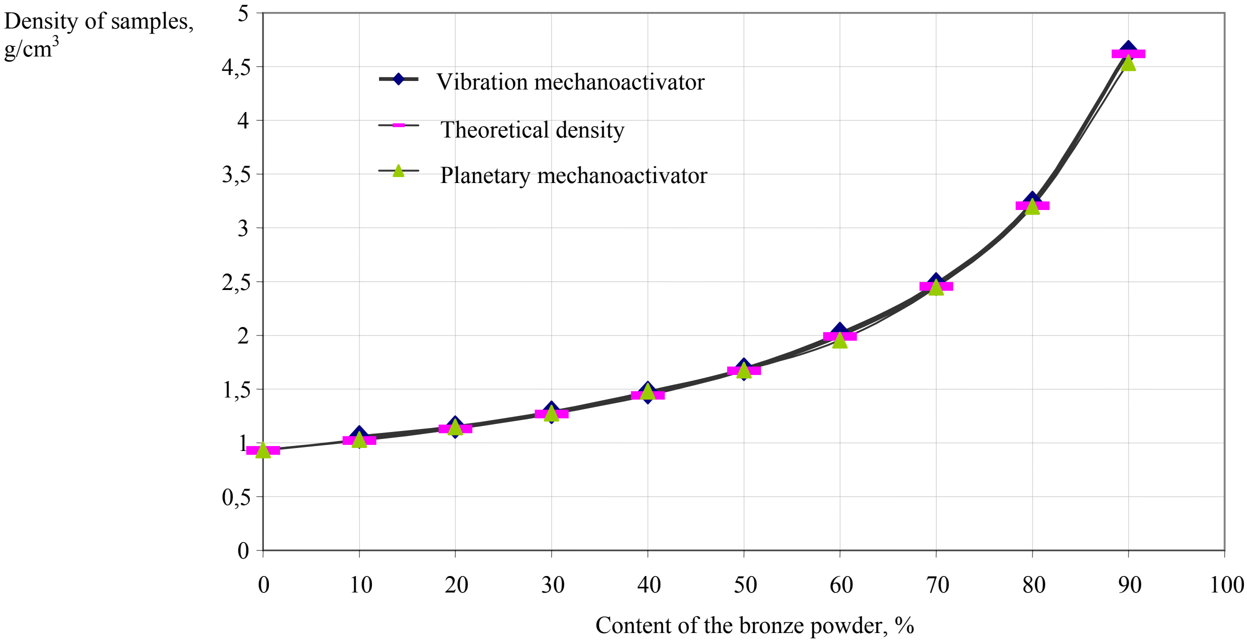

Figure 4: Calculated and actual densities of the pressed samples made of SHMPE and bronze powder mechanoactivated during 30 minutes at the planetary mill and 24 hours at the vibration mill as a function of the percent content of the bronze powder

So, only average values of the index of complete destruction of samples were considered further in the analysis.

Figures 5 and 6 show the dependencies between physical and mechanical properties of the composite at stretching and the concentration of the bronze powder in the material. The effect of the way of mechanoactivation using different mechanoactivators on the properties of the ready material was evaluated.

Analyzing the produced dependencies σ_{pp} and ε_{pp} we may note that they have rather evident extremes. For breaking point at stretching these extremes correspond to about 10 – 20 % content of the bronze powder. Besides, these curves of the strength dependencies on the content of the bronze powder are practically the same both for the planetary mechanoactivator and the vibration mechanoactivator. In a similar way the range from 10 to 20 % content of the bronze powder is important for the relative elongation at rupture. So, additional experiments for the planetary mechanoactivator were performed with the concentration of the bronze powder of 12.5; 15; and 17.5 % wt, aiming at clarification of the drop in the relative elongation at the rupture from 500% at the 10 %-content of the bronze powder and practically down to the zero at the 20%-content.

Coefficient of elasticity E_p, (see Figure 7) grows from about 500 MPa up to 3500 Mpa and higher with the growth of the percent content of the bronze powder. Though the produced curves reveal extremes, nevertheless the obtained dependencies are described with exponential dependences of a very similar character for both planetary and vibration mechanoactivators with a high degree of credibility.

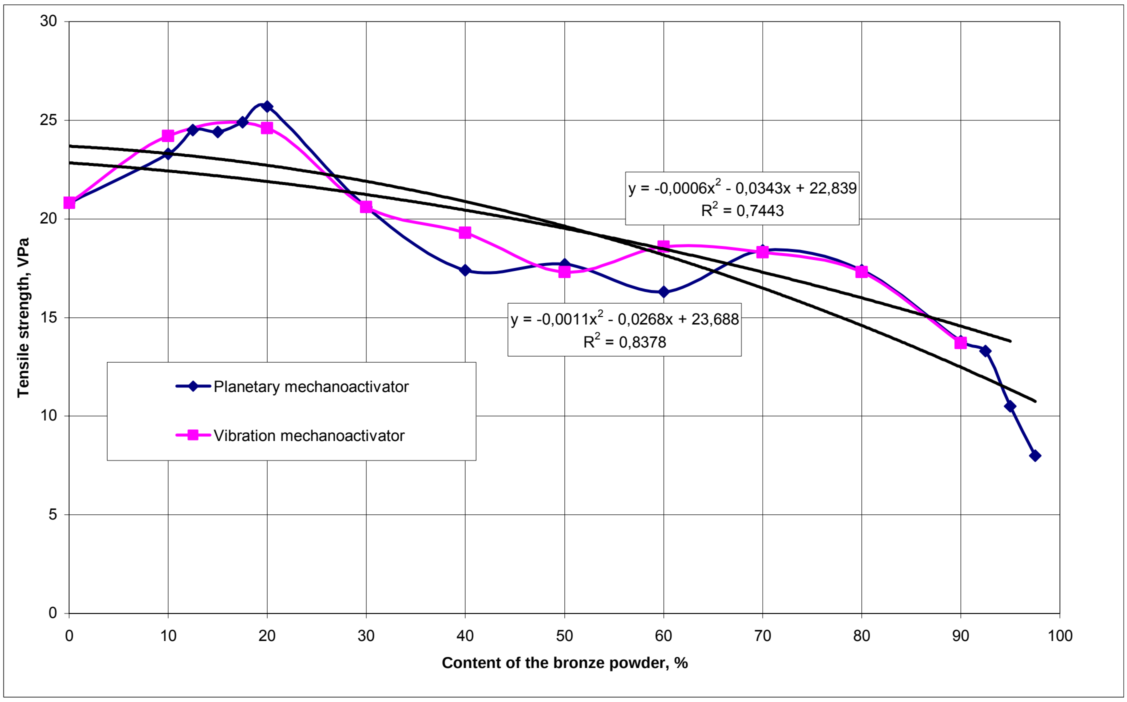

Figure 5: σ_{pp} as a function of the percent content of the bronze powder

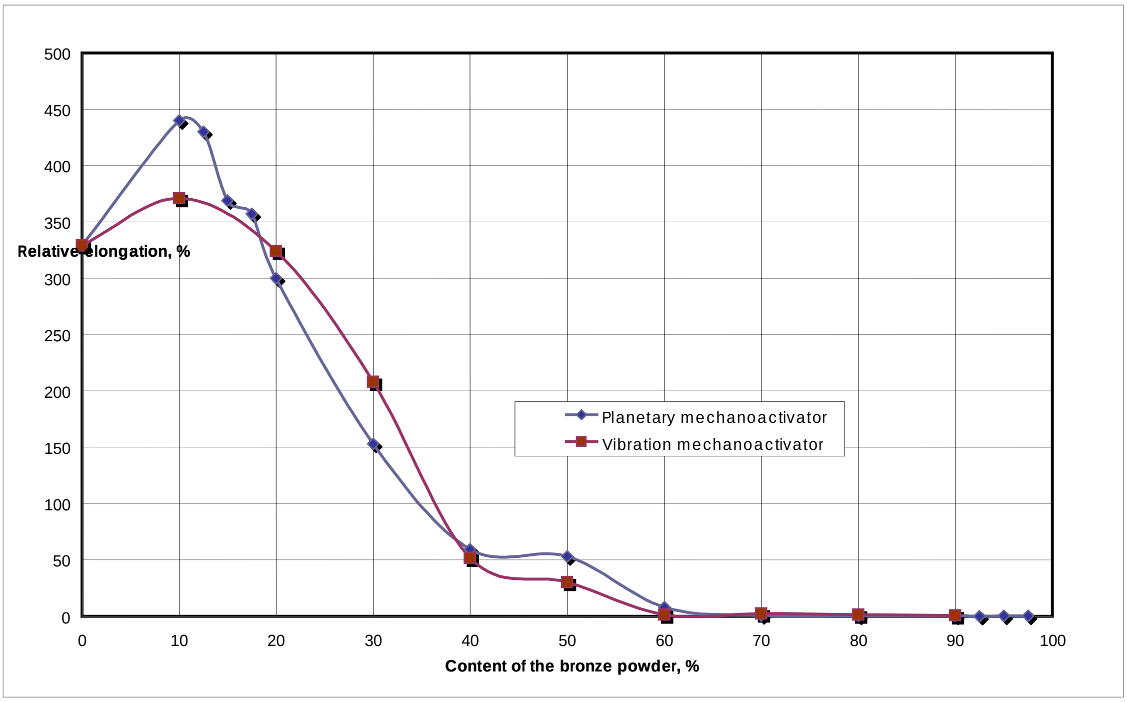

Figure 6: ε_{pp} as a function of the percent content of the bronze powder

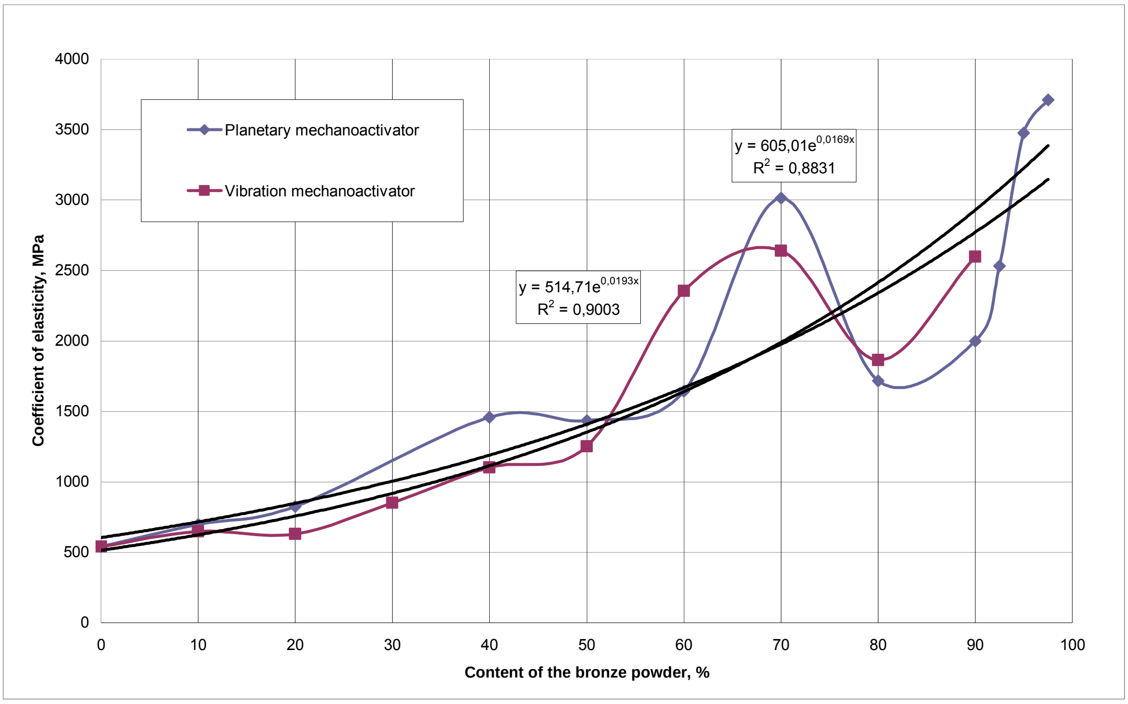

Figure 7: $\boldsymbol{E_p}$ as a function of the percent content of the bronze powder

The similar monotonous character of the dependence of the coefficient of elasticity on the content of the bronze powder is testified by the fact that at even very high concentrations of bronze there are single values of the coefficient equal to 6000 MPa, and even to 8000 MPa.

Figure 8 shows the dependencies of physico-mechanical properties of the composite at bending on the content of the bronze powder in the material. The produced dependencies with a high degree of probability are described with linear functions. The produced dependencies are practically of the same character both for planetary and vibration mechanoactivators.

The functions of the linear expansion coefficient in the temperature range from 20^{o}C to 60^{o}C is given in Figure 9. The produced dependencies are similar and have the general tendency to reduction of LEC values for both types of mechanoactivators.

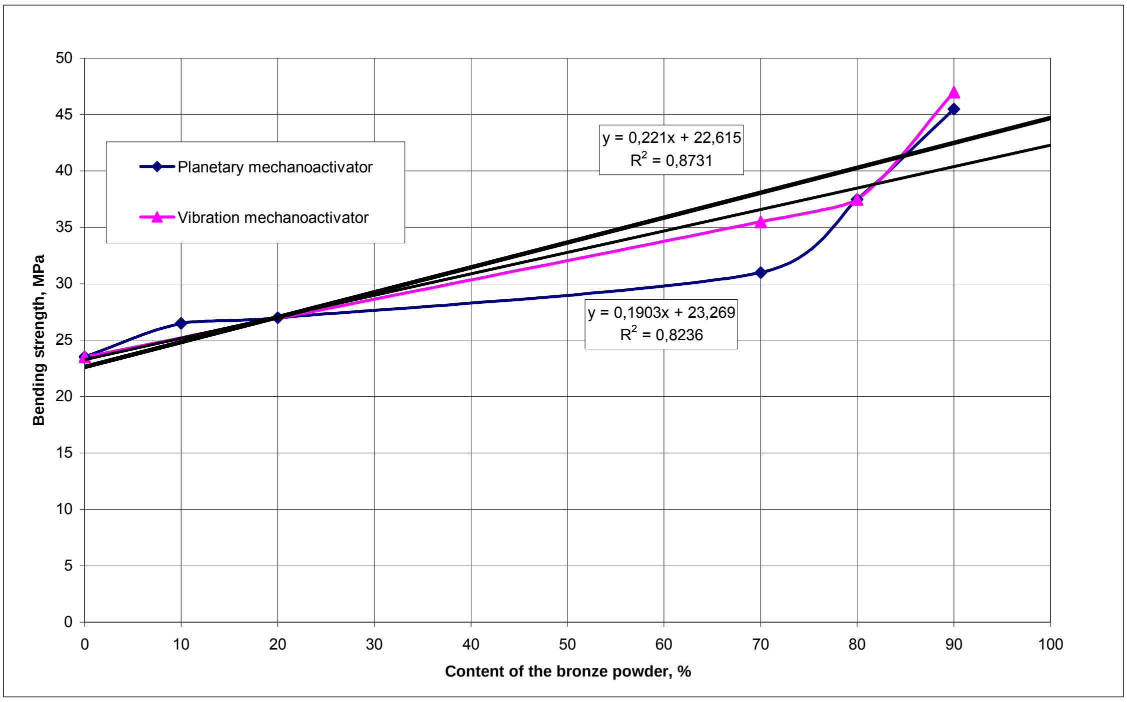

Figure 8: $\boldsymbol{\sigma_{bend}}$ as a function of the percent content of the bronze powder

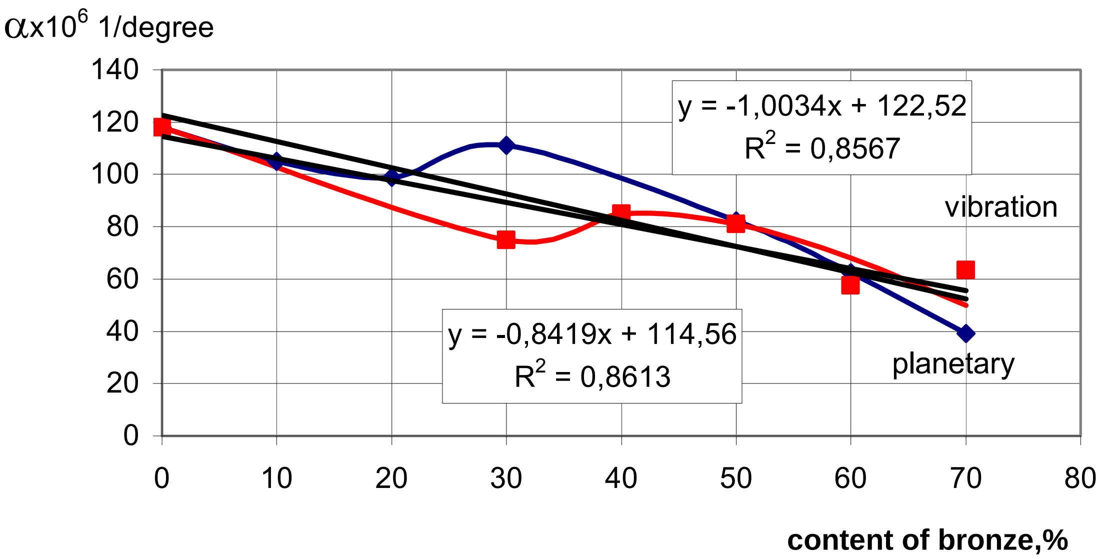

Figure 9: The linear expansion coefficient in the temperature range from 20°C up to 60°C as a function of the percent content of the bronze powder different mechanoactivators.

CONCLUSIONS

A technology to produce a mechanoactivated composite material on the basis of SHMPE with 10 up to 97.5% of the bronze powder was developed and the properties of the produced material were studied.

It was found out that mechanoactivation can effect the properties of the pure polymer. For example, the strength at compression of the pure SHMPE after mechanoactivation goes down by 10 %, the relative elongation at rupture grows by 10 %, and the coefficient of elasticity goes down almost by 30 %.

It was found out that when the content of the bronze powder is up to 50% wt., the packed density does not practically depend on the way of mechanoactivation. The time of mechanoactivation of 30 minutes at the planetary mixer practically provides the stability of the properties of the produced composition.

The way the composition is prepared (30 minutes at the planetary or 24 hours at the vibration mill) does not practically influence the resulted density of the composite material.

The dependencies of physico-mechanical and thermal physical properties of the composite produced with different mechanoactivators are of a similar character and practically coincide.

For the breaking point at stretching $\boldsymbol{\sigma_{pp}}$ and for the relative elongation at stretching $\boldsymbol{\varepsilon_{pp}}$ the functions are of extreme character with the maximum at 10-20%-content of the bronze powder in the composition. For the coefficient of elasticity $\boldsymbol{E_p}$ the produced dependencies most probably are described with exponential curves.

The functions of the linear expansion coefficient in the temperature range of 20^{o}C up to 60^{o}C are rather similar and have the common tendency for reduction of the LEC values for both types of mechanoactivators.

In general, the performed work showed that introduction of the bronze powder into SHMPE followed by mechanoactivation results into the following changes:

- Growth of strength at stretching by 25%,
- Growth of relative elongation at stretching from 300% up to 500% followed by the drop down to almost 0,
- Growth of the coefficient of elasticity at stretching from 500 MPa up to 3500 MPa,
- Almost 2 times growth of breaking point at bending;
- 2/5-times reduction of the linear expansion coefficient.

ACKNOWLEDGEMENT

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