Radiomodification of mechanical properties polydicyclopentadiene of electrons

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Abstract. The results of experimentally obtained data on the change in the physicomechanical properties of a thermosetting polymer with a unique complex of technically valuable properties are considered and analyzed. In the study of mechanical properties, the dependence of the tensile strength of radio-modified polydicyclopentadiene synthesized by the PolyHIPE technology on the dose was revealed. A study of the modification of the physicomechanical properties of the polymer showed an inhomogeneity in the dependence of the voltage change on deformation, observed when the samples were irradiated by electrons in the entire range of doses, at 50 kGy, this effect is most clearly represented. A reduction in the strength limit by 42% was established for irradiation. The growth of tensile stress in the dose range from 20 to 40 kGy was determined experimentally to the value for the unirradiated sample. A graph of the strain-force dependency family is presented for irradiation with different doses, irradiation with a dose of 40 kGy, the curve characterizes the change in the deformation properties of the material, despite a general decrease in the strength characteristics of the material.

1. Introduction
The possibility of obtaining composite materials with predetermined physical and chemical properties causes their wide application at the present time. Composition materials based on polymeric binders, in particular, based on thermo-reactive polymers have a unique combination of technically valuable properties, such as high values of modules of the tensile strength and Flexural strength, low elongation deformation, high-temperature resistance and electrical conductivity. The possibilities of polymer materials are extremely wide due to the variety of binders and fillers, the inexhaustible variability of composites compositions based on them and methods of their modification.

One of the most popular monomers for the production of thermosetting polymers and raw materials for fine organic synthesis abroad was Dicyclopentadiene (DCPD). In Russia, DCPD is rarely used, only a few large enterprises use polydicyclopentadiene as a structural material. The thermosetting crosslinked polymer obtained from DCPD has unique properties – low density, high strength, resistance to chemical agents, as well as mechanical resistance at low and high temperatures [1].
connection with the stated purpose of this work is to study the radio-modification of the physical and mechanical properties of Dicyclopentadiene.

2. Materials and methods
To study the modification of the physical and mechanical properties of the polymer, the material was exposed to accelerated electrons. The choice of this type of irradiation is explained by the possibility of specifying the dose characteristic, the best geometric characteristics of the field relative to the point source and the absence of possible residual radioactivity in contrast to the reactor irradiation. Irradiation of samples was carried out at the pulse linear accelerator ILU-6, having a range of operating energy of 1.2-2.5 MeV, beam power up to 40 kW at the energy of 2 MeV and up to 20 kW at the upper and lower energy limits [2].

To study the behavior of polymeric materials in the field of ionizing radiation were acquired for the samples on the basis of thermoregulating – polydicyclopentadiene (PGCPD) synthesized according to the PolyHIPE technology (HIPEs – High Internal Phase Emulsions) [3]. The material produced by the hipe technology is viscous, paste-like emulsions, the internal phase (water) of which usually amounts to more than 70% of the emulsion volume and is dispersed in the form of proportional homogeneous drops inside the continuous external phase (monomer), forming an emulsion of the water-in-oil type. Further, the emulsion is polymerized by reacting-injector molding, forming a porous material of PDCPD. Each sample was made of polymer material by mechanical processing according to the requirements of GOST 11262-80 with the use of scaling (figure 1).

![Figure 1](image)

Figure 1. Type of sample (dimensions in millimeters).

The study of changes in the physical and mechanical properties of irradiated polymer material was carried out on the Zwick Roell Z2 test machine.5 (Zwick GmbH & Co. KG, Germany).

3. Experimental data analysis
The irradiation of samples the energy of the accelerated electrons up to 1.8 MeV, and the dose rate of 1.1 kg/s. The range of irradiation was raised 0-300 kGy, however, the samples irradiated above 120 kGy – crumbled due to increased brittleness, instance, irradiated to 120 kGy, was broken for the same reason, in the process of its installment in equipment. Below is the result in graphical form (figure 2).

The graph shows that the dependence is complex. The curve is characterized by the presence of the initial area of a sharp increase in strength to a maximum of 40 kg, followed by a decrease in values.
Figure 2. The dependence of the tensile strength ($\sigma_B$) of the material on the dose (D).

The irradiation of the material occurs in two mutually opposite process of radiation crosslinking and degradation. The predominance of material destruction over the cross-linking is seen from a significant reduction in the required effort to destroy the sample with an increase in the radiation dose, however, despite the fact that the strength characteristics of the material during dilation decrease with an increase in the dose of absorbed radiation, the dependence is not unambiguous. In the dose range from 20 to 40 kGy, there is an increase in the tension, so that the values for the unirradiated sample and irradiated dose of 40 kGy is almost the same. This can be explained by a certain balance of radiation cross-linking and destruction. It is obvious that further research in the field of these doses is needed to determine the dependence.

Figure 3. The family of dependencies of deformation force at different irradiation doses kGy.
The most interesting dependence in the analysis of the obtained graphic data (figure 3) is the stress-strain curve under irradiation of 40 kGy, the nature of which shows a change in the deformation properties of the material, despite the overall decrease in the strength characteristics of the material.

4. Conclusion
It follows from the above that small doses of radiation up to 40 kGy lead to a decrease in the degree of cross-linking of the material, to an increase in the molecular mobility of polymer chains in the amorphous phase, to an increase in the relaxation ability of the poorly irradiated material and, as a consequence, to a simultaneous increase in its strength and deformation properties. According to the data [4], small doses of radiation primarily cause the destruction of the stressed through-chains in the amorphous phase. A statement of radiation resistance in the field of low doses of material and modification of the structure may be premature before confirmation by statistical data.

5. References
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