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BRIEF OVERVIEW ON RESEARCH AND DEVELOPMENT OF RADIATION SHIELDING PROTECTIVE COMPOSITE MATERIALS BASED ON POLYSTYRENE

E.M. Prokhorenko[1], V.V. Lytvynenko[1], A.A. Zakharchenko[2], M.A. Khazhmuradov[2], T.G. Prokhorenko[3], A.P. Ben[4]
[1]Institute of Electrophysics and Radiation Technologies NAS of Ukraine, Kharkiv, Ukraine;
[2]NSC "Kharkov Institute of Physics and Technology", Kharkiv, Ukraine;
[3]Kharkiv National Automobile and Highway University, Kharkiv, Ukraine;
[4]Kherson State Maritime Academy, Kherson, Ukraine
E-mail: forshad58@gmail.com

Experimental samples of composite materials were made. These composites are based on polystyrene, which has been reinforced with powder of aluminum, with the addition of powder of tungsten for radiation shielding. The optimum modes of operations of production equipment were selected experimentally. Tensile testing of composite materials was carried out at temperatures of 250, 290, 320 K. The maximum tensile strength, at a temperature of 290 K, was a value 45 MPa. Composites with such strength are not destroyed when creating temporary or permanent radiation shielding structures. Using the code Geant4 v 4.9.6p03, calculations of the relative attenuation of the absorbed dose were performed. A layer of composite material 10 mm thick completely absorbs ionizing radiation with energies up to 100 keV. The energy for maximum half-attenuation level is 600 keV for solid layer and 300 keV for balls and loose layer.

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INTRODUCTION

In modern energy, industry, medicine, and science, sources of ionizing radiation are widely used. Also areas of particular risk are storage and disposal sites for spent nuclear fuel and various radioactive wastes.

At the same time, increased doses of ionizing radiation have a negative effect on the human body (carcinogenesis, radiation burns, various mutations, failure of organs, cordially vascular diseases). Also, ionizing radiation can change or impair the performance of equipment and devices. All these factors emphasize the need to use radiation shielding equipment.

It is not possible to completely avoid radiation exposure, it is therefore necessary to create shielding (protection), which will reduce a radiation to the safe level.

The following requirements are imposed on materials of shielding: effectiveness of radiation shielding, strength, lightness. It is possible to create such materials by combining several different components. The choice of components of these composite materials is an important problem.

Recently, considerable attention has been paid to the study of radiation- shielding materials based on polymers with the addition of various fillers [1–3]. A lot of work has been done on this topic (bibliography for reviews [1–3]). Various radiation shielding additives were used as fillers. The choice of radiation shielding component depends on the protection requirements. The choice of component is determined by the intensity of ionizing radiation and its type.

Effective shielding against neutrons is provided by Bi additives [4].

In article [5] and its bibliography, the results of radiation attenuation of gamma quanta with energies of 59.5 and 1408.0 keV are presented when composite materials based on polystyrene with a radiation-protective additive of CdTe are used. The addition of CdTe was 5, 10% of the mass of composite. Experimental results have a high coincidence with theoretical calculations [5].

A special place is occupied by composites with a radiation shielding component of tungsten [6–12]. These composite materials have a wide range of applications.

It was found that composites containing tungsten and aluminum effectively scatter electromagnetic radiation. Consequently, they can be used to protect various objects from detection by radar stations (stealth technology) [10, 11]. Radiation shielding composites were used in the manufacture of aircraft that are poorly detected by radar.

Composite materials will also be effective for radiation shielding of storage facilities for radioactive waste and spent nuclear fuel [13]. In this case, there are no restrictions on the thickness of the shielding layer. Therefore, additives with low radiation protective characteristics can be used.

Composite materials were studied in which steel powder was used as a radiation shielding additive [6–12, 14–17]. Steel powder is obtained during the production of various products [15–17]. Steel powders are production waste. Steel powders are cheap and, accordingly, the cost of composites is low.

Composite materials are characterized by several parameters. The most important parameters are: radiation shielding characteristics; characteristics of strength, hardness.

In this work, polystyrene and tungsten composite materials were considered and their main characteristics were studied.

OBJECTIVES OF TNE STUDY

The objectives of tne study were as follows:

1. Improvement of the technology for manufacturing composite materials of the C08YYZZ type [6] and production of experimental samples.
2. Determination of the dependence of the tensile strength characteristics for composite materials with a high content of metal components.
3. Study of radiation shielding characteristics of materials of type C08YYZZ.
4. Choice of optimum ratios of the number of components of composite to create protective structures and screens.

CONDUCTING EXPERIMENTS AND DISCUSSION OF RESULTS

The results of work on the development and production of experimental parties of polystyrene of metal composite materials (PS-W-Al [6]) were presented in articles [6–8, 11, 12]. Some of these composites have already passed laboratory tests and have been used in practice. It was found that these composites have high performance characteristics.

The creation of composite materials requires solving a number of problems. It is necessary to select the material of base. Also, it is necessary to select a material for reinforcing the composite and creating its framework. Depending on the type of ionization radiation, it is necessary to determine a radiation shielding additive. An important stage in the creation of composite materials is the development of technological processes for the production of composites.

Materials of composites. When creating radiation shielding composite materials, the following components were used: polystyrene, tungsten and aluminum.

Polystyrene [18, 19] was used as a base. Its softening point is 86…92 °C, melting point is 196…200 °C. Polystyrene has low hygroscopicity, high water resistance, and is resistant to acids and alkalis. It should be noted that polystyrene is resistant to ionizing radiation (electrons, ions, X-rays and gamma rays, neutrons). Thus, polystyrene is an effective material that is used as a base in the creation of radiation shielding composites.

Powder of tungsten was used as a radiation shielding additive for composites. Composites with the addition of tungsten have high radiation shielding properties [8–13]. Highly dispersed powder of tungsten was manufactured in accordance with the requirements of document TU U 24.4-41010958-001-2017, ISO 4499-2:2020 [20, 21]. The particles of powder could have sizes: 20…40, 50…60, 120…150, 180…210, 230…280 μm.

Tungsten does not interact well with polystyrene because polystyrene does not wet tungsten. Therefore, it is necessary to apply another component that will reinforce the composite.

Highly dispersed aluminum powder was used as a component that helped reinforce the composite material. The strength of the bond between the filler and the base is determined by the type of adhesive interaction.

Tungsten powder interacts weakly with polystyrene. Finely dispersed aluminum powder has a high mechanical interaction with polystyrene.

Note that the presence of aluminum improves the volumetric distribution particles of tungsten in the composite material.

In the manufacture of composite materials, powders of aluminum were used. The powders were obtained from aluminum types ASD-6 or 2014, 6111 [22, 23]. Powders of aluminum comply with the standards given in the documents: ISO 209-1, TU 1791-007-49421776-2011 [24, 25]. Particles of aluminum can have the following sizes: 10…20, 30…40, 60…90 μm.

Improvement of equipment. In the production of composite materials, the following installations were used: Kuasy 100/25, Windsor SP 80. Using this equipment, they not only produced products from reinforced polystyrene, but also refined the technological process for the production of composite materials.

The Kuasy 100/25-1 and Windsor SP 80 are horizontal injection molding machines. The production of composite materials using them is carried out using the extrusion method.

Therefore, the equipment has been improved. The raw material supply system was modified and an additional device for mixing the components was added. Additional heating blocks are installed. The temperature control system has also been improved. Original appearance of equipment after the conducted revisions is presented on photographs in works [8, 10, 11].

Some of the blocks that have been improved are shown in the photograph (Fig. 1).

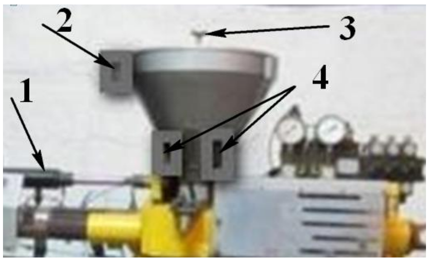

Fig. 1. Photo of the improved raw materiali supply system and hopper: 1 – raw materials supply motor and rotation system; 2 – motor for the raw materials mixing system; 3 – IR camera for control of heating; 4 – are heater blocks

The mixing system was supplemented with blades and bunker rotation devices (see 1, 2 in Fig. 1). A mixer was added to the bunker. These devices had adjustable rotation speeds. By changing the rotation speed, an operating mode is selected in which maximum uniformity of the distribution of components throughout the entire volume is achieved Unfortunately, the rotation speeds of the blades and the feed system are different for each type of composite material and each type of component grain size.

The selection of rotation speed values is carried out experimentally and this is a very labor intensive task. Work was carried out to select speeds. Speed tables are an addition to the technological process.

Also, the system of heating has been improved. Additional heaters have been added (see 4 in Fig. 1). These heaters allow the temperature of the mixture components to be equalized due to their different thermal characteristics.

The mixing homogeneity control system has been improved. Various techniques are used to control the homogeneity of mixing. The color on the surface of the mixture was monitored using optical instruments. The degree of homogeneity of mixing of the composite components was determined by shades of gray and steel colors. Optical methods make it possible to determine the number of lumps.

Control of temperature was carried out using a pyrometer (Fluke). The imperfection of the pyrometric method is that the temperature is measured at only one point. That is, there is no information about the overall temperature of the mixture. A temperature in separate parts of mixture can differ substantially. Reason of it is low heat conductivity of polystyrene.

Therefore, IR radiometric methods were used to determine the temperature field on the surface of the mixture. For this purpose, thermal imaging devices Lend Ti-814, Fluke-10, Fluke-25 were used [26]. Using IR radiometric methods, a thermo gram of temperature gradients on the surface of the mixture was obtained in real time. Also, using IR radiometric methods, the degree of mixing of the components and the presence of lumps of material were determined (Fig. 2).

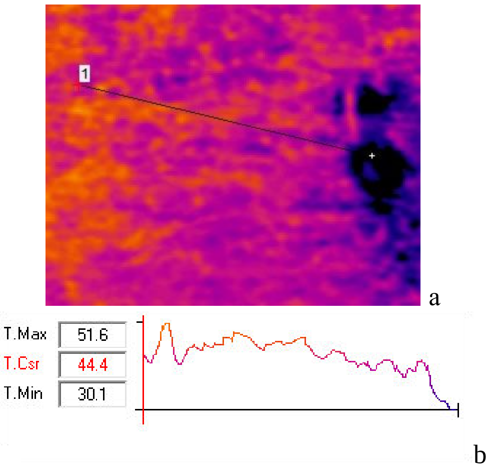

Fig. 2. Photograph of a thermo gram of the mixture surface at the initial stage of composite production (a). Graph of changes of temperature on the surface of the mixture along line 1 (b)

The thermo gram (see Fig. 2,a) was obtained at the initial stage of the composite materials production process. On the left side of the photo (point 1) there is higher heating of the components than in other places.

At this point, a high uniformity of distribution of components throughout the volume of the mixture was obtained. There are several dark spots on the right side of the photo.

This indicates the presence of several lumps of polystyrene in this volume area. The thermal conductivity of tungsten and aluminum is higher than polystyrene, so they warm up faster. The photograph (see Fig. 2,b) shows how the temperature on the surface of the mixture changes along section line 1. In the area where the polystyrene lumps are located, the temperature is lower than in the area where the mixture is heated and mixed.

Composite materials were marked as follows: CXXYYZZ [6]. Here XX is the volumetric content of polystyrene, YY is the volumetric content of tungsten, ZZ is the volumetric content of aluminum. The choice as a unit of volume measurement is determined by the specifics of the production of composite materials. Certain volumes of components are loaded into the apparatus for producing composites. In general, the total load of the apparatus was 15 special “measuring” containers. Therefore, in the future, all calculations were performed taking into account this limitation.

The following basic characteristics of composite materials were studied in the work: hardness characteristics, strength characteristics, radiation shielding characteristics.

To determine the hardness of composite materials, various methods were used: Barkol's method, Shore's method, Rockwell's method. The Rockwell method was chosen as the main one. When using it, a minimum number of measurements must be performed. It was found how the hardness of the composite depends on various parameters. The parameters of the composite were as follows: type of components, ratio of components, sizes of grains of components, degree of uniformity of distribution of grains of components throughout the volume of the composite [6–8, 10, 11].

In the manufacture of composite materials, powders of aluminum and tungsten of fixed sizes were used. The size of the grains of aluminum was 10…20 μm. The size of grains of tungsten was 50…60 μm.

Calorimetric tests of the samples were carried out. From calorimetric tests it follows that there are no transformations of the components over the entire temperature range, up to the melting of polystyrene. That is, there is no chemical interaction between the components. Consequently, strengthening of the composite material occurs only due to the mechanical bond between polystyrene and grains of metal. Also, strengthening increases due to the stretching of polymer chains and their reorientation.

Conducting ultimate tensile strength measurements. To carry out measurements, several types of composite material samples are needed. When measuring hardness, plates (70×40×10 mm) were used. Such dimensions are also necessary in experiments to measure the absorbed dose. These measurements were carried out using sources of ionizing radiation ^{241}Am (gamma rays with an energy of 60 keV) and ^{90}Sr [10].

Also, plates of such sizes are convenient when used in individual protective kits [6, 7].

An important characteristic of composite materials is strength. The strength of the composites was studied using a tensile testing machine. Tensile tests of composites were carried out in accordance with the requirements of regulatory documents ISO 527-1 [27].

To operate the tensile testing machine, samples of composite materials were used in the form as rods by length of 120 and 10 mm in diameter. From experiment can find the tensile strength of composites, the value of relative elongation, and the limit of fluidity.

There are works in which composites are studied under compression [28]. Comparison of the results that were presented in [28] with the results that were presented in [11] and presented in this work allows us to identify general patterns of changes in strength characteristics.

The main parameter that is studied when conducting experiments on tensile testing machines is the tensile strength on a break.

It was found that the tensile strength of composites is higher, than higher the dispersion powders of tungsten and aluminum. Also, the tensile strength strongly depends on the ratio of the volumes of the components of tungsten and aluminum. The higher the aluminum volume content, the higher the tensile strength.

After studying of composites C12YYZZ and C10YYZZ [11], the question arose of studying the characteristics of composites that have a higher amount of volumetric metal components. Such composites are composites of the C08YYZZ type. The composite material C08YYZZ consists of 8 parts of polystyrene and 7 parts of a metal component.

From the group of composites C08YYZZ, composites C080106, C080304, C080403, C080601 were studied.

For clarity, the appearance of composite of C080403 is shown in Fig. 3.

Fig. 3. Original appearance of sample of S080403. Size of grains of component: Al – 10…20 μm, W – 50…60 μm

The appearance of sample C080403 (see Fig. 3) has a characteristic appearance for composites of the C08YYZZ class.

In composites of the C08YYZZ class, the amount of the metal component is almost equal in volume to the polystyrene component. In works [1–3, 6–11, 28] it was noted that the hardness and strength of composite materials increases when the amount of the metal component is increased.

But this statement is true within certain limits. Maximum strength is achieved with an equal number of components.

The values of the mass%. and densities of composite materials are given in Table 1.

The first column of the table shows the types of composites and their densities. The remaining cells: is the mass of each component (in percent).

To control the accuracy of the tensile testing machine, tensile tests were performed on pure polystyrene samples. The tests were carried out at a temperature of 290 K. The rupture occurred with tension. In this case, a neck was formed. The elastic modulus had a value of 2.1 GPa. The relative elongation was equal to 95…96%. Pure polystyrene had a high limit of fluidity, which is equal to 24…25 MPa. The tensile strength value was 22…23 MPa.

Table 1

Percentage content of components in composites type C08YYZZ

Material/ density, g/cm^3	Polystyrene (PS), mass %	Tungsten (W), mass %	Aluminum (Al), mass %
C080106/2.95	19.9	43.6	36.5
C080304/5.17	11.4	74.7	13.9
C080403/6.27	9.4	82.0	8.6
C080601/8.49	6.9	90.9	2.2

At the next stages of research, the strength limits of composite materials of class C08YYZZ were measured.

Composites are used in various weather conditions. Therefore, the studies were performed at three fixed temperatures (250, 290, 320 K). The results of mechanical tests using a tensile testing machine are given in Table 2.

Table 2

Tensile strengths for materials of C08YYZZ type composite

Tape T, K	250 K, MPa	290 K, MPa	320 K, MPa
PS	37.0	23.0	22.0
C080601	41.5	42.5	41.9
C080403	42.2	43.8	43.3
C080304	42.8	44.5	44.2
C080106	43.5	46.5	46.3

These results were also presented graphically in Fig. 4.

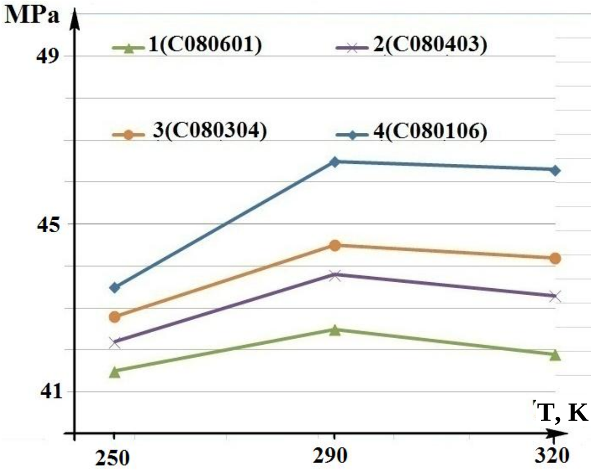

Fig. 4. Values of tensile strength of composite materials C08YYZZ depending on temperature

Comparison of results. At the first stage, the tensile strength of composite materials of C08YYZZ were measured at a temperature of 250 K (-23 °C). For all composite materials, the ruptures were brittle. When stretched, no neck of the sample was formed.

Also, it is not discovered microscopic necks on the surface of the rupture. It should be noted that there is a significant increase in the fragility of polystyrene. This is due to the transition of a significant part of polystyrene to the “glass” state.

At a temperature of 250 K, composite materials are very sensitive to inhomogeneities in the distribution of components throughout the volume of the composite. That is, it is possible that a brittle rupture may appear at points where the thickness of the composite is inhomogeneous. The sensitivity of polystyrene to cuts has increased. Brittle rupture appeared in areas where there was material delamination. The relative elongation was no more than 1%. The tensile strength values are given in the first column of the Table 2.

The tensile strengths of C08YYZZ composite materials differ from each other. The differences depend on the ratio of the amounts of components of aluminum and tungsten. The tensile strengths are greater than for composites of the C12YYZZ and C10YYZZ classes [11]. The differences between the tensile strengths of composites of classes C12YYZZ and C10YYZZ, at a temperature of 250 K, also depend on the amount of polystyrene.

The main temperature regime in which composite materials are used is the temperature range around 290 K. Therefore, the main attention was paid to experiments at a temperature of 290 K.

The rupture occurred with the formation of a neck, which was short. The relative elongation was 10…15%. The rupture surface is significantly different from the rupture surfaces of the C12YYZZ and C10YYZZ composites. For clarity, Fig. 3 shows a photograph of the rupture surface of the composite material C080106. He has maximum tensile strength values. The reason for this is the maximum amount of highly dispersed powder of aluminum. Microscopic necks were found on the surface of the rupture (Fig. 5).

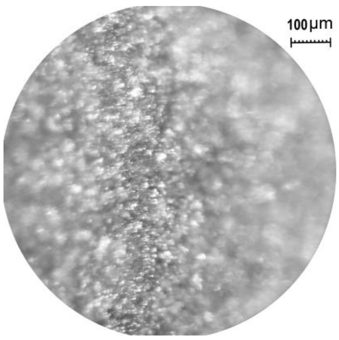

Fig. 5. Photograph of the fracture surface of composite material C080106

The necks have very little elongation. This is due to the fact that all the polystyrene has come into contact with the particles of the metal component. The maximum elongation of the necks is observed only in the areas of homogeneity defects, where there is free polystyrene. These effects fit well with the theory of ruptures in graft copolymers that have been reinforced.

Experiments were also carried out at temperatures of 320 K. The relative elongation was 15…20%. The rupture occurred with the formation of a small neck. Microscopic necks were also found on the surface of the rupture. In this case, both the rupture neck and the microscopic necks had a height slightly greater than at a temperature of 290 K. This difference has a simple explanation. As the temperature rises, polystyrene softens. Accordingly, the sample is stretched more strongly. The microscopic necks on the surface of the rupture also become longer.

For C08YYZZ samples, the fracture neck and microscopic necks on the fracture surface are less elongated than the necks for composites of the C12YYZZ and C10YYZZ types [11]. The reason for this is the presence of free polystyrene. Since composites of the C12YYZZ and C10YYZZ types have the amount of metal component less than the amount of component of polystyrene.

That is, the density of filling the matrix with reinforcing components (grains of aluminum and tungsten) is also less than for the C08YYZZ composite. And with increasing temperature, the plasticity of free polystyrene increases, which contributes to an increase in the neck of the rupture and elongation of the microscopic necks on the surface of the rupture.

Tensile strength depends not only on the amount of the metal component, but also on the size of the grains. From the graph Fig. 2 shows that the maximum tensile strength (46.5 MPa) has the composite material C080106. This composite has six volume parts of aluminum and only one volume part of tungsten. The degree of interaction between aluminum and polystyrene is higher than the degree of interaction between tungsten.

Also, grains of aluminum are smaller in size (10…20 μm) than grains of tungsten (50…60 μm). Consequently, reinforcing a composite material with grains of aluminum is more effective than with grains of tungsten. The number of grains of tungsten is significantly less than that of grains of aluminum. Therefore, each grain of tungsten is fixed in the composite material with a frame made of a mixture of aluminum and polystyrene. At the same time, the strength of the composite only increases.

Composite material C080106 has the lowest tensile strength (42.5 MPa) in this group of composites. It contains six volumetric parts of tungsten and one part of aluminum. The size of grains of tungsten is three times larger than grains of aluminum.

Therefore, polystyrene is reinforced with tungsten with a small amount of aluminum. And the connection between tungsten and polystyrene is much lower than the connection between polystyrene and aluminum. Accordingly, the value of the tensile strength is lower than for composites of this type, but with a higher content of aluminum components.

From experimental measurements of the tensile strength we can obtain the height of shielding structures. Shielding structures can be higher than five meters when composite materials of type C08YYZZ are used. In this case, the shielding objects (balls or plates) are not destroyed.

Calculation of radiation shielding characteristics. The main characteristic of radiation shielding composite materials is their shielding properties. In the case of actual use of composites, it is necessary to know their radiation shielding characteristics. Practical measurement characteristics of shielding is a long and labor-intensive process. Therefore, software packages have been developed to calculate the attenuation of ionizing radiation. The Geant4 v 4.9.6p03 software package was used for calculations [29, 30]. For the calculations that were carried out, the package was improved [31].

Previously, studies of the characteristics of composite materials with a low content of metal components have been carried out. Theoretical calculations of radiation shielding properties were performed [6–8] and experimental measurements were performed [10]. Also, the radiation shielding properties of the C12YYZZ and C10YYZZ composites were studied [11]. A high agreement between theoretical calculations and experimental measurements was found.

The basic parameter of efficiency of shielding is the relative attenuation of dose of ionizing radiation. This parameter is calculated on a mathematical formula:

$$\eta = 1 - \frac{D}{D_{air}}, \qquad (1)$$

D_{air} – is the calculated dose, in the absence of shielding; D – is the calculated dose when shielding; η – is the degree of relative attenuation of the absorbed dose of gamma radiation by a layer of shielding made of a composite material. In these calculations, the effect of ionizing radiation on a biological phantom was considered.

Calculations of protective characteristics were carried out for composite materials of the C08YYZZ type. Samples of two types were studied. One of the samples looked like plates measuring 70×40×10 mm. But in practice, working with samples of this type is not always convenient. Therefore, it was proposed to use a composite material in the form of balls. Composite materials were manufactured in the form of balls with a diameter of fixed sizes (1, 2, 5, 10 mm).

The use of composite materials in the form of balls makes it possible to quickly create protective structures of complex configurations. The crumbly structure of the composite material makes it possible to create shielding structures with filling of all cavities and openings. Therefore, in the case of working with low-intensity ionizing radiation flows, it is advisable to use crumbly radiation shielding composite materials.

Graphs were obtained showing the values of attenuation of the absorbed dose of ionizing radiation. The graphs are presented in Fig. 6.

The thickness of the composite material was 10 mm. The choice of this size was determined by several conditions. Plates of composite material with a thickness of 10 mm are convenient for installing the shielding layer. Samples of this thickness were used to measure absorbed dose or hardness in experimental work. The same thickness of the shielding layer was in the case of crumbly composite materials.

On Fig. 6 shows graphs of attenuation of ionizing radiation. As limiting cases, curves are shown for pure polystyrene (continuous curve of black) and composite material C051000 (continuous curve of black with markers).

From the graphs Fig. 6,a it can be seen that composite materials effectively absorb gamma radiation with energies up to 100 keV. A significant number of different equipment and devices operate in this energy range.

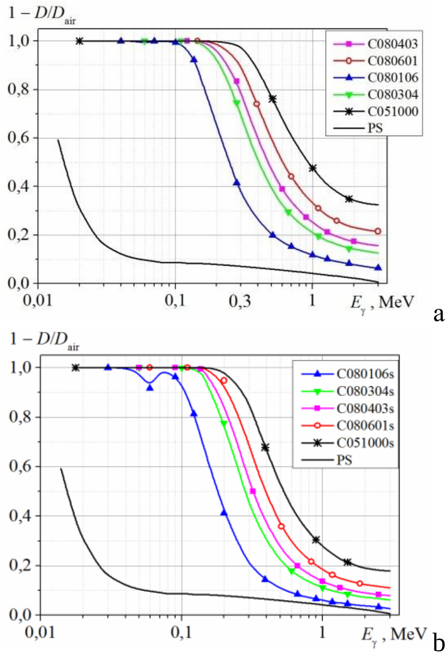

Fig. 6. Graphs of attenuation and absorbed dose of ionizing radiation:
a – continuous layer of the C08YYZZ composite;
b – layer of balls with a diameter of 5 mm

Thus, XRD analysis and mammography devices operate in the energy range up to 10 keV. X-ray machines designed for dentistry operate with radiation up to 68 keV. For the needs of medical computer tomography and the work of services of security (airports, various access zones), sources of ionizing radiation with energy of 100 keV are required.

Also, calculations were performed for composite materials that were made in the form of balls. Initially, the calculations for crumbly composites took into account the size of the balls, their curvature, shape and number of cavities. For comparison, the protective properties were calculated when the reduced density of the composite was used instead of these characteristics. They got results differ insignificantly.

Therefore, in the calculations we used the reduced distribution densities of the composite material over the volume of the sample. For crumbly compos charts were presented on Fig. 6,b. The crooked weakening have a form similar with the form of curves resulted on Fig. 6,a.

Note that not in all cases, complete absorption of ionizing radiation is necessary. For safe operation, it is necessary to reduce the level of ionizing radiation to safe limits. Therefore, the half-attenuation value is also an informative parameter.

For the composite material C080601 we have the following half-attenuation values: a) 600 keV (solid layer); b) 400 keV (there was a crumbly filling of the layer). For the composite material C080106 we have the following half-attenuation values: a) 250 keV (solid layer); b) 100 keV (there was a crumbly filling of the layer).

Composite C080601 has the maximum shielding characteristics among composites of the C08YYZZ class. The C08YYZZ composite contains the maximal amount of tungsten. Similar proportions of characteristics of shielding are preserved and for composite materials C080403 and C080304.

For quanta with energies above 1 MeV, the shielding efficiency of composite materials of this type is low. Therefore, the use of such composite materials is advisable for protection against ionizing radiation with quanta gamma energies up to 500 keV.

Combining the results of experimental studies and theoretical calculations makes it possible to select the required composite material. At the same time, the composite has predetermined radiation shielding characteristics and strength parameters that are necessary for each specific case. The synthesized materials can be used in conducting research with man-made and natural low-background sources of ionizing radiation [32].

CONCLUSIONS

Samples of composite materials of the C08YYZZ series were manufactured. The optimal proportions of the amount component of aluminum and component of tungsten and the sizes of their grains were selected.

Research has been carried out to create a technological process for the production of composite materials of this type.

For composites C080106, C080601, C080403, C080304 mechanical tests of tensile strength were carried out. Tests were carried out at temperatures of 250, 290, 320 K. It was found that the maximum tensile strength occurs at a temperature of 290 K.

It is found that the tensile strength generally increases with increasing amount of aluminum component. It was determined that composites with the smallest particle sizes of components had the maximum tensile strength.

The numeral calculations of coefficients of weakening of ionizing radiation are executed for composite materials with the equal volumes of components of polystyrene and metal.

Composite materials in the form of a continuous layer and in the form of balls were studied.

It is got, that the coefficient of weakening of ionizing radiation is increased with increasing of component of tungsten and has a maximum value for the composite of C080601 (90.9% composite masses).

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КОРОТКИЙ ОГЛЯД ДОСЛІДЖЕНЬ ТА РОЗРОБКИ РАДІАЦІЙНО-ЗАХИСНИХ КОМПОЗИТНИХ МАТЕРІАЛІВ НА ОСНОВІ ПОЛІСТИРОЛУ

Є.М. Прохоренко, В.В. Литвиненко, О.О. Захарченко, М.А. Хажмурадов, Т.Г. Прохоренко, А.П. Бень

Виготовлено експериментальні зразки композиційних матеріалів. Ці композити створені на базі полістиролу, армованого порошком алюмінію, з додаванням порошку вольфраму для радіаційного захисту. Експериментальним шляхом підібрано оптимальні режими роботи виробничого обладнання. Проведено випробування композиційних матеріалів на розрив за температур 250, 290, 320 К. Максимальне значення межі міцності на розрив за температури 290 К становило 45 МПа. Композити з такою міцністю не руйнуються під час створення тимчасових чи стаціонарних захисних споруд. За допомогою коду Geant4 v 4.9.6p03 виконані розрахунки щодо ослаблення поглиненої дози. Прошарок композиційного матеріалу товщиною 10 мм повністю поглинає іонізуюче випромінювання з енергіями до 100 кеВ. Максимальний рівень половинного ослаблення є 600 кеВ для суцільного прошарку та 300 кеВ для прошарку, що складається з кульок.