PERFORMANCE RATIO HARDNESS CHARACTERISTICS POLYSTYRENE-METAL COMPOSITE MATERIALS

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The methods of measuring the hardness of layered polystyrene-metallic composite materials. It is proposed to use powder-like tungsten and powder-like steel as radiation-protective layer. A measurement of the hardness of composites of different composition, and given its dependence on the particle size and their form. The possibility of increasing the hardness of the composites reinforced with metallic additives. Radiation-protective characteristics were calculated for the studied species of composite materials. Influence of the quantitative composition of the metal components is studied on the change of the absorbed dose of gamma radiation.

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INTRODUCTION

The questions of creation and perfection of radiation protection materials remain a priority the during exploitation of nuclear facilities. This is due to more stringent requirements for the protection of personnel and equipment, and also environment. Traditional protection materials (primarily lead-based) have a number of advantages, but do not meet modern requirements. The improvement and the creation of protective materials is based on the modern achievements of science and technology. Thus several materials together with certain radiation-protective properties. Primary materials have different properties that allow to obtain a composite material with the required parameters. New composite materials with high radiation-protective characteristics must also have a number of additional properties that are determined by the specific conditions of application. In this paper we study a polymer-metal composite material for radiation protection of biological objects and equipment.

PURPOSE OF WORK

Study of the main characteristics of the polymer-metal composite materials intended for radiation protection. The choice of methods of measurement of hardness and the rationale for their accuracy. Finding of hardness of different types of composition materials depending on material of component, sizes of constituents and quantitative composition.

Determination of the components to simultaneously maximize the radiation-protective characteristics, high hardness and a minimum density of matter. The study of the protection of the absorption of gamma rays by composite materials of different chemical composition. Comparison of changes in the absorbed dose of gamma radiation for composites with the addition of tungsten or steel.

THE MAIN PART

The question of protection against ionizing radiation is divided into protection from his separate kinds. In a broad sense ionizing radiation consists of streams of alpha and beta particles, streams of neutrons, X-ray and gamma radiation. For each of these types of radiation has its own specific protection. When protecting against neutrons used light elements (B, H, N), which have a large absorption cross section. Elements with high atomic masses (Pb, W, etc.) to protect against X-ray and gamma radiation. Consequently, the development of composite materials with a wide range of radiation qualities. Earlier [1–4], it was proposed to use a polymer-metal composite material. They were made of polystyrene reinforced with metallic components. Production of this material took place on a standard equipment. Used on injection molding automat VLM-150 and KUASY 1400/250. This equipment is intended for the production of multi-component reinforced composite material from thermoplastic polymers. Injection molding machines have been modified with additional systems of thermostatting,, monitoring and control of heating. For this purpose applied the devices IR radiometry [5, 6] (Ti-814). Infrared Emission from the surface of mixture was registered Ti-814. The efficiency of mixing the mixture homogeneity was determined by heating the image on the thermogram. The sensitivity of the imager Ti-814 is 0.08 °C, allowing to accurately determine the temperature and homogeneity of the components in the mixture.

For the composite materials of different chemical composition have been calculated their radiation-protective properties [1–3, 5, 7]. The areas of energies in which a gamma-radiation is taken in with maximal efficiency are found. The features of the absorbed dose changes depending on the type of composite material are studied.

The composite material was manufactured in the form of balls. From the experience of practical use of selected sizes of balls. In this case, the radiation-shielding material was used in several versions: a) the protective layer of protective kits; b) a filler stationary protective structures. The most convenient to use balls with a diameter of 2 mm. The balls of this size allows the protective layer to be mobile and flexible. This achieves the maximum filling of the protective layer. The protective layer in a stationary protective structures can be filled with these balls.

The composite should be: a) the possibility of processing and utilization; b) low sorption and chemical activity; c) resistance to swelling under the influence of radiation. Polystyrene is resistant to ionizing radiation.

The phenolic radical provides resistance. Therefore, the basis is polystyrene.

One of the additional requirements that apply to the developed composite materials is that they must have low heat-conducting properties. Polystyrene is a good thermal insulator. His thermal conductivity thermal of 0.12 W/(m·K). Heat conductivity of composite is a bit below as compared with pure polystyrene. The results of experimental verification of heat-shielding properties of different types of composite materials are in [8] resulted. Dependences of heat conductivity are found on component composition of composites. Increased metal components impairs heat-shielding properties. Various types of metal components have different effects on the thermal conductivity of the material.

Thus, when using tungsten powder composite heat-shielding characteristics is lower than when using the aluminum powder, since the thermal conductivity of aluminum is six times higher than that of tungsten. Depending on the number of components of the thermal conductivity of the metal may vary within 10…25%. This is due to the high thermal conductivity of aluminum.

Structuring the composite material also improves the thermal insulation properties. Application of the composite form of beads with a diameter of 1 mm reduces the heat flow rate is – 7%, and in the form of spheres 4 mm – 10%. Thus, the development of composite materials present factors as increasing the thermal conductivity, and reducing it. When using the polymer of metallic composition materials arises up question of their durability. Depending on the degree of durability determined by the size of temporary protective buildings filled with the protective layer of the composite material balls.

The destruction of the elements of the composite material leads to a change in the shape of the protective structure, a violation of his integrity, deterioration of radiation-protective properties. For determination of strength of material the concept of hardness is entered.

Term “hardness” behaves to different properties of composition material and has a wide spectrum of properties: a) hardness can be defined as resistance of material of remaining deformation; b) in the study of coating hardness measurement can be used to determine the stability of the coating scratch resistance to abrasion, cutting characteristics, the ability to handle grinding; c) the degree of hardening of the coating – hardness; d) the hardness is determined by the penetration resistance, resistance to pressure.

Dependence has between hardness and other properties of materials. Therefore, the hardness is an important finding in the study of polymer-metal composites. Various methods are used to determine the hardness. They are based on the ability of a material to resist to introduction in him of other body.

Several techniques used to measure the hardness of plastics, rubber, soft metal (such as tin, aluminum). These techniques can be applied to determine the hardness of the polymer-metal composition materials. Currently, the most often used method Shore (Shore A, D), method Barcol, method Rockwell – scale (P).

The method of Shore is based on measurement of the depth of penetration of the indenter into the material. Steel indenter is embedded in the material. To work with plastics using use the indenters of two kinds. When measuring hardness of softer materials are used indenter (scale A) as a hardened steel rod of a diameter of 1.25 mm. Rod ends with a truncated cone with an apex angle of 35° and a diameter of 0.79 mm tops (site area of 0.49 mm^2). When measuring the hardness of composite rod (scale D) ends with a cone with an apex angle to 35°. The radius spearhead of 0.1 mm, the area of spearhead 0,008 mm^2. The indenter is introduced into the sample by a spring. The force of the spring is fixed at a value of 50 H (D), 12.5 N (A). This helps to minimize the effect of heterogeneity of the impact on the sample. Departure sting 2.5 mm. A sting is pulled out on 2.5 mm. The depth of imprint is fixed on the indicator of moving. The indicator has 100 divisions. Every division corresponds to moving of indenter 0.025 mm. The limits of permissible error of measurement of the value of 0.5 divisions. Measuring the depth of penetration of the indenter are held to within 0.0125 mm. The method has a high accuracy.

The main disadvantage of this method is the correlation with other measurement methods. The measurement results obtain in units Shore. Measurements are taken at different scales. Also, it is impossible to carry out a complete accordance between the values of hardness of different methods. The method provides a Shore hardness of different materials with high precision. Method Shore is one of the most used methods of measuring the hardness of soft materials. He is certified in many countries.

His application is regulated by the followings documents: GOST 263-75, GOST 24621-91, ISO 868, DIN 53505, ASTM D 2240, ISO 7619, NFT 51-174, BS903, FTMS 406, JIS K7215. We use measuring device of GT GS-702N. This device is equipped with two indenters and bed, which allows its use both in the laboratory and in production. An analogue of this device NOVOTEST-TS (A, D).

The method of measuring Barcol on the principle of action is similar to the method of measuring the hardness of Shore. Also, the material is introduced steel indenter. The indentor has the form of a truncated cone with an apex angle of 26°. Square Area 0.0198 mm^2. Introduction is produced under the action of saltatory effort. The maximal value of effort is fixed. Departure indenter of 0.76 mm. A degree depends on the depth of penetration of indenter in material. However unlike the method of Shore, a comparison is made with the depth of penetration of indenter into the test samples. The measurement accuracy is ± 2 divisions of scale. It is sufficient for industrial purposes, but requires additional measurements on research. The result is determined from the weighted average of several measurements. For soft plastics must be no fewer than 10 measurements to get a reliable result. The method of measuring Barcol widely used in industry and production.

Measurements are performed in accordance with ASTM B648-2000 and ASTM D-2583. Use the table and graphs translation given in E140-97 (Standard

Hardness Conversion Tables for Metals). To test the polymer-metal composites are most suitable measuring equipment Series 934 and 935. We used hardness (penetrometer) TPBa-935 (GYZJ-935).

Hardness of plastics is measured by the method of Rockwell. It is based on measuring the penetration depth into the sample probe. At measuring of hardness of plastics apply the scale of P. As the indenter used steel or tungsten carbide ball with a diameter (12.7 ± 0,015) mm. The measurements are performed in the following order. The ball is pressed into the material under the effect of preload of 10 kgF (98.07 N). Then, the main load is applied equal to 50 kgF (588.4 N). The maximum penetration depth of 0.26 mm ball. Difference of depths under act of the basic and preliminary loadings and characterizes hardness. The use of the preliminary loading enables to remove influence of heterogeneity of surface. Time of loadings is regulated. The depth of pressing of ball is measured in material. This amount consists of the total depth of the indentation under the influence of the total load minus indentation preliminary effort. Measurement accuracy is very high and amounts to a value of 0.002 mm. The hardness values obtained on the instrument dial. When using the scale P, hardness is calculated as:

$$HR = 130 - (H - h) / 0.002, \quad (1)$$

where h – depth of introduction of the ball under the preliminary loading, H – depth under the basic loading. For test verification of hardness of resilient plastics and other materials apply the method of Rockwell alpha (super Rockwell). From the method of Rockwell he differs that after influence of the basic loading its removal is produced. The measured value is different from the depth of penetration of the indentation as measured by Rockwell. This amount consists of the total depth of the indentation under the influence of the total load minus the elastic recovery and minus indentation preliminary effort. The relative error of hardness of the load does not exceed ± 2% for pre-load and ± 0.5% for complete.

Disadvantages Rockwell should include standard units of measurement. They reflect resistance to influence of indenter only. There are translation tables into other hardness unit. However nonlinear dependence is between different sizes. Therefore, there is no exact correspondence between the values measured by different methods.

The basic terms of leadthrough of measurings on the method of Rockwell are expounded in GOST 9013. specific terms of measuring of hardness of plastics used in GOST 24622, ISO 2039/2. During the leadthrough of measurings applied the device of NOVOTEST-TP (analogues of TK-2, TSH-500, TK-1500).

When measuring hardness of polystyrene-metallic composite materials according to the procedures Vickers, Brinnel, Asker, Shore (rebound) the results have a high variation and low repeatability. In the case of Vickers and Brinnel the area of print of indenter is measured. In plastics, along with the process of destruction exists and plastic compression process which, after cessation of exposure indenter material tends to return to its previous state

Accordingly, the reduced area of the print, which does not get an accurate result. When measured by Asker produced scratching the surface, which is useful in measuring the hardness of the surface layer. Asker method may not reflect the change in the structure of the material in depth. Method Shore (rebound) measures the velocity of a falling and bouncing on the surface of an indenter. The method does not work for plastics

RESEARCH DISCUSSION OF THE RESULTS

In our experiments we used samples of the polymer-metal composites dimensions 70×120×15 mm. The use of these models allows to conduct research using all the techniques. In the manufacture of composites using polystyrene powder and metal fillers. basis polystyrene brand PSM-115. The fillers used aluminum and tungsten, aluminum and steel.

Aluminum powder meet the requirements of TU 1791-99-024-99. The particle sizes of 10…20 and 30…40 μm. The powdered tungsten (TU 49-19-101-84) had three types of sizes: 30…40, 60…80, 180…210 μm. Powder steel St3sp with a particle size of 180…210 μm. Composites different percentages of the components and the size of the particles. Examines three groups of composites PS-W-Al. In each group, fixed content by volume of polystyrene and metal components. Correlation of metal components differed.

In the first group were composites which incorporates had 66.7% of polystyrene, 33.3% of the metal components. The second group – 53.33% of polystyrene, and 46.67% metal component. The third group – 33.3% of polystyrene, 66.7% powdered metals. To test the effectiveness of the composite material also resize the component particles. A similar relation was for composite materials PS-Fe-Al. The exact values of the bulk composition of each of the components shown in Table 1.

Selection of components is carried out for reasons of ease of manufacture and efficiency of radiation-protective characteristics.

The main part of the measurement was carried out using Rockwell (HRP). The measurements by the method of Shore given for comparison. Indications are given on a scale of Barcola only for individual items.

This is due to the necessary number of studies. So, to get the results with a dispersion of $D = 1.55$ and standard deviation $\sigma = 1.75$, it is necessary to make measurements 1-2 Rockwell, 4-5 Shore measurement method, measuring 9 by the method of Barcola. At $D = 1.05$ and standard deviation $\sigma = 1.45$, it is necessary to make measurements 4–5 Rockwell, 9–11 Shore measurement method, measuring 15 by the method of Barcola. For dispersion measurement $D = 0.358$, standard deviation $\sigma = 0.632$ – 8–9 measuring Rockwell, Shore 15–18, 27–30 Barcol. This significant number of samples is necessary because of the heterogeneity of the material.

We measured the hardness of pure polystyrene. It consists of the following values: 72 HD, 52 HBa, 78 HRP. To simplify the analysis of the hardness of different types of composites are plotted graphs in Fig. 1.

Table 1

Volumetric composition of the composites (PS-W-AL)

Material	Polystyrene (PS), vol.%	Tungsten (W) vol.%	Aluminum (Al), vol.%
C100104(1)	66.67	6.67	26.66
C100203(2)	66.67	13.33	20.00
C100302(3)	66.67	20.00	13.33
C100401(4)	66.67	26.66	6.67
C080106(5)	53.33	6.67	40.00
C080304(6)	53.33	20.00	26.67
C080403(7)	53.33	26.67	20.00
C080601(8)	53.33	40.00	6.67
C050109(9)	33.33	6.67	60.00
C050307(10	33.33	20.00	46.67
C050505(11	33.33	33.33	33.34
C050703(12	33.33	46.67	20.00
C050901(13	33.33	60.00	6.67

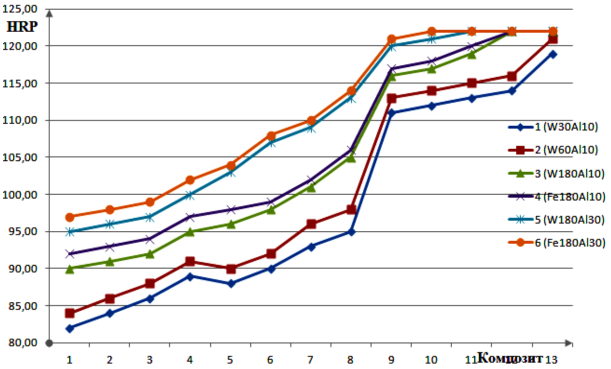

Fig. 1. Curves dependences of hardness (HRP) component of the composition

Curve 1 in Fig. 1 (blue markers-rhombus) corresponds to a composite in which the aluminum component has a particle size of 10…20, 30…40 µm tungsten. Similar characteristics and composites with a particle size of 60…80 µm of tungsten (curve 2, brown, markers-square). The increase is due to a decrease in the volume of hardness component of aluminum with 26.66 to 6.67%, and the increase of the share of tungsten with 6.67 to 26.66%. I. e., at a constant volumetric content of metal components increases the number of larger particles. When using the Rockwell hardness is defined as resistance to indentation. That is, with increasing particle size and increasing their cross-sectional area that increases the force necessary for their embedment into the material.

Points 5–8 correspond to composites with metal volume content of components equal to 46.67%. Reduction in the hardness of sample 5 (C080105), due to the fact that the composition of metallic components only 6.67% of the volume fraction of tungsten with larger particle sizes. With the increasing volume fraction of tungsten components and increases the hardness of composite materials.

The points 9–13 – hardness composites which are composed of 66.67% of the metal components. Jump hardness at points 8 and 9 (composites X080601 and X050109), due to the sharp change in the amount of metal component. Composites X050307 (point 10) X050505 (11) X050703 (12) have in their composition the same amount of metal component. The amount of tungsten, which has a large particle size increases smoothly. Therefore, we have the graph plateaus. Different hardness composite X050901 (point 13), in which the maximum value of tungsten.

Curve 3 (green color, a marker is a triangle) represents the hardness of composites in which the aluminum has a particle size of 10, 180 µm tungsten. For comparison, the hardness of composites, which replaced the component of tungsten steel (St3sp).

This curve 4 (violet color, a marker is crosses). Steel had a particle size of 180 microns, aluminum – 10 µm. In comparison with the curves 1 and 2, curves 3 and 4 have higher hardness values. This is due to larger particle sizes of aluminum and steel. General characteristics of the hardness changes on the structure of the composite material is also similar. All conformities to law are saved.

The hardness of the composites with steel components, higher than composites component tungsten. The reason for this there are different forms of the particles of steel and tungsten. These differences are visible in the photographs cut. Composite picture (C0800403) is shown in Fig. 2.

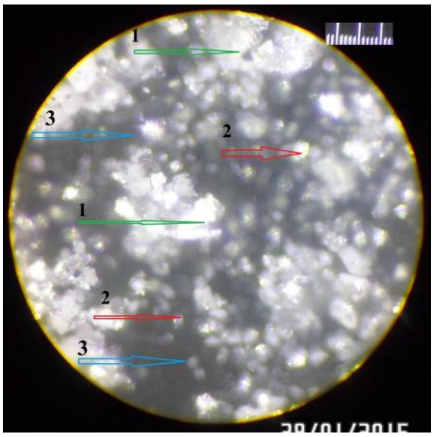

Fig. 2. The structure of the composite material C080403

In the photo there are various components. Arrows 1 (green) marked tungsten particles. They have a rounded shape. The size of 80…100 µm. Arrows 2 (red) aluminum particles with a size of 10…20 µm. Arrows 3 (blue) shows the space filled with polystyrene. Metal component fills less than half of the composite material. A similar structure has composite Fe080403. The composite structure is given in Fig. 3.

Green arrows (1) indicate the particles of steel (St3sp), red (2) – the aluminum particles, blue arrows (3) – the space filled with polystyrene. The of steel particles have the form of rectangles. Their edges with protrusions.

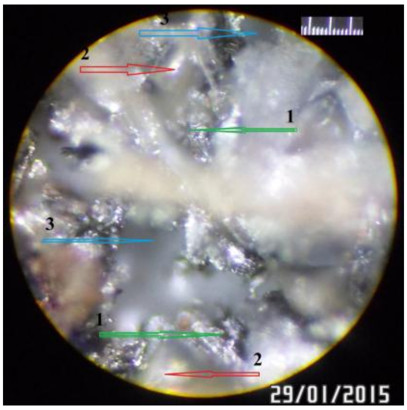

Fig. 3. Photo of cut of composite material of Fe080403

Tungsten particles are spherical particles of steel-rectangular. Therefore, they have different pressed into polystyrene. At pressing of particle it is necessary rectangular to make a greater push, then at pressing spherical. Therefore, hardness is large. In absolute terms, these values vary from 3 to 5%.

Curves 5 (blue color, marker-crossed Cross) and 6 (orange color, marker-circle) in Fig. 1 characterize the change in hardness for composites with a particle size of 30…40 μm of aluminum, steel and tungsten sizes 180…210 μm. The shape of these curves is similar to the previous schedule. Maximum hardness equal to 122 HRP achieved for composites X050307.

The greatest dependence of the hardness of the composite on the size and shape of the additive particles is observed at low degrees of filling composite metal components. I. e. in those composite materials, where between the particles of the metal component is a layer of polystyrene. When measuring hardness of Rockwell indentation ball occurs in the composite material. The particles of the metal components are displaced. This process has been shown in Figs. 4 and 5.

The steel components of particles indicated by green arrows (1). Particles were displaced and adjoin verges. Squeezing out of polystyrene happened from space between particles. This is evidenced by the appearance of bubble fraction. It is well observed in Fig. 5. Polystyrene to beginning of measuring had a smooth and continuous structure (see Fig. 4).

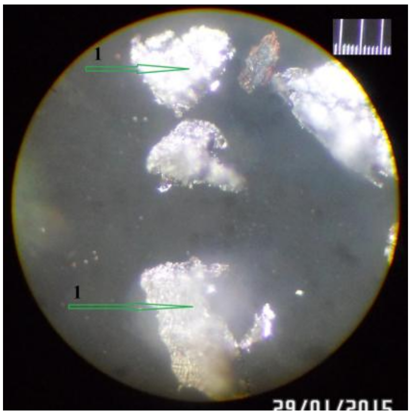

Fig. 4. Photo of cut of composite material of Fe100401

Green arrows (1) indicate the steel particles. The rest of the space is filled with polystyrene. The cut after displacement is shown in Fig. 5 photos.

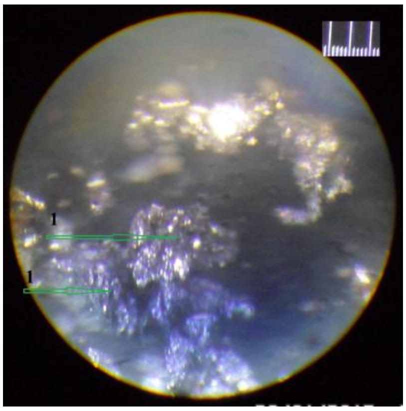

Fig. 5. Photo of cut of composite material of Fe100401 after measurements

Effect of particle shape of the component hardness decreases with increasing amounts of metallic additives.

Image of the region in which the individual particles come into contact with each other. For composites Ps-W-Al polystyrene layer does not cover the individual particles, but whole clumps of particles. Since the compressibility of the metal particles and small particles of weakly penetrate into polystyrene, we obtain maximum hardness. In this case, the hardness value is close to the value of the compression fracture (Fig. 6).

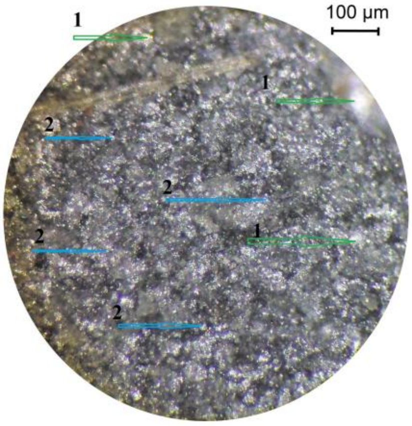

Fig. 6. Photo of cut of composite material of C050109

Measurement of hardness using durometers Shore and Barcol these composites not give exact results. This is due to the environment in which the falls rod indenter. The hardness values are different in polystyrene, aluminum, tungsten. Significant impact on the hardness value is the quality of manufacturing composite materials. Hardness decreases when there are voids, caverns, cracks.

Select the type of composite material is determined by the conditions in which it will be operated. In papers [1–3, 6–8] studied radiation-protective characteristics of various composites. They were obtained by means of mathematical modeling. Modelling the interaction of radiation with matter carried out using the software package Geant 4 v4.9.6p04 [9]. In [4, 7] it showed approval of the calculated results with experimental data. In this study a comparison of the radiation-shielding properties of the composite materials with the filling of tungsten or steel. Mass composition tungsten composites component shown in Table 2.

Table 2

Mass components of composite materials (PS-W-AL)

Material	Polystyrene (PS), mas.%	Tungsten (W), mas.%	Aluminum (Al), mas.%
C100203	19.06	66.90	14.04
C080304	9.35	82.04	8.61
C050505	4.76	83.55	11.69

Composite materials were obtained in which the volume content of tungsten components and aluminum components are approximately equal. There have also been studied composites, which, ceteris paribus, instead of using tungsten steel. The mass composition of the composites is shown in Table 3.

Table 3

Mass components of composite materials (PS-Fe-AL)

Material	Polystyrene (PS), mas.%	Steel (Fe+), mas.%	Aluminum (Al), mas.%
Fe100203	31.59	45.15	23.26
Fe080304	20.38	54.61	25.01
Fe050505	9.43	67.41	3.42

In all types of composite materials used aluminum powder-like with a particle size of 10...20 μm, tungsten – 200 μm, the steel particles – 180...210 μm. The calculation of radiation-protective descriptions was conducted for protective material which were manufactured in the form of beads having a diameter of 2 mm.

We evaluate the effectiveness of protection for the relative decrease of the absorbed dose of gamma radiation in the biomaterial phantom. It is located behind a protective layer. The thickness of the protective layer 10 mm. This size is due to the fact that the composite material used in the individual protective kits. The use of these composites in the stationary shield apparatus reduces the weight requirements, quality of manufacture. The results of numerical simulation are shown in Fig. 7.

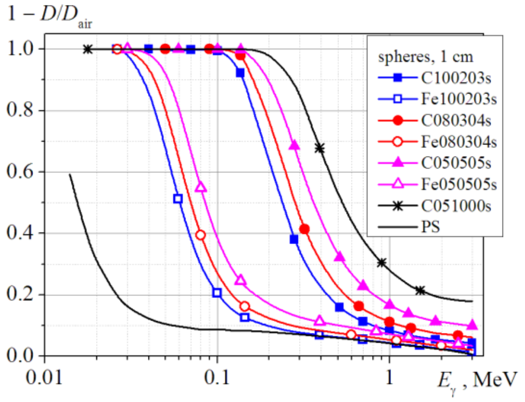

Fig. 7. Change the relative weakening of the absorbed dose of gamma radiation of different composites, depending on the energy of the gamma rays. (Composites in the form of balls)

D_{air} value will be denoted by the estimated dose which absorbs biomaterial-equivalent phantom in the air, that is, in the absence of the protective device. The estimated dose to the phantom, which is located behind the protective layer is referred to as D. The amount of $1–D/D_{\text{air}}$, a relative weakening of the absorbed dose of gamma radiation according to the protective layer.

The black lines on the graphic are the maximum and minimum marks weakening of the absorbed dose. The maximum protective properties of a composite C051000. It is composed of 93% tungsten. The minimum values has a clean polystyrene. Composites are divided into two groups. Each group has a similar radiation-protective properties. The first group of composite materials comprising tungsten. In the second -steel. In each group, the curves of the relative weakening of the absorbed dose close to their values.

Fully absorbed gamma rays with energies up to 100 keV for composites that contain tungsten. Completely blocked the line 122 keV (^{57}Co). In this energy range is radiation of many medical devices. Half attenuation occurs for gamma rays with an energy of 200…300 keV. With increasing energy radiation-protective properties deteriorate. And at an energy of 1 MeV absorbed no more than 10…15% of the primary amount of gamma radiation. For the 1.33 MeV line (^{60}Co) is absorbed by no more than 5…7% of the initial stream. The second group includes composites which comprise steel. For the composite of this type radiation-protective properties considerably below. Fully absorbed gamma rays with energies up to 40 keV. Further absorption properties deteriorate sharply. And half of the weakening occurs already at energies of 80…90 keV. When gamma energy 100…110 keV absorbed no more than 20% of the radiation flux. Line 1.33 MeV (^{60}Co) is not delayed. The absorption is not more than 2%.

Composites Ps-W-Al (containing tungsten), have a five-fold absorption at energies of 100…200 keV. Composites Ps-Fe-Al (containing steel) – only at 60…80 keV. All calculations were performed with the protective layer thickness of 10 mm. Thus, for use in the personal protective kits (IPK) should be used composite materials that use tungsten. The use of composites with the addition of steel IPK ineffective. Composite materials Ps-Fe-Al have lower density and a higher hardness than the materials Ps-W-Al. Therefore, they are suitable for use in stationary defenses. This is due to the fact that the thickness of the protective layer, we can use any. For polystyrene-metal composites there is only restriction on the height of the protective layer. As a result of calculations we got the max height of насыпного protective layer a 18 m. This value was obtained by taking into account the weight of the balls, the forces required for their destruction. The power of destruction is found of from measuring of hardness on the method of Rockwell.

Consequently, these polystyrene-metal composite materials have high radiation-protective properties, a sufficiently low density, significant strength characteristics. All this, in combination, allows you to choose the most effective type of protective material for specific conditions.

CONCLUSIONS

1. Spend refinement of techniques for measuring the hardness of polystyrene-metallic composite materials.

2. Performs work on the improvement of the technological process of polymer composites and improved IR radiation monitoring of production.

3. The dependence of hardness composites PS-W-AL and PS-Fe-AL is measured on the quantity of metal components.

4. The increase of hardness of composites is rotined at deviation of form of particles of filling from spherical.

5. We studied the weakening of the absorbed dose of gamma radiation mathematical methods (Monte Carlo method), for various types of composite materials.

6. According to the research suggested Composites Ps-W-Al type used in personal protective complete sets, and type Ps-Fe-Al stationary protective buildings.

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СООТНОШЕНИЕ ТВЕРДОСТНЫХ ХАРАКТЕРИСТИК ПОЛИСТИРОЛМЕТАЛЛИЧЕСКИХ КОМПОЗИЦИОННЫХ МАТЕРИАЛОВ

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Отработаны методики измерения твердости слоистых полистиролметаллических композиционных материалов. Предложено использовать в качестве радиационно-защитной добавки порошковый вольфрам и порошковую сталь. Проведено измерение значений твердости композитов различного состава и даны её зависимости от размеров частиц и их формы. Показана возможность увеличения твердости композитов армированием металлическими добавками. Радиационно-защитные характеристики рассчитаны для исследованных видов композиционных материалов. Изучено влияние количественного состава металлической компоненты на изменение поглощенной дозы гамма-излучения.

СПІВВІДНОШЕННЯ ХАРАКТЕРИСТИК ТВЕРДОСТІ ПОЛІСТИРОЛМЕТАЛЕВИХ КОМПОЗИЦІЙНИХ МАТЕРІАЛІВ

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Відпрацьовані методики виміру твердості шаруватих полістиролметалевих композиційних матеріалів. Запропоновано використовувати як радіаційно-захисну добавку порошковий вольфрам і порошкову сталь. Проведено вимір значень твердості композитів різного складу і надана їх залежність від розмірів часток і їх форми. Показана можливість збільшення твердості композитів армуванням металевими добавками. Радіаційно-захисні характеристики розраховані для досліджених видів композиційних матеріалів. Вивчений вплив кількісного складу металевої компоненти на зміну поглиненої дози гама-випромінювання.