IMPROVING OF CHARACTERISTICS OF COMPOSITE MATERIALS FOR RADIATION BIOLOGICAL PROTECTION

E.M. Prohorenko, V.F. Klepikov, V.V. Lytvynenko, A.I. Skrypnik*, A.A. Zaharchenko*, M.A. Khazhmuradov*
Institute of Electrophysics and Radiation Technologies NAS of Ukraine, Kharkov, Ukraine;
****National Science Center “Kharkov Institute of Physics and Technology”, Kharkov, Ukraine***

Offered an individual protective system designed for the needs of radiation-biological protection. As the protective layer is applied the polymeric matrix composite material based on aluminum reinforced polystyrene, with the addition of particulate tungsten. The composite was made in the form of fixed-size granules with a homogeneous distribution of the filling volume. Numerical methods, the efficiency of absorption of ionizing radiation. It is shown that when the thickness of the composite material (protective layer) equal to 1 cm, absorbed all the gamma-quanta with energies up to 70 keV and 70% of the energy flux carried by gamma-quanta with energies up to 200 keV

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INTRODUCTION

The further development of nuclear power and wide application of various sources of ionizing radiation in many areas of a national economy (medicine, defectoscopy etc.) demand presence of radiation-protective materials. Therefore it is impossible to diminish importance of questions of creation of new materials, behavior research under radiation, control of a state of structure, manufacturing techniques development. Now in all these directions the considerable successes are reached. However, requirements shown to protection become more rigid that forces to lead operations on development of more perfect and effective protective.

THE MAIN PART

Under the characteristics radiation -protective materials can differ on usage areas, conditions of application, a level of lowering of influence of ionizing radiation, efficiency of absorption. They can be used as stationary security facilities of the equipment and biological objects, components to building materials, individual defense means. In our operation the materials intended for individual defense of staff, by the nature of the activity contacting to objects of the raised radiation danger were studied. The given materials can be applied at creation new and finishing of already existing individual protective complexes (IPC). The main requirements shown to IPC, are: high radiation-protective properties, warmly and chemically insulating qualities, low sorption of radioactive substances, the high durability, the reduced weight. Also, for functionality increase, certain flexibility of a protective complex is necessary. Thus, usage of protective elements made of plates, bands, rigid frames, is irrational as reduces overall performance of attendants.

As basic model IPC it was offered to use modified heat-insulating a waistcoat of the mine-rescuer [1]. It is necessary to carry that the given model already is made. To its advantages, it is widely exploited and can be simply enough advanced for needs of radiation biological protection. The waistcoat is equipped heat-insulating and cooling elements which allow to be about two hours, at temperature 45°C.

Also, it is calculated for maintenance in chemically excited environments. Functionally, it is fitted to layout on it of additional elements in which quality elements of radiation biological protection can be used. However, the construction superimposes certain requirements, to their form and structure.

Restrictions on weight of protective elements as usage IPC implies its durable carrying are one of them. At performance by attendants of some operations mobility and flexibility is necessary. It was offered to use free-flowing materials which were located in special overlays on a waistcoat. Application of free-flowing materials allows to produce protective elements with the raised flexibility, the necessary form and homogeneous for density filling. At filling usage in a free-flowing type, process of manufacture and fixing (fastening) of separate elements of protection on a waistcoat becomes simpler. There is a possibility to make layerwise protection. At the expense of reduction of a thickness of edge areas and their superimposing against each other it is possible to solve a simple method a question of the adjustable thickness, elements weakening ionizing radiation, in various parts IPC. That is essential to the decision of tasks of radiation protection. At a choice of a material for creation of protective elements of radiation protection various variants were considered. As pacing factors posing threat are neutrons and a X-ray-scale radiation materials capable effectively first of all were considered to absorb the given types of radiations. Absorption of a flow of neutrons by most effectively light elements (B, H, N, a C, etc.) and their connections. For the decision of tasks of protection from X-ray and gamma of radiation on the radiation the absorbing properties heavy metals (Pb, W, Mo, etc.) well approach.

Thus, required materials, having in its composition and light and heavy elements. However, products made from these materials are heavy, making them difficult to use in the IPC. For combining these resin materials are used matrix composites. Among the polymers can highlight those which possess improved ductility (non-friable), low thermal conductivity, strength, corrosion resistance and low weight. These features allow operation of the polymers in a wide range of pressures, temperatures. They are normally applied in a vacuum may, at high pressure, corrosive environments. To avoid destruction of polymers increased, which occurs under the influence of ionizing radiation, they are reinforced with various fillers. Given the wide range as the polymeric material and filling material, it is possible purposefully to obtain the necessary properties and characteristics of composite materials. Preparation of the desired properties is achieved by varying the composition ratio, a dispersion, etc. The principles of the filling Currently works on the production of polymer - composite materials based on different bases with a wide range of materials required. In [2], a protective material comprising a matrix of aluminum-magnesium alloy (20…60%) and a filler of finely divided iron- mechanically activated hematite concentrate (40…80%). Its disadvantages include low mechanical strength, due to the low compatibility of hematite iron concentrate with metallic aluminum. More and more attention is paid to the development of composites with filling in the form of nanopowders. In [3] The characteristics of the protective properties, by X-ray radiation and thermal neutrons, based on the materials for ultrafine based media, which is significantly higher than conventional filling. Also were considered developed and researched in joint-stock company «Research and development and designer institute of mounting technology – Atomstroj» the composite materials modified BN or B_4C with filling tungsten [4], which effectively weaken ionizing radiation along with high strength and rigidity characteristics. It is shown that usage nano-sized powder particles of radiation- absorbing materials (BN, B_4C, Pb and W) leads to magnification of coefficient of absorption of neutrons in 1.5 time and coefficient of dispersion of gamma radiation on 30…40%.

In our operation radiation-protective properties polymer of a composite material on the basis of polystyrene were researched. Polystyrene usage gives the chance to lower essentially weight of a protective complex as because of its low heat conductivity and high thermal insulating properties necessity for layout on IPC a heat-shielding layer disappears. For obtaining of flowability polystyrene, was made in the form of balls in diameter from 2.5 to 5 mm. The magnification of efficiency of absorption of ionizing radiation was reached by adding of powder tungsten. The composite material was reinforced by aluminum. Manufacture of a composite material is carried out by grinding all components with the further hot extrusion that gives uniform enough allocation of particles of the filler in polystyrene. Application as the filler powder materials gives the chance to change smoothly weight and density of an aggregate and accordingly simplifies research of its properties.

For estimation, efficiency of radiation-protective properties of the material offered polymer-composite, researches were led by methods of mathematical modeling.

Originally, for creation of the reference data, as object of research, pure polystyrene was used. Its thickness was 3 cm. This value was equal to a thickness of protective overlays on IPC. As a composite material in the form of granules there is a possibility to select its density depending on diameter of a granule. A flow of gamma quanta received from a source ^{57}Co.

Results of change of a spectrum of gamma quanta from a source ^{57}Co after passage of a layer of pure polystyrene by them in the thickness of 3 cm received by means of methods of mathematical modeling, are presented in a Fig. 1.

For a line 122 keV the initial flow of gamma quanta decreases to 60.5% (55.1%), accordingly. However, because of dominance of Compton scattering for this energy easing of an initial flow of energy appears esentially smaller.

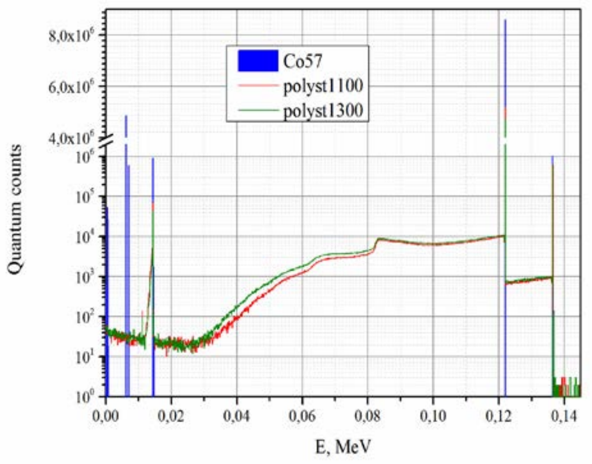

Fig. 1. Change of a spectrum of gamma quanta, from a source ^{57}Co, depending on energy, after passage of a layer of pure polystyrene by thickness 3 cm

Proceeding from the results presented in a Fig. 1, we receive energy reduction at passage of a flow of gamma quanta through a polystyrene layer. For density of a protective layer of 1100 kg/m^3 this value makes value of 87.9 % from an initial flow. With magnification of density of polystyrene the amount of the last gamma quanta decreases even more and for value of density of 1300 kg/m^3 makes value of 86.2% from the initial. It is necessary to pay attention on two special points on the schedule where we watch intensity races (points in the field of lines of energy 14.4 and 122 keV). Analyzing results, we receive that in the field of energies 14.4 keV, there is an easing of intensity of falling gamma quanta more than on the order. Numerically it makes: 4.7% from an initial flow for density of 1100 kg/m^3, 7.5% for density of 1300 kg/m^3. Thus almost all energy is absorbed in a protective layer. For a line 122 keV easing of an initial flow makes almost half (60.5 and 55.1%, accordingly). But in the field of the given energies Compton scattering, therefore easing of an initial flow of energy prevails it appears much more smaller.

Creation on the basis of polystyrene of a composite material with switching-on of dispersible tungsten and aluminum allows, at the same thickness, it is essential to refine efficiency of absorption of ionizing radiation. Results of the numerical account are resulted in a Fig. 2.

Let's compare energetic dependences of mass transmission ratio of energy of gamma quanta for polystyrene and a researched protective material. In case of polystyrene usage, the small magnification of value of this coefficient in the field of energies of gamma quanta above 100 keV is watched. Given coefficient increase it is connected to growth of section of the Compton effect [5]. Apparently from 2 schedules resulted in a Fig. 2, adding of metals (Al and W) increases more than by the order in comparison with pure polystyrene efficiency of absorption of energy of gamma quanta a composite material in the field of energies to 300 keV where the maximum of the gamma radiation dispersed by environment is normally allocated.

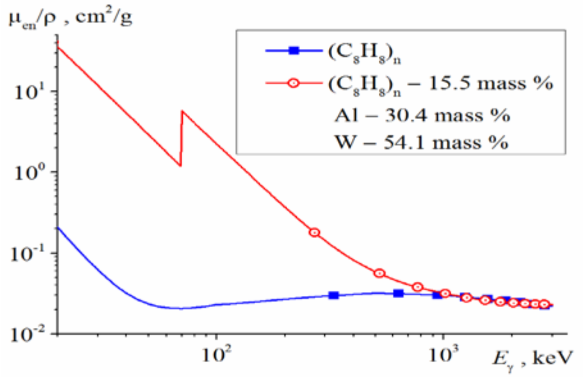

Fig. 2. Dependence of mass transmission ratio of energy (mass energy transfer coefficient) from energy of gamma quanta for a composite material

At a following stage comparing of rated values of efficiency of absorption of gamma quanta by layers of a protective material with various thickness was led. Energy of gamma quanta changed to value of 3 MeV. A thickness of a protective material varied in the range from 0.5 to 3 cm. For modeling of efficiency of absorption packet Geant4 v 4.9.6p02 [6] was used.

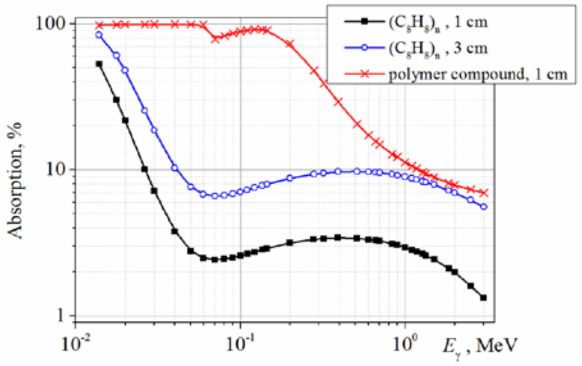

Fig. 3. Efficiency of absorption of gamma quanta layers of protection of a various thickness

For thickness of polystyrene of 1 and 3 cm distinction in absorption makes a maximum of 10% on all interval of energies from 10 keV to 3 MeV. The increase of efficiency of defence requires the increase of thickness of protective layer in times, that unacceptable in our case is creation of individual protective complexes. Calculation of absorbing characteristics of the offered composite material showed that at a thickness of 1 cm, a composite material absorbs all gamma quanta with energy to 70 keV and more than 70% of a flow of the energy transferred in gamma quanta with energy from 70 to 200 keV. Mass density of a composite material of 1 cm is almost equal in the thickness to mass density of polystyrene of 3 cm (Fig. 3). Thus efficiency of absorption of gamma-quanta energy in area from 20 to 500 keV for the investigated composite is more than 2 times exceeds efficiency of absorption for radiation defence from clean polystyrene. At higher energies efficiency of absorption decreases, and in region 1 MeV composite material makes 10% from the general flow that is comparable with a polystyrene layer.

As the free-flowing filler balls from an aggregate (Fig. 4) were applied.

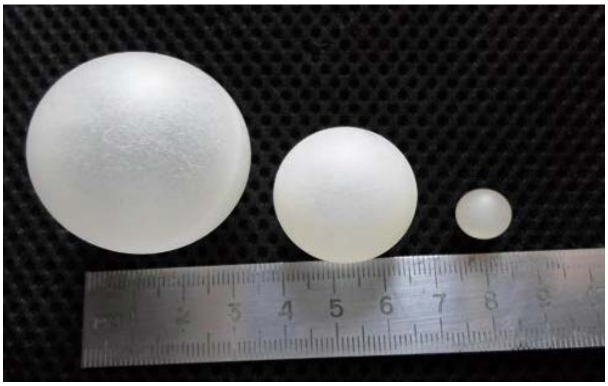

Fig. 4. Balls from a composite material for protective layer filling

Experiments were conducted to determine the optimal size of balls required. Diameter changed in the range from 30 to 2 mm. Most effectively filled volume balls with a diameter from 3 to 8 mm. Manufacture polystyrene full-spheres of such size, also, is not problem. As aggregate filling powder aluminum and tungsten were used. For uniformity of their allocation on a full-sphere body, in the heated up capacity agitation was produced. Frequency of rotation changed in the range from 10 to 90 min^{-1}. Uniformity of allocation was checked by means of microscopy. A photo on a cutoff of the received aggregate it is presented in a Fig. 5.

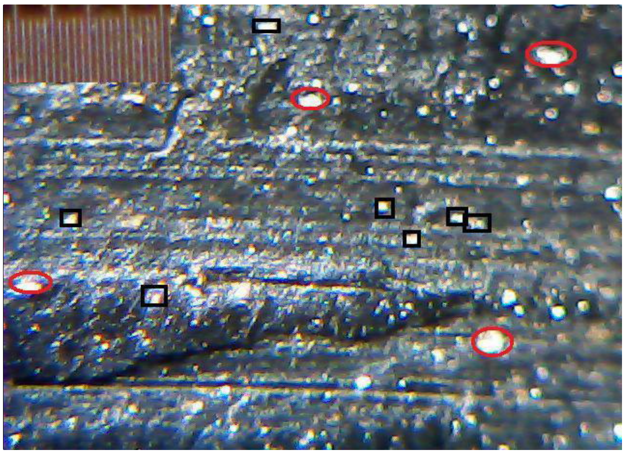

Fig. 5. Cutoff of a composite material

The most homogeneous allocation, for the data at us the sizes of particles of aluminum and tungsten, was reached at frequency of turns of blades equal 50 min^{-1}. Faster rotation of the warmed-up compound creates dispersion of a dispersible powder on compound edges. At slow rate happensслипание комкование aluminum filling and drop-out of a tungsten component in the lower part. Faster rotation heated mixture produces a spread of dispersed powder mixture to the edges. At low speed sticking occurs aluminum content and the tungsten component coming into the bottom of. In picture markers define separate particles. Square – aluminum particles, oval – tungsten. The size of aluminum is 10…20 microns, tungsten 30…40 microns. As, balls intend for filling of plates of protection they are not exposed to physical activities. Therefore the strength characteristics (hardness, integrity), can be weakened. Thus, microcracks of a material which are watched in a photo, do not render the considerable influence on necessary radiation protective characteristics.

All resulted values of easing of a flow of gamma quanta are maximum. In a real case they are reduced for following reasons: gap presence between balls; microcracks and cavities which are formed at pouring out; heterogeneity of allocation of aluminum and tungsten on volume of balls.

CONCLUSIONS

1. For needs of radiation -biological protection usage polymer of a matrix composite material, on the basis of polystyrene reinforced by aluminum, with filling particulate tungsten is offered.

2. Numerical methods, check up efficiency of absorption of ionizing radiation with reference to a basis of a composite material.

3. Easing of a flow of gamma quanta at passage of a layer of a composite material is shown.

4. The form of objects of filling of elements of protection is offered.

5. The aggregate structure is considered.

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УЛУЧШЕНИЕ ХАРАКТЕРИСТИК КОМПОЗИЦИОННЫХ МАТЕРИАЛОВ ДЛЯ РАДИАЦИОННОЙ БИОЛОГИЧЕСКОЙ ЗАЩИТЫ

Е.М. Прохоренко, В.Ф. Клепиков, В.В Литвиненко, А.И. Скрыпник, А.А. Захарченко, М.А. Хажмурадов

Предложен индивидуальный защитный комплекс, предназначенный для нужд радиационно-биологической защиты. В качестве защитного слоя применяли полимер-матричный композиционный материал на основе полистирола, армированного алюминием, с добавлением мелкодисперсного вольфрама. Композит изготавливался в виде гранул фиксированных размеров с однородным распределением наполнения по объему. Численными методами проверена эффективность поглощения ионизирующего излучения. Показано, что при толщине композиционного материала (защитного слоя), равной 1 см, поглощаются все гамма-кванты с энергией до 70 кэВ и 70% потока энергии, переносимого гамма-квантами с энергией до 200 кэВ.

ПОЛІПШЕННЯ ХАРАКТЕРИСТИК КОМПОЗИЦІЙНИХ МАТЕРІАЛІВ ДЛЯ РАДІАЦІЙНО-БІОЛОГІЧНОГО ЗАХИСТУ

Є.М. Прохоренко, В.Ф. Клепіков, В.В. Литвиненко, А.І. Скрипник, О.О. Захарченко, М.А. Хажмурадов

Запропоновано індивідуальний захисний комплекс, призначений для потреб радіаційно-біологічного захисту. В якості захисного прошарку застосовували полімер-матричний композиційний матеріал на основі полістиролу, армованого алюмінієм, з додаванням дрібнодисперсного вольфраму. Композит виготовлявся у вигляді гранул фіксованих розмірів з однорідним розподілом наповнення за об'ємом. За допомогою числових методів перевірена ефективність поглинання іонізуючого випромінювання. Показано, що при товщині композиційного матеріалу (захисного прошарку), рівній 1 см, поглинаються усі гама-кванти з енергією до 70 кеВ і 70% потоку енергії, який переноситься гама-квантами з енергією до 200 кеВ.