Раздел третий
ФИЗИКА РАДИАЦИОННЫХ И ИОННО-ПЛАЗМЕННЫХ ТЕХНОЛОГИЙ

METAL CONTAINING COMPOSITION MATERIALS FOR RADIATION PROTECTION

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In individual protective complete sets, for application as elements of radiation biological protection, five types of composition materials are offered. Their basis is polystyrene reinforced by an aluminum with addition of powder-like tungsten. By means of numeral methods efficiency of absorption of ionizing radiation is rotined. The technological modes of making of composition materials were worked off. It is discovered that hardness of standards increases with the increase of amount a metallic constituent. It is suggested to use the methods of IR-radiometry for control of homogeneity of composite

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INTRODUCTION

Radiation protection personnel is one of the basic conditions for safe operation of nuclear objects f. Development of radiation- shielding materials is carried out in two main directions: a) fixed protection equipment and technology, working in conditions of radiation exposure, and b) the biological protection of personnel of nuclear objects. In turn, biological protection can be both stationary and individual. One of the most convenient and effective remedies can be individual protective complete sets (IPC) [1]. Scope of individual protective equipment is not limited to nuclear power stations. They are used in the work of the staff of emergency services, medicine, etc.

PURPOSE OF WORK

The aim of the work is, the development and improvement of radiation protection materials intended for use in radiation protection complete sets to meet the requirements for thermal protection, weight, etc.

THE MAIN PART

During exploitation in the area of enhanceable radiation-damage protective materials are subject to intumescing, that entails the change of material and his properties. Destruction of material is possible. For diminishing of speed of development of these processes apply retrofitting of materials different additions [2]. Having different materials makes it possible to purposefully adjust obtaining a composite material with appropriate characteristics (hardness, strength, thermal conductivity and radiation-protective properties). To create the composite material is necessary to determine its chemical composition. On the characteristics of protection have a significant impact and parameters such as physical dimensions of the elements filling their spatial orientation, uniformity in volume. Creating composite difficult and purely technological difficulties. In general, it can be argued that the decision of the problem of obtaining a composite material with a specific combination of properties is non-trivial.

Since individual protective complete set is designed for operation in the zone of exposure to ionizing radiation, its main objective has radiation protection of the biological object (person). The material from which created IPC must ensure the maximum possible reductions of the absorbed dose and low radiation sorption, to be non-toxic. Using the IPC in the environment of high temperature imposes a condition of effective thermal protection. Also the protective material should have considerable strength characteristics. An important requirement is the simplicity of its production and processing.

As an object of research, we used a composite material, which is used as a protective layer waistcoat rescuers (WR) [3]. WR design made of the following elements: structure framework, system of pendant of protective elements, additional thermal protection devices. To simplify the design, we offer improvements to enhance radiation heat-absorbing properties. Previously, as a base layer of the heat was proposed to use a polystyrene [4].

It has low thermal conductivity, weak chemical activity and sufficient durability. Melting polystyrene is in the range 180…200 °C. Since IPC applied "hot" area where the ambient temperature does not exceed 60 °C, then there is no change in the structure due to the melting of polystyrene. Using IPC as equivalent to the clothing significantly reduces the requirements for durability. Since the absence of physical impact on the break, compression, blow. Radiation-protective properties of pure polystyrene investigated in [4]. IPC used in the protective layer of polystyrene can provide effective protection against radiation energy gamma rays up to 150 keV.

At higher energies (up to 1.5 MeV) weakening of the absorbed dose is no more than 10%. In order to improve the radiation-shielding properties, various additives include polystyrene. To protect from the light elements of the neutron flux (B, H, N, C). Protection against X-ray and gamma radiation is heavy metals (Pb, W, Mo). Thus, the metal-polymer composite materials provide an opportunity to solve the problems of radiation protection. Currently available materials which may significantly improve the radiation protection of biological objects and equipment. However, for concrete cases, it is necessary to create specialized materials with certain properties.

LEADTHROUGH OF WORKS

Application of polystyrene is expedient taking into account his low heat conductivity. Were additionally conducted work on the improvement of heat-insulating properties. It is known, that decline of heat transfer and increase of thermal resistance it is possible to attain, replacing a continuous heatcover layer stratified or discontinuous. I. e., in a heat-insulating layer it is necessary to enter additional heat-insulating intervals. Because basic heat transfer is carried out a diffusive heat transfer, there is a break of thermal stream on these intervals. Consequently, a diffusive (pin) heat transfer is replaced radiate, which considerably less than pin (differs on an order). For the increase of amount of these mini-intervals a heat-insulating layer was executed as balls. Experimental a way the size of ball, allowing to create a certain amount warmly interrupting intervals.

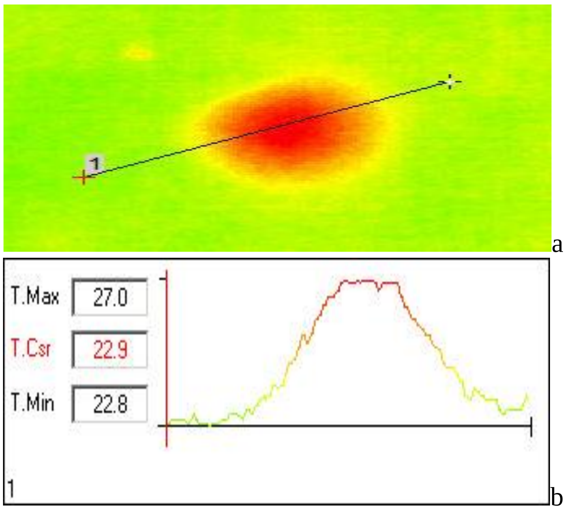
Depending on a location on framework of IPC, a thickness of protective layer is in the range of 10…30 mm. 2 mm created the use of balls from 4 to a diameter 14 heat interrupting intervals, and measuring 4 mm, from 2 to 7 intervals. These stratified structures give decrease of thermal stream on 15% as compared to continuous material [5]. Choice of size 2…4 mm due to the requirements of practice. At such sizes can achieve the maximum fill volume of the cavities with a protective material to the chassis to reduce the rigidity of the structure. In addition, for the manufacture of balls the size of data is a well-proven technology. In this case, the technology of creating a polymer composite material was as follows. Granular polistirol, powder-like aluminium, powder-like tungsten was mixed up. Taking into account the technological features of making verification of receipt of material of defence was conducted with the different in size particles of filling. Particles of aluminium were three sizes: 10…20, 50…60, 100…110 μm. For a tungsten sizes of particles were in the ranges of 30…40 and 200…210 μm. For the choice of the most optimum sizes in pairs mixed up different factions. Maximal homogeneity of mixture is attained at the size of particles of aluminum of 10…20 μm and tungsten – 30…40 μm. At other values of sizes of particles greater time of interfusion is needed and found out a permanent remaining division on fractions. It is necessary to mark that a division goes not only in a vertical plane (due to different weight) but also in horizontal – from sizes. In the each mixture every heavy particle of tungsten is surrounded a few by easy of aluminum.

Since all work is carried out on a standard industrial equipment with the expectation issue separate serial parties, we tried maximally to simplify the manufacturing process and control. The mixture is heated to the melting temperature of polystyrene (200 °C) and stirred to obtain a uniform distribution of powder, by volume. In the manufacture of polystyrene may be used blow molding, extrusion, injection molding

In this case, the most effective ways are extrusion and injection molding. The quality of mixing depends on exactness of observance and temperature uniformity of heating. Control of the temperature field carried thermovision Ti-814. Its sensitivity is 0.08 °C, which allows to identify any deviations from the recommended temperature. Also, the use of infrared (IR radiometry) thermographic control gives you the opportunity to detect various defects in the process of mixing.

Warming mixtures depends and from the heat capacity of separate components. Tungsten and aluminum have high heat conductivity, polystyrene – low. On the initial stage of heating the process of warming up takes place as follows: in mixture with prevailing maintenance of polystyrene a layer, contiguous with a heater, is heated above all things. In mixture, where more metallic components, due to more high heat conductivity all volume is warmed up.

Warming up of areas with more high maintenance of polystyrene takes place slower. Especially expressly to heterogeneity of heating and heterogeneity of distributing of constituents on mixture show up in the case of sticking together clot formation (formations of lump) of one of components. This case is considered on Fig. 1.



a

b

Fig. 1. Termogramma on surface of mixture (a) and graph of change of temperatures (b) at presence of clinging

On Fig. 1,a thermogram of surface of mixture in which presented lump of powder-like aluminum. In the process of heating and interfusion he was moved to the surface. His temperature is higher, than temperature of surrounding material, and made a value 27 °C. From a graph, presented on Fig. 1,b, see that on the border of section there is sharp gallops of temperature. It takes place at finding of the heated metal in material with low heat conductivity (polystyrene).

The subsequent process of preparing a composite material occurs at constant heating and stirring. Thermogram of this process is shown in Fig. 2.

Thermogram (see Fig. 2) to witness heated portions, where the temperature (see Fig. 2,b) differs by 7 °C. These portions are arranged in parallel. They were formed by the mixer when the lumps were crushed with a higher temperature. Furthermore, the surface layers were hotter polystyrene. Subsequently the structure of the mixture did not change. Thermograms are seeing increased the overall temperature of the material. The heating is accompanied by the appearance on the surface of the individual layers at a higher temperature. The change begins to occur when the mixture is heated to the melting point of polystyrene. Equalization of temperature takes place as the surface of the material on the entire volume.

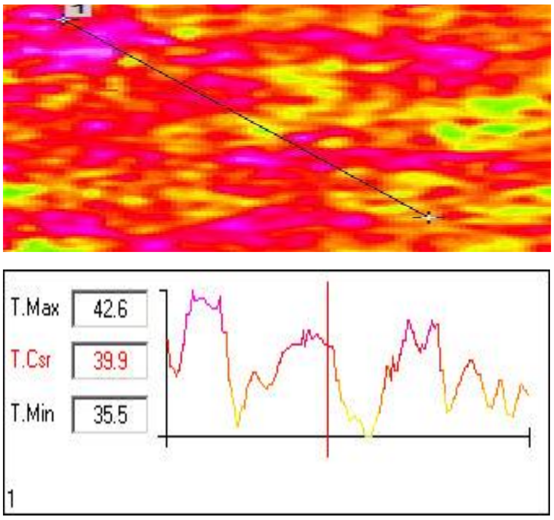


Fig. 2. Thermogram of (a) and a graph of the temperature (b) of the mixture during heating

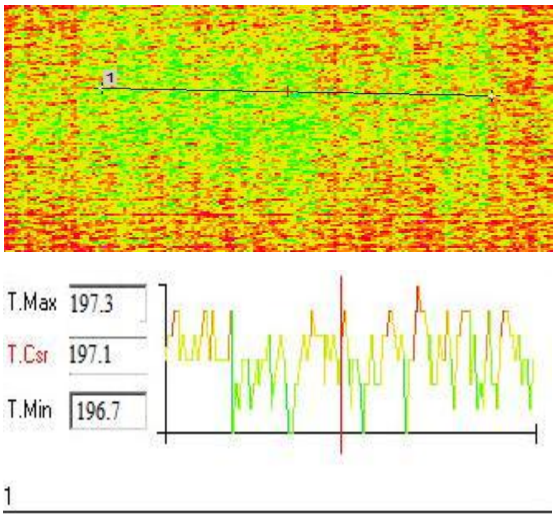


Fig. 3. Thermogram of (a) and a graph of temperature (b) when melting mixture of polystyrene

Fig. 3,a shows the thermogram field of temperature changes on the surface of the molten material. In fusion there are not points with an enhanceable or lowered temperature. Also there are not features which testify to the defects of structure. Deviation of the temperature field is 0.3 °C (see Fig. 3,b). Uniformity of distribution of the metal component by volume mixture attained by adjusting the stirring speed and temperature of the mixture.

Change in temperature regulated density polystyrene in the liquid state. The higher the temperature, the lower the density of the polystyrene, which leads to an increase in settling of the powder metal into the lower portion of the fraction. In colder melt may form lumps. The rotational speed of the mixer is achieved uniformity of metal powder by volume of the mixture. Contributes to an increased rate of motion of the particle to the periphery contributes to reduced speed – subsidence. Permanent particles IR radiometric control allows to detect incipient defects and make their removal by changing operating modes.

Additionally, the primary control of the uniformity of distribution of the metal component carried by the color of the resulting mixture, the same as the color and no dot indicates inclusions slurry homogeneity.

The most important parameter influencing the radiation-protective properties of the composite material has a composition. Selection of components and their proportions of components is carried out taking into account the requirements for a given material. For example, it is known that the maximum protective properties are heavy metals. But the increase in the proportion of heavy metals can significantly increase the weight of the IPC and reduces its thermal insulation properties. Reducing polystyrene – increases the thermal conductivity and of the composite fabrication difficult. Small amounts of aluminum – changes the strength characteristics. Therefore it is necessary to solve the problem of obtaining maximum performance is not one of the options, and all the complex. We investigated the protective samples with mass composition given in Table.

Mass components in composite materials

Material	Poly-styrene PS, mas.%	Tung-sten W, mas.%	Alumi-num Al, mas.%	Thickness protective Inserts for IPC, cm
C01	52.1	11.4	36.5	1
C02	15.3	16.5	68.2	0.72
C03	15.3	37.3	47.4	0.43
C04	15.3	72.4	12.3	0.26
C05	7.4	65.3	27.3	0.28

All samples of the composite materials shown in Table are the difference in hardness, the radiation-shielding properties, cost of manufacture. However, these differences allow you to pick composite materials that best meet the set requirements.

Measuring the hardness produced samples revealed its dependence on the percentage of aluminum in the composite. Measurement is carried out by the method of Rockwell. For material C01 (36.5% Al) value was 69 on a scale M. This value corresponds to the hardness of pure polystyrene. For C03 (47.4%) – 75. For C02 (68.2%) – 80. That is, with increasing aluminum content increases and the hardness of the material. Significantly different hardness of samples C04 and C05. It amounted to a value of 100 on the scale of M. It is associated with a significant content in the composite metal components. Used in the manufacture of aluminum particle size of 10…20 μm and tungsten – 30…40 μm. Hardness depends on the particle size of the metal and the percentage of components.

Currently developed and tested numerical mathematical methods of investigation of radiation-protective properties of various materials. Mathematical modeling results agree well with experimental data. We have investigated the radiation-protective properties of obtained composite materials, using mathematical modeling methods. Absorption efficiency for modeling package was used Geant4 v 4.9.6p02 [6]. Fig. 4 shows the calculated absorption of the energy flux transported by gamma quanta, in the protective layer of the submissions received.

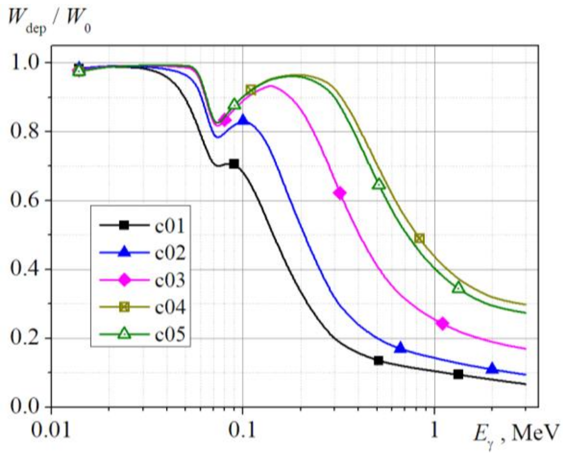


Fig. 4. Stake of stream of energy, transported by with gamma quanta, which is taken in a protective layer by the thickness of 1 cm

Increased absorption in the energy region above 90 keV due to the presence of tungsten in the composition of the composite material. The maximum absorption is observed for materials C03, C04, C05. IPC should provide a substantial weakening of the absorbed dose in the gamma energy of 300 keV. In this energy range, the maximum amount of concentrated gamma radiation scattering medium. The fraction of absorbed energy gamma rays samples C03, C04, C05 is four times higher than for samples C01 and C02. (As compared with a pure polystyrene – five times).

Since developed on materials intended for use in the IPC, we have restrictions on weight and size of the protective layer, they must be minimized. From experience with IPC rescuers, the total thickness of the protection elements must not exceed 15 mm. On the radiation-shielding layer is 10 mm meaning. Recalculating the full amount, we find that the size of the IPC 48…52 weighs 21…29 kg, 54…60 size – weight 24…33 kg. The minimum density of the material is C01, maximum – C04, C05. For these materials with a thickness of 1 cm were considered [7] weakening of the absorbed dose (Fig. 5).

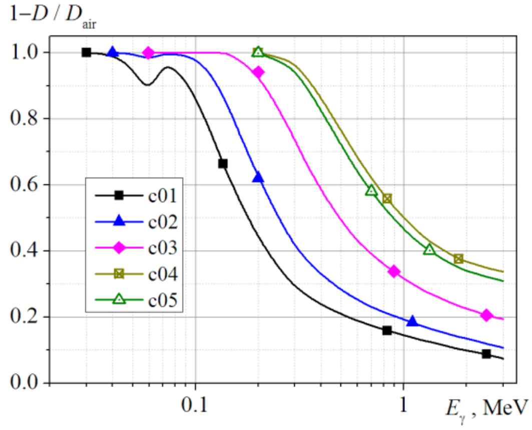


Fig. 5. The weakening of the absorbed dose of gamma radiation protective layer 1 cm thick

The most effective materials C04 and C05. In the energy range 100…400 keV, they absorb three times more gamma rays than the composite C01. Especially noticeable differences in the energy 700 keV…1 MeV. Pure polystyrene reduced dose of gamma radiation at 5%, material C01 and C02 reduced dose of gamma radiation at 10%. Composite materials for C04 and C05 weakening dose in this energy range is about 40%. In Fig. 6 shows the calculated radiation dose to the weakening of the protective layer of the IPC of the investigated composite materials of the same mass thickness.

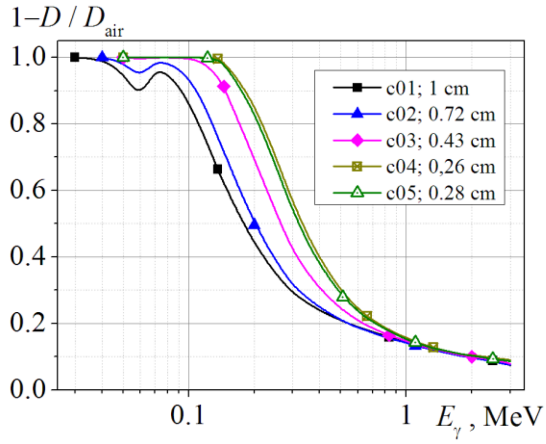


Fig. 6. The weakening of the absorbed dose of gamma radiation protective layers of equal mass thickness ($\rho_{mass} = \rho \times d$)

From these graphs it is clear that composite materials C03, C04, C05 in to 300 keV (energy region of scattered gamma rays) have higher efficiency weakening twice than C01, C02. At higher energy gamma rays, this difference decreases at higher energies (1 MeV) graphics merge. Considering in Figs. 5 and 6 points a neighborhood of 1 MeV, we can conclude that at high energies absorbing characteristics of composite materials depend on the thickness of the protective layer, the type of metal, the amount of metal components.

CONCLUSIONS

1. Various modifications of matrix composition material are offered, for application in IPC as an element of protecting from an ionizing radiation.

2. Is studied using the numerical methods, the dependence of attenuation of the absorbed dose of gamma radiation from composition of composite.

3. The composition. of composites are found in a most degree weakening the stream of gamma-quanta.

4. The technological modes which are used at making of radiation-protective materials are got.

5. Shown that the hardness of the composite material increases with the increase amount of metal-containing components of.

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МЕТАЛЛОСОДЕРЖАЩИЕ КОМПОЗИЦИОННЫЕ МАТЕРИАЛЫ ДЛЯ РАДИАЦИОННОЙ ЗАЩИТЫ

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В индивидуальных защитных комплектах для применения в качестве элементов радиационной биологической защиты предложены пять видов композиционных материалов. Их основой является полистирол, армированный алюминием с добавлением порошкового вольфрама. Посредством численных методов показана эффективность поглощения ионизирующего излучения. Отрабатывались технологические режимы изготовления композиционных материалов. Обнаружено, что твердость образцов возрастает с увеличением количества металлической составляющей. Предложено использовать методы ИК-радиометрии для контроля однородности композита.

МЕТАЛОВМІСНІ КОМПОЗИЦІЙНІ МАТЕРІАЛИ ДЛЯ РАДІАЦІЙНОГО ЗАХИСТУ

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В індивідуальних захисних комплектах для застосування в якості елементів радіаційного біологічного захисту запропоновано п'ять видів композиційних матеріалів. Їх основою є полістирол, армований алюмінієм з додаванням порошкового вольфраму. За допомогою чисельних методів показана ефективність поглинання іонізуючого випромінювання. Відпрацьовувалися технологічні режими виготовлення композиційних матеріалів. Виявлено, що твердість зразків зростає із збільшенням кількості металевої складової. Запропоновано використати методи ІЧ-радіометрії для контролю однорідності композиту.