THE USE OF HIGH-CURRENT RELATIVISTIC ELECTRON BEAMS FOR THE STUDY OF THE EFFECTS OF IONIZING RADIATION ON MATERIALS STORAGE RAW

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Efficiency of application of heavy-current electron beams was studied. The electron beams were used for the imitation of influence of ionizing radiation and physical loadings on the walls of waste storage facilities. The revision of methods of IR-radiometric control of moisture-capacity of surface of mountain breeds was conducted. We measured the hardness of granite, depending on the depth. We studied the changes in the surface structure of the material.

PACS: 621.715:539.376

INTRODUCTION

The development of nuclear energy, the widespread use of radioactive elements in the industry, the military sphere is accompanied by a significant amount of radio-active wastes (RAW) and highly radioactive waste (HRAW) [1].

RAW appear on all technological steps of nuclear fuel cycle (NFC). Utilization of these wastes is an important task. At its consideration it is necessary to decide the questions of their protracted storage; an exception is creation of emergency situations, dangerous for people and environment.

This problem requires serious research [2]. Necessary to develop and to find science-based regulations, the criteria for determining and assessing the state of storage and their environment in a real natural, environmental, technocratic factors.

In addition, you must take into account the strengthening of the requirements in relation to the disposal of HRAW [3]. These wastes are the sources of radiation contamination of environment during thousands and even millions of years.

The existence of protective structures for a long time can be effected in a stable and steady state only in a complex use of different techniques and technological solutions (engineering structures) combined with natural rocks characteristics which are located in the repository.

The technological solution is defined as a multi-barrier protection. In accordance with the requirements of the IAEA protection should be for a long time to carry out the insulation properties when subjected to a pressure of 50 MPa at a temperature range of 250…330 K. At present, there are several different types of storage RAW/SNF [4]. Among them are “wet” and "dry" storage, burial grounds [5].

The special place is occupied by storage in hydrochloric layers [6, 7]. Halite formations, in the form of crystals, are perspective geological objects for the burial place of radio-active nuclear wastes.

Currently, the global practice of over 60 million cubic meters of liquid waste RAW/HRAW was pumped into the salt tank through boreholes [3]. However, despite the widespread use of such radioactive waste storage RAW/HRAW in halite breeds, considered that the issue cannot be solved completely.

The questions of diffusive distribution of defects, questions of creep, changes of structure of material, under the action of radiation, questions of migratory motion of brine and active matter are not solved.

We will mark that at an irradiation the ionizing radiation of hydrochloric layers the creep of materials of walls appears, there is a hold-out of walls, that diminishes the general volume of storage and there is squeezing out of the placed brine or active matter.

The study of these questions is continuing and at the present time that allows you to build new, more secure and improve existing storage RW/SNF.

Another important perspective direction of creating stores RAW has their placement in rock formations or waste workings. The main insulating elements are mountain breeds consists of which mountain massif.

It is necessary that in geological repositories mountain rock mass meet certain geological, geophysical, geochemical, hydro geological characteristics. Among them: the mechanical stability, the possibility of continued existence, the ability to isolate the radionuclides, avoids migration of radionuclide’s.

It is necessary to consider the breeds of granite or granite-gneiss, nuclear depositories are located in which, on a blow and propensity to fragile destruction.

It has done a lot of work. Researches are conducted. You cannot get a forecast for the store walls. It is necessary to study the materials of rocks.

For the development and the creation of a theoretical study of issues of RW storage RW/SNF is necessary to solve several tasks.

In particular: a) the study of natural and anthropogenic heat flows, the definition of cash flows of heat; b) the location of existing underground water flows and gas flows; c) the accounting effect of movement and migration of radionuclides.

PURPOSE OF WORK

The study of changes in the structure and characteristics of the walls of the radioactive waste storage when exposed to ionizing radiation. Investigation of the impact of high-current electron beam on the mountain breeds.

THE MAIN PART

The results of empirical research on the natural objects in the real world to get hard. Since this is due to the long exposure time of passage. Therefore, the effects of radiation-induced transformations that occur in the rock mass are studied by means of simulation.

Its essence lies in the irradiation of the samples with ionizing radiation. The work is performed until the material will not receive the integral dose, which can be obtained in real conditions. Perform this work possible by using a number of different settings. In particular, to carry out these experiments using pulsed high-current electron accelerators.

When exposed to ionizing radiation of the sample stream (in this case an electron beam), a strong radiation exposure is carried out, there are high mechanical loads, the surface is heated.

Carrying out a simulation of radiation do not can fully meet the natural processes that occur in the rocks under the influence of radiation from storage RW/HLW, as there is a process greatly stretched in time for the radiation intensity, physical activity, water thermal parameters.

Nevertheless, the impact of conducted enable assessment of rock response to the extreme impact of the seismic nature, thermal shock, radiation exposure.

Imitation is also carried out with different temperature regimes and water-air (moist sample different barometric environment).

RESEARCH DISCUSSION OF THE RESULTS

Processing of samples was carried out on the accelerator “TEMP-A”. Its parameters [9]: electron energy ~ 0.3 MeV; beam current ≤ 5 kA; current pulse duration of 5 ms; the total energy of the beam 3 kJ. Beam diameter of 60 mm. The energy density of 100 J/cm^2. Energy density distribution over the cross section is uniform beam.

Irradiation was carried out in a vacuum. As a material used granite ball. The ball had a diameter of 50 mm. Granite was used from the Rogowski field Zhytomyr region. Granite had a medium grained. General view of the ball prior to treatment is shown in Fig. 1.

When exposed to a sample beam of accelerated electrons we get several kinds of exposure.

One of them, which promotes the formation of craters – the impact force, in particular thermal shock. The extent to which the energy beam is released, determined by cross-sectional area of the electron beam and mileage. We believe that a small number of electrons scattered at large angles (over 120°) and left volume of the sample.

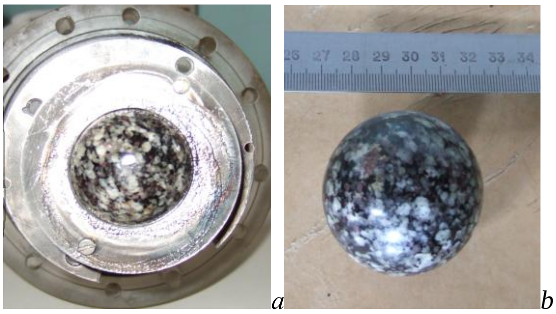

Fig. 1. Type of the experimental sample of granite, which is made in the form of a ball: and – a fixed accelerator target; b – perspective view

The rest underwent an inelastic collision that led to the ionization of the medium. The electron-ion relaxation 10^{-9} s. During this time, the electron energy is converted into heat energy. Since the pulse width is the time closest acoustic relaxation time, the thermoelastic stresses occur which lead to the destruction of the surface and near-surface layer of the sample which is irradiated.

Maximum destruction was 200 μm in the irradiated sample. Also, when the beam interacts with the sample, due to the rapid heating of the surface layer may have its evaporation. It forms a plasmoid that the expansion produces an additional blow to the granite material. We can evaluate the pressure of the plasma clot that formed as a result of the energy beam. For this we use the expression [11]:

$$P = (\gamma_f - 1)\, w, \quad (1)$$

where P – the pressure in the zone of influence of the beam, $\gamma_f \approx 1.19$ – specific heat ratio of a plasma cloud formed and granite material, w – the volume density of the energy absorbed is calculated from the expression:

$$w = \rho(Q - H_f) + \frac{W_D}{\Delta z_1}\ , \quad (2)$$

ρ = 2700 kg/m^3; Δz_1 = 100 μm – thickness which melts; W_D – energy density beam; W_D – an exothermic reaction energy which is released in the bed; H_f – the energy of melting the surface layer.

This expression for the energy density of the energy of the electron beam, which is absorbed in the interaction region in the surface layer, as well as take into account the energy released in an exothermic reaction with a net energy spent on melting.

As a result of the beam comes complete destruction of the rock material. In practice the rate of destruction of the calculation is different. This may be due to the deposition of the vaporized beam hitting rocks place appearance in front of the sample cloud of particles which reduce the intensity of the beam, etc.

In our case, after treatment of the sample with an electron beam granite surface layer structure has changed significantly. The appearance of the treated granite ball is shown in Fig. 2.

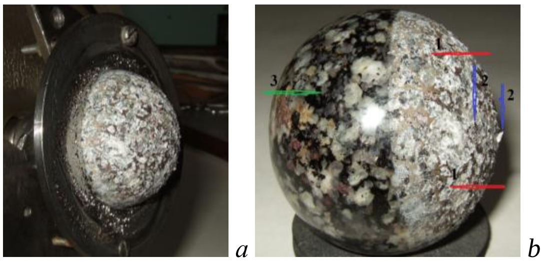

Fig. 2. Appearance irradiated sample:
a – in the target; b – perspective view

The displayed image demonstrates that exposure to ionizing radiation (electron beam) changes the surface structure of the material. Fig. 2 red marker (1) denotes a surface that was subjected to electron beam processing, the blue marker (2) – exfoliate flake sample material; green marker (3) – polished raw beam surface.

Work to clarify the granite hardness was carried out in the following irradiation. For this purpose, geological methods. It is known that the hardness of geological samples is determined on the Moos scale. This scale gives a comparison with the reference samples. Hardness is done by scratching the surface of the sample. Take measurements of the hardness of the irradiated area of the center to its edges with 5 mm pitch.

Several measurements were performed, which were carried out by different curves. At the same time it was observed that in general, performed circular symmetry with respect to the target center. This may indicate that in the first place to the uniformity of the beam in the cross section, and on the weighted average of the target material homogeneity of granite.

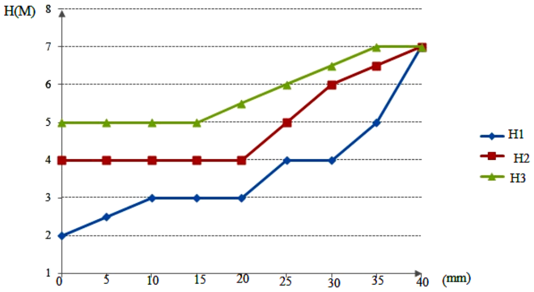

Fig. 3. Graphs surface hardness with distance from the center

The x-axis (Fig. 3) is given the distance from the center of the ball to the edge of the vertical axis – Mohs hardness. The curve H1 (blue, diamond-marker) corresponds to the hardness of granite ball after irradiation. With increasing distance from the center of the target hardness increases as the absorbed dose is reduced. The surface has a layered structure and scratched even amber.

Hardness corresponding initial achieved only at the irradiated area, where an insignificant impact of charged particle beam. In the second stage we had a surface treatment by means of ultrasound [13, 14]. This procedure simulates the mechanical effect on the storage surface during operation.

The thickness of the damaged layer is reduced by an amount of 0.5…9 mm. the most prominent elements have been removed. Due to the decrease in the number of lamellar and scaly point violations we are seeing an increase in hardness. Data are given curve H2 (red, square-marker).

In the third stage we carried out further sonication. Note that the thickness of the damaged layer is decreased slightly. After the secondary surface treatment reduction was the value of 0.1…0.3 mm. However, this has led to a substantial increase in the surface hardness curve H3 (green curve marker triangle). This effect can be explained by the almost complete removal of delaminated flake breed.

The hardness increases with increasing distance from the center to the edges. From these pictures we can be concluded that the number of defects and structural changes depending on the absorbed dose. With the increase of the absorbed dose is increased and the amount of change. The distribution of the absorbed dose can be calculated from the expression [12]:

$$D(r,t)=g(t)\int_{0}^{t}d\tau P(r,\tau), \qquad (3)$$

where $g(t)\sim\cos\varphi$ – factor; $P(r,t)$ – the absorbed dose rate. determined by the geometry of the target surface. In this case it is proportional to the angle between the line connecting the center of the sample with the electron source and the radius directed at the point on the ball surface, we define where the absorbed dose.

Status granite surface has been studied by IR radiometry and rock techniques [10, 12]. The structural changes in the emission of infrared radiation at different degrees of flooding breeds available to it various defects (cavities, cracks, pores).

Considered several different types of state of the surface of granite.

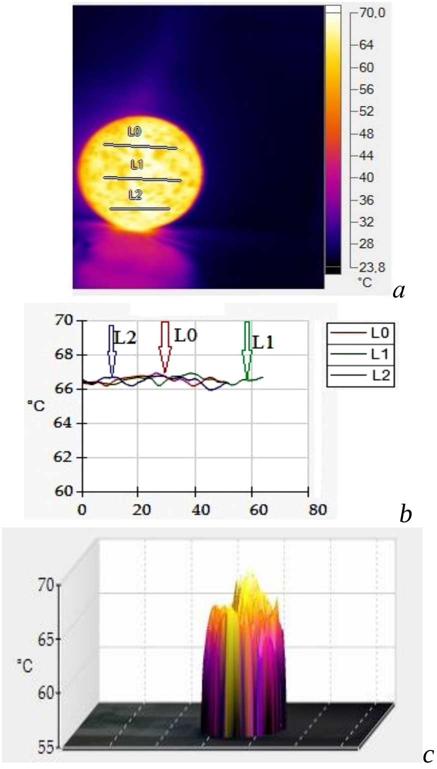

Fig. 4. The thermogram (a); graph (b), and 3D image (c) non-treated surface of the ball in the absence of moisture

From Fig. 4 observe, that the surface has a relatively uniform temperature field. temperature jump depends on the type of macro grains granite. They have different specific heat that influences the final temperature. 3D image takes the form of individual peaks. Each vertex – a platform separate inclusions macro grains.

To check the ball surface was subjected to intense water flow. And it was then dried. Ie held rain simulation, snow, fog, to the outer layers of granite rock and water seepage through cracks to the inner layers.

We get results similar to those given in Figure 4. The water did not stay on the surface of the ball and has not penetrated inside. This indicates that there are no defects in the material.

The next step was studied thermogram surface granite ball that was irradiated with an electron beam. The whole party, which has undergone treatment, turned to the imager.

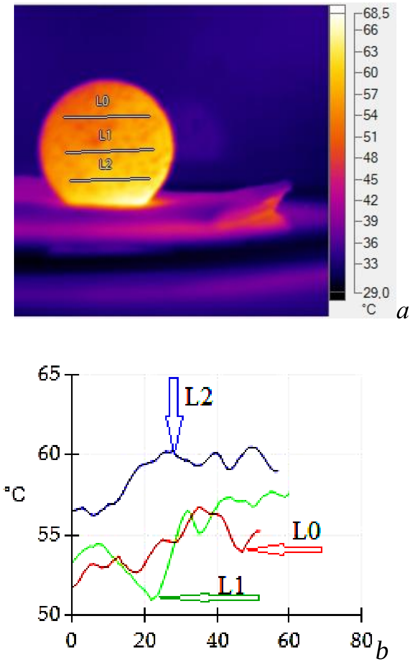

Fig. 5. Characteristics of the exposed side of the ball
a – thermogram, b – temperature graph

Boll pre-heated. Warming up allows you to get a sharp image, and emphasizes the individual defects are not only on the surface but also inside.

Temperature fluctuations have graphics. Fluctuations depend on the heterogeneity of the individual heating elements surface. Undulating temperature jumps do not occur in the individual grains, and a whole array of granite. This proves the existence of boundaries, where a change in heat flux. The height of the curve L0, L1, L2 depends on the uniformity of heating the entire volume of a sphere. We, the maximum heating had its lower part.

To simulate wetting specimen was placed in a container of water. After a while it removed and rubbed the surface. After that, a thermal imaging survey was carried out.

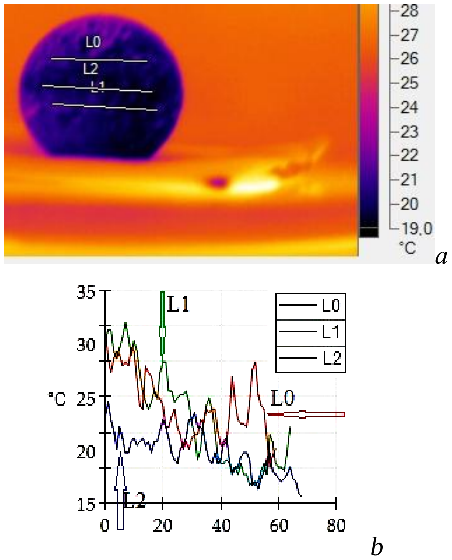

Fig. 6. Characteristics of the exposed side of the ball, after the impact of water flow:
a – thermogram; b – temperature graph

Thermogram shown in Fig. 5,a has a pronounced setback area. Charts are also significantly different. The graph shown in Fig. 5,b has a smooth change of temperature. Fig. 6,b they dramatically change their meaning and level. This is due to the following reasons.

The surface consists of grains of different types, different heat capacities and dimensions. In this case, the irradiated surface has a scaly structure with different heights of individual grains (Fig. 2,a). Between the individual grains are present various remelting oxides. As a result of the accelerated electron beam on the surface of the ball is formed of the granite micropores.

After contact with moisture occurs it spread into the sample. These formations are thermal insulators and change the speed of the heat flow. Consequently, heat transfer is reduced the diffusion that causes the difference in the heating of individual rock grains macro.

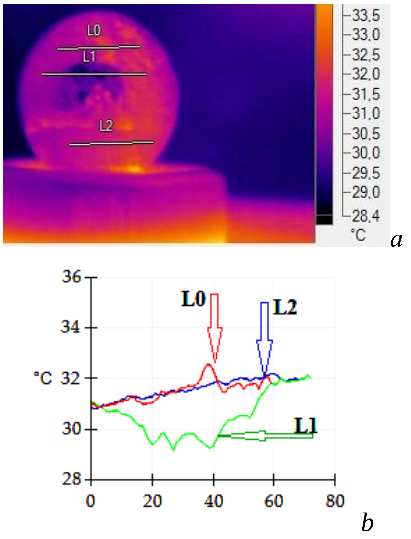

Fig. 7. Characteristics of the ball with a defect:
a – thermogram; b – temperature graph

To check the efficiency of diagnosis of the state of rock materials investigated granite samples with lesions on the surface. Considered ball in which mechanical damage is present. Pre balloon was warmed up. Test results of this case are shown in Fig. 7.

The temperature on the L0 and L2 sections slightly changing and growing. Fluctuations in temperature flowing. Anomalies are absent. Curve L1 passes through the defective area. The value of the temperature is lower than in the surrounding area. Because the ball has been preheated, the smoothed difference between the temperatures of individual macro grains.

Research sphere continued after processing the flow of water.

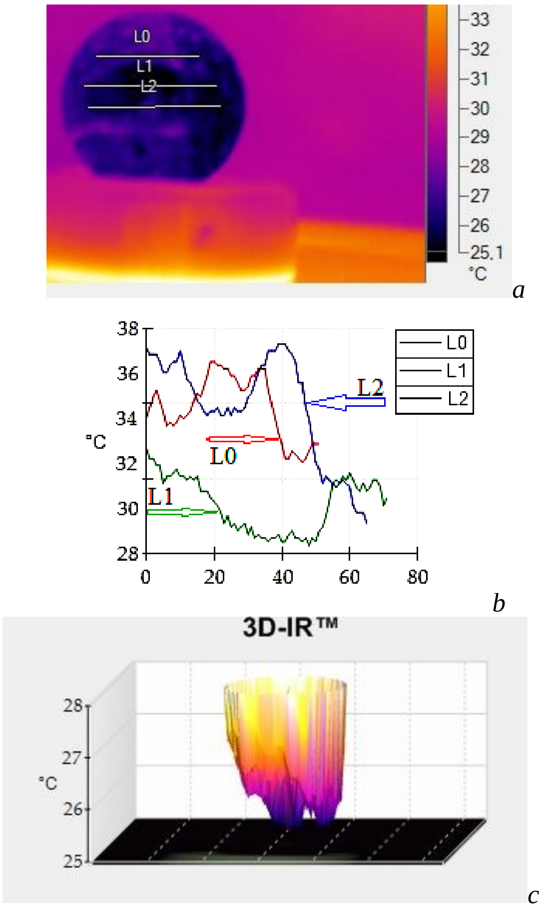

Fig. 8. Features of the ball with the defect that was treated with water: a – thermogram; b – temperature graph; c – 3-D image

Fig. 8 shows the characteristics of the ball with the defect which has undergone treatment with water. The right side of the ball has been treated accelerated electron beam and has a structure given in Fig. 2. Fig. 7,a. The observed differences between the images of these areas. Treated land has significant differences in temperature anomalies.

The reason for this is the formation of cracks and pores, allowing water to penetrate deep into the rock. Consequently, leakage of water flow is determined by the thermographic image. On the thermogram the presence of a well-fixed surface damage. The penetration of moisture into the damage observed a darker color.

By analyzing the graph (see Fig. 8,b) we can say that each ball element (each macro grain) is heated to a certain temperature, different from the temperature of adjacent macro grains. Proof of this assertion are the temperature jumps on each macro grain. The reason for this is, in the presence of the grain refining space rocks.

Thus, such alloys are formed, a structure in which microcracks are present that are different from their main breed specific heat and other characteristics. This is clearly seen in the 3-D image (fig.8.c) where different temperature anomalies in the irradiated area and the area of the defect.

Thus, when exposed to the surface of rock samples beam of accelerated electrons are several processes. Among them: the gradual generation of an rock material breach of surface and subsurface structure, the formation of a significant amount of microcracks

CONCLUSIONS

1. Having examined the effectiveness of high-current relativistic electron beams to simulate the effects of ionizing radiation on the walls of storage of radioactive waste.

2. The revision of methods of IR-radiation control of change of heat control, moisture insulation, adsorbent descriptions of materials of mountain breeds was conducted.

3. The parameters of the surface hardness of the rock, depending on the depth, after treatment with a beam of accelerated electrons.

4. It has been shown that the use of methods of remote infrared radiometry, makes it possible to detect and the identification of defects in the walls of the storage material.

5. It was found that the processing of granite beams changes the structure of the surface layer. There are areas with a substantial amount of micropores decreases hardness, strength decreases.

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Статья поступила в редакцию 15.02.2016 г.

ПРИМЕНЕНИЕ СИЛЬНОТОЧНЫХ РЕЛЯТИВИСТСКИХ ЭЛЕКТРОННЫХ ПУЧКОВ ДЛЯ ИЗУЧЕНИЯ ВОЗДЕЙСТВИЯ ИОНИЗИРУЮЩЕГО ИЗЛУЧЕНИЯ НА МАТЕРИАЛЫ ХРАНИЛИЩ РАО

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Изучалась эффективность применения сильноточных электронных пучков для имитации действия экстремальных факторов на гранит, который является кандидатным материалом для захоронения РАО. Проводилась доработка методики ИК-радиометрического контроля влагоемкости поверхности горных пород. Измерялась твердость гранита в зависимости от глубины после воздействия пучка ускоренных электронов. Исследовалось изменение структуры поверхности материала.

ЗАСТОСУВАННЯ СИЛЬНОСТРУМОВИХ РЕЛЯТИВІСТСЬКИХ ЕЛЕКТРОННИХ ПУЧКІВ ДЛЯ ВИВЧЕННЯ ДІЇ ІОНІЗУЮЧОГО ВИПРОМІНЮВАННЯ НА МАТЕРІАЛИ СХОВИЩ РАВ

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Вивчалася ефективність вживання сильноточних електронних пучків для імітації дії екстремальних чинників на граніт, який є кандидатним матеріалом для сховищ РАВ. Проводилося доопрацювання методики ІЧ-радіометричного контролю вологоємкості поверхні гірських порід. Вимірювалася твердість граніту, залежно від глибини, після дії пучка прискорених електронів. Досліджувалася зміна структури поверхні матеріалу.