Hard radiation of reological explosion

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Abstract. The paper presents the results of experimental research of hard radiation going with reological explosion of solid bodies at the Bridgman’s anvils. The results of experiments gives evidence of electromagnetic character of radiation as in process of explosion, as after it. The energy of quanta of radiation, going with explosion was less, than some tens of keV and was less then some hundreds of keV in case of afterglow.

1. Introduction
Reological explosion is the specific kind of breaking of solid matter under pressure, combined with plastic deformation. It is rapid transformation of the energy of compression of the matter, on conditions that this energy is higher, than bond energy of this matter, to kinetic energy of components of this matter. The triggers of explosion are high-energy clusters, which are arising in the matter in the case of it’s plastic deformation under the pressure. This phenomenon is known under different denominations as long as the investigations of behavior of solid bodies under high pressure and shear stresses were begun to carry out. The term «reological explosion» for this phenomenon was first introduced by Gorazdovski and Shienok in the year 1975 [1] and is using widely now.

Reological explosion have many features which are observing during experiments [2]. One of such features is hard radiation during the explosion and after it. Radiation during breaking of solids, such as heat and light radiation, is widely known phenomenon, but it don’t attract a steadfast attention of investigators due to apparent simplicity of explanation of it’s nature. Conventional explanation of said phenomenon consist of assumption, that it is heat radiation of incandescent breaking solids, which are heating due to transformation, through a mechanism of friction, as a rule, of mechanical energy of any kind to heat energy. Such explanation have good correlation with proportion between the energies of light quanta and mechanical energy per atom, which have a solid before breaking.

There is no explanation from this or any other generally accepted points of view of existence of hard radiation in process of breaking of solids with average energy of some electronvolts per atom. Hard radiation was observed in different cases of breaking and high-energy deformation of solids [3–7] and reological explosion is a one. Qualitative investigation of hard radiation of reological explosion was carried out in the works [8, 9]. Results of quantitative investigations are described here.

2. Experimental Procedure
The studies were carried out with the apparatus (Figure 1) included one pair of Bridgman’s anvils one of which were fixed at the ram of 100 tons hydraulic press and another at the shaft of mechanical reductor, which were mounted at this press. The reductor allowed to rotate said anvil around the axis, passed through the centers of both anvils. The angle of rotation was measured with accuracy of $\pm 4 \times 10^{-3}$ radian and was unlimited. Speed of rotation was constant with valuation about $1.8 \times 10^{-2}$ rad/s.

Figure 1. Scheme of the apparatus (1 – upper anvil, 2 – sample, 3 – lower anvil, 4 – shaft of reductor 5 – scintillation counter, 6 – amplifier-analyzer, 7 – counter of impulses, 8 – recorder).

The anvils had a form of truncated cones made of alloy steel forced up HRC60, or of cemented carbide with 8% of cobalt. The working surfaces of anvils had a square of 2 – 3 cm$^2$ and were grinded for roughness of a few of microns.

Pressure was valuated as average force to square of working surface of anvils because it was not hydrostatic with maximum in the center. Moreover, gradient of pressure was changing during deformation. Thus exact measuring of pressure was useless. Deformation valued as the angle of rotation of anvil because it was different in different points of the sample and exact measuring was useless too. The samples exploded when pressure and deformation achieved some values, individual for each material. The objects of investigations were polycrystalline dielectrics. Most convenient object from the point of view of purposes of this work was chalk.

Measurements of radiation was carried out with scintillation counter, which included NaJ (doped Tm) crystal, guarded with Al–alloy shell, photomultiplier, amplifier-analyzer, counter of impulses and recorder. The crystal had volume 30 cm$^3$, working square 10 cm$^2$ and detected 80% of ingressed electromagnetic quanta. Other kinds of particles don’t excited scintillations in this crystal and because of this, there was not possible to know true the kind of primary radiation as electromagnetic radiation could be a result of interaction of other kinds of radiation with the shell or matter of crystal. The amplifier-analyzer allowed to adjust the range of energies of counted particles with required upper and lower bounds. The counter of impulses allowed to adjust duration of counting and interval between periods of counting. Minimal time in both cases was 0,5 s and was by a factor of $10^3$ grater, than a time of explosion. This case strongly degraded signal-to-noise ratio, but it was necessary for catching the moment of explosion. Noise depended strongly on the width and limit values of the range of energies – the more the width, the more the noise and the lower bottom limit, the more the noise (effect of rising of upper limit was smallish). This case necessitated to adjust manifold the range of energies on the basis of getting of optimal signal-to-noise ratio. So, there was not possible to make conclusions about any characteristics of radiation, except of intensity in reference to noise and a value of energy in selected range. Recorder registered the results.
Expected intensity of radiation was low and its energy was conjectural, so it was necessary meticulous measurements of native noise radiation, elimination of every possible obstacles and carrying out of a lot of pilot experiments.

The counter was mounted at shock damper, in the plane of projection of particles at the distance about 30 cm from exploding tablet and was protected with some layers of fabric from impacts of flying particles, what was necessary for preventing damage of the counter. No electric commutations were done in the moment of explosion and during 5 s before and after it, for preventing from breakthroughs. The radiation had a possibility to propagate free only in space angle of about 1.5 radian due to features of experimental apparatus. So, the counter can catch only about $10^{-3}$ of initial quantity of radiation only on geometric grounds. Moreover, the probable source of radiation was the tablet with relation of diameter to height from 10:1 to 20:1 and only a part of radiation, which passed through a lateral surface of a tablet, could be detected and other part was absorbed in the anvils. The quantity of radiation, which the counter could catch in such conditions, decreased by an order of magnitude.

Each explosion and results of measurements were very specific and so, any conclusions were possible only after analysis of great number of observations. Registration of any radiation in such conditions gave evidence of a great success in experiments or of a large-scale primary intensity of this radiation.

Measurements of afterglow of tablets after explosions was done too. The tablet was placed directly at the crystal of the counter as quickly, as possible and then the quantity of impulses were recorded. The series of some tens of measurements were than carried out with time of counting 1 s and dead time 0.5 s. The upper and the lower bounds of the range of energies were adjusted on the basis of getting minimal noise signal because of low intensity of measurable radiation. Noise was measured before and after counting the signals from the tablet. The noise in presence of source material with mass manifold greater, then a mass of tablet, was measured too. It was ascertained, that presence of any source material no changed the noise. The assessment of results was made with taking into consideration full quantity and average quantity per measurement of counted particles in series, maximal and average deviation from average quantity in series for each measurement.

3. Results and Discussions

There were gotten next results in such conditions. Immediate measurements of radiation which gone with explosion was carried out generally with chalk, as source material, due to maximal stability of characteristics of explosions. This measurements shown, that the exceeding of quantity of counted impulses over noise was changed in wide range from one experiment to another – from absence to manifold. Maximal exceeding (by the order of value) was observed in the range of energies from 1 – 5 to 20 – 30 keV, especially in the cases of very strong explosions. Increasing of the value of the lower bond leded to decreasing of total amount of counted particles - as noise, as a value of exceeding from noise. Decreasing of this bond leded to increasing of noise, which merged useful signals. Decreasing of the upper bond leded to decreasing of total amount of counted particles - as noise, as a value of exceeding from noise. Increasing of the upper bond leded to insignificant increasing of total amount of counted particles without effect on the exceeding of noise. This facts gives evidence, that the energies of majority of quanta of radiation, going with explosion were less than 20 – 30 keV with more or less surgeless distribution over the range. There was not possible to establish with confidence presence of quanta with higher energies and a value of lower bound of energies.

Measurements of afterglow were carried out with tablets of pure chalk, chalk, doped with materials, which could help to get maximum information about primary radiation in process of explosion and increase responsivity of the method due to possible nuclear reactions with atoms of this materials. Boron with effective interaction with neutrons and aluminum with short-lived isotopes was among such atoms. The best results was obtained for tablets of chalk, doped with boric acid in the range of energies 200 – 500 keV. The exceeding of average quantity of counted particles and average
deviation from average quantity over noise was about 50% in this case and repeated well from one experiment to another. Maximum deviations from average were manifold in some cases, just when there was about 20% for noise. The same results in this range, but with less exceeding, were observed for tablets of polymethylmethacrylate. The results were worse in other cases because other materials gave less quantity of particles in this range. The exceeding over noise was about some particles per second in this experiments. Reducing of lower bond of the range of energies for catching of the particles with lower energies leaded to increasing of noise and there was impossible to reveal reliably exceeding of noise, when noise was more, than some tens of impulses per second.

4. Conclusion
Some parameters of hard radiation, which is attending reological explosion, were detected in this work. The results of experiments gives evidence of electromagnetic character of radiation as in process of explosion, as after it. The energy of quanta of radiation, going with explosion was less, than some tens of keV and was less then some hundreds of keV in case of afterglow. Presence of boron enhanced intencivity of afterglow, what can point out involvement of neutrons in process of occurrence of radiation.

Acknowledgments
The work was carried out according to the state task No 075-00947-20-00

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