ELECTROHYDRAULIC PULSE GRINDING OF RADIOACTIVE SOLID NF WASTE SIMULATION MATERIALS

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A technique used for the grinding of radioactive waste simulation materials using water spark discharges has been proposed. Two modes of the material grinding have been specified. The mass loss of grinded materials versus the amount of pulses and the work volume of electrohydraulic reactor has been compared.

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INTRODUCTION

Consideration was given to the regeneration of the nuclear fuel (NF) waste using physical methods [1, 2]. Element groups were subdivided into fission products (FP) with masses of 65 to 170 and actinoides. i. e. the elements with masses above 235. Important aspects of such a separation are the heating of the NF waste to provide high temperatures that exceed 2000 °C and the use of the vacuum distillation. Such a heating allows for the removal of 75% of FP, and ZrO, NbO oxides and lanthanide oxides are left. The diffusion is considered to be the main factor here that defines the efficiency and the energy costs required for the removal of admixtures. For rather rapid removal of the admixtures by the diffusion it is recommended to perform the process using no bulk fuel elements. It is suggested to use powdered fuel elements with the size of 50 to 100 μm. Such powders can be prepared both in HF-reactors and by direct grinding of the glassy content of fuel elements with the simultaneous removal of admixtures. We will consider here the second method, because it is more problematic. And the comparison of both methods should be done taking into account many parameters, in particular the expenditures of energy, capital expenditures, the purity of the treated product, the possibility of the environmental pollution, the nuclear safety, etc. The electrohydraulic mode of grinding and crushing different materials including elastic materials showed itself to good advantage [3–5]. It has many advantages in comparison with other methods, in particular with mechanical methods and destruction-based methods using the explosives. We have an opportunity to vary the ranges of the discharge energy, to select the chamber design that meets the requirements of the specific technology, external parameters, in particular the pressure under which the spark discharge occurs, and the main point is that we can select the operating environment that provides appropriate properties for the final product.

This scientific paper gives thus consideration to the opportunity of grinding the specimens that simulate the glassy elements of NF waste in the water in the electrohydraulic reactor with a changeable internal configuration

The objective of this scientific paper is to obtain experimental data substantiating the possibility of the grinding of solid RAW-simulating materials using the electrohydraulic method. The influence produced by the chamber size on the material grinding process has been defined. It has been established that the particles of treated specimens of 10 μm can be obtained.

1. EXPERIMENT STATEMENT

The treatment effect is achieved through the intensification of the hydrodynamic process, heat mass exchange, and physical and chemical processes that occur in the material and that affect a change in its structure-dependent processes. Using as an example previous experiments carried out to determine the electrohydraulic effect on remelted metals [6], we established that the phenomena that accompany the spark discharge in the liquid destroy the dendrite structure of the ingots in the way that each pulse terminates the growth of one grain and gives way to the growth of another grain. The similar effect can visually be evaluated using as an example the influence of the pulse train on the ice structure (photos in Fig. 1).

A high energy concentration in the channel results in the origination of pressure waves very similar to shock waves that are transformed into acoustic waves with the wide spectrum range, powerful hydraulic flows, cavitation, and electromagnetic and thermal fields. These phenomena allow for the change both in the geometric dimensions of the object and in the material structure to impart the materials appropriate mechanical and physical properties.

Fig. 1 gives the photos of the ice-containing vessel that has a volume of one liter placed at a distance of 5 cm from the interelectrode gap; the interelectrode gap is 5 mm, the discharge voltage is 25 kV, the discharge energy is 375 J. The number of pulses is 50. This experiment allows for the determination of zone edges for the effective action of the hydraulic shock and the propagation direction of shock waves. The region marked by the red color is given in Fig. 1,b and it is 10 cm high; the ice was crushed here in small pieces of 5 mm to 3 cm in their section.

These experiments prove the availability of high pressures near the discharge channel and shock waves caused by the high energy input at a time period of about 100 μs.

The experiments related to the grinding of the materials that simulate solid radioactive waste were carried out using the electrohydraulic “Hydra” plant. The amount of energy stored in the capacitor varied in the range of 125 to 875 J. The 1/4 of the volume of the working chamber of 2.1 liters was filled with the liquid (Fig. 2), and afterwards the working gap in the liquid was exposed to the capacitor discharge. The electrode 1 is located on the chamber axis and the chamber bottom 4 serves as the second electrode. Glass specimens with the diameter of 15 mm were placed into the chamber (Fig. 3).

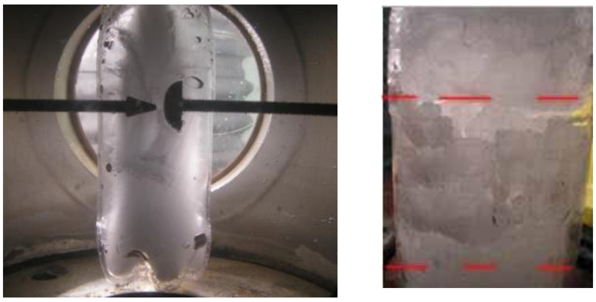

a *b*

Fig. 1. Disruptive action of the electrohydraulic shock generated by the "Hydra" plant (a, b)

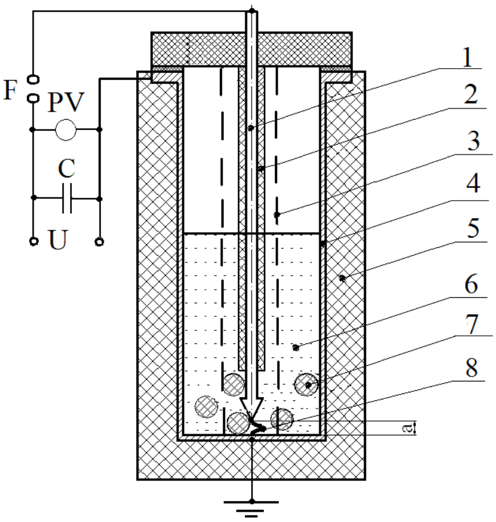
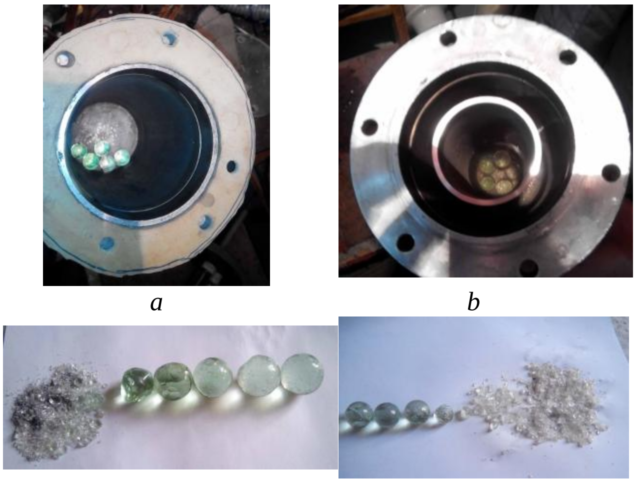


Fig. 2. The discharge chamber structure for the electrohydraulic grinding in the liquid:
1 – high-voltage electrode-anode;
2 – the caprolon isolator of the electrode;
3 – insertable dielectric cylinder;
4 – the cathode chamber; 5 – heat insulation;
6 – liquid; 7 – solid RAW-simulation materials made of glass; 8 – spark channel; F – interelectrode gap;
U – the capacitor charge voltage

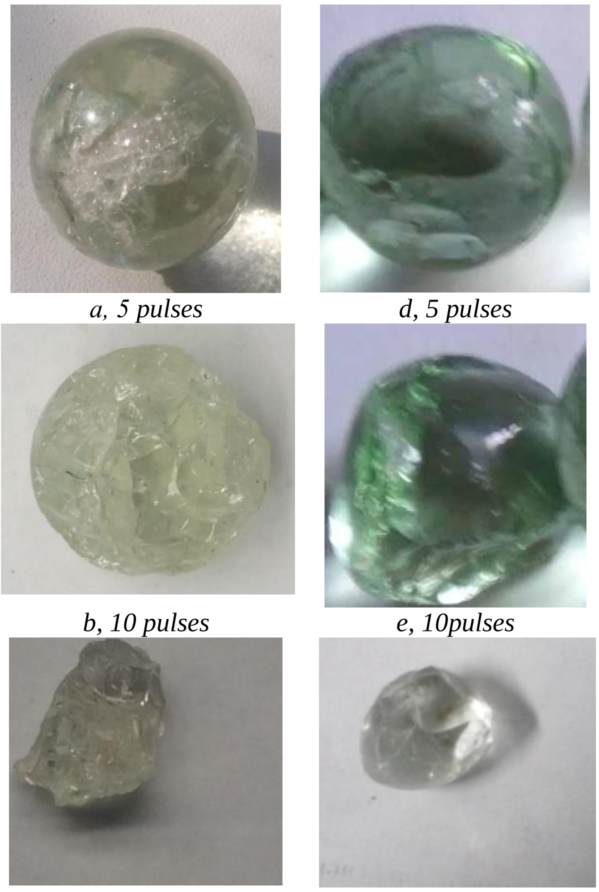
2. EXPERIMENTAL PART

Fig. 4 gives photos of treated specimens subjected to the electrohydraulic pulse grinding in the water. The visual inspection showed that the grinding process can progress in two ways, in particular through the crushing, when the entire specimen practically keeps its shape during the first 10 pulses, however the disruptions are observed over the entire volume and subsequent pulses completely crush the specimen making of it a granulated material with the size of granules less than 1 mm. The second way is characterized by the cleavage, when glass pieces seem to separate from the specimen. This process takes more time and is essentially characterized by the availability of the fragments of a large area (≈ 3…10 mm^2) of an elongated shape.


a *b*

c *d*

Fig. 3. Glass specimens simulating the solid RAW:
a is the volume No 1, where $R_{reactor1} \geq 3R_{specimen}$;
b is the volume No 2, where $R_{reactor2} \leq 3R_{specimen}$;
c is the destruction of the specimens after 20 pulses in the water environment, the volume No 1;
d – the destruction of the specimens after 20 pulses in the water environment, the volume No 2


a, 5 pulses *d, 5 pulses*

b, 10 pulses *e, 10pulses*

c, 15 pulses *f, 15 pulses*

Fig. 4. Specimen milling steps:
a, b, c – grinding by way of crushing;
d, e, f – grinding by way of the cleavage

Fig. 5 gives photos of the specimens after the electrohydraulic grinding in the water. The sizes of obtained granules varied in the range of micron units to 5 mm.

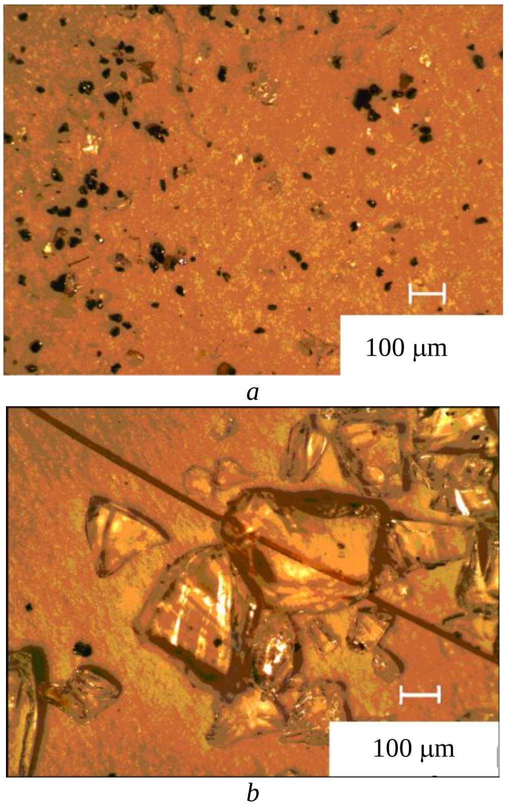


Fig. 5. USB microscope photos of grinded specimens;
a – specimens that have the size less than 1 mm;
b – specimens larger than 1 mm

Fig. 6 shows that the specimens are subjected to the most efficient grinding process during the first pulse train of five pulses as the curves 1, 2 and 3 show. The coarse grain is prevailing during the first ten pulses, and then the amount of the material with the grain size less than 1 mm is increased. In this option the grinding process follows mainly the cleavage way and the vulnerable places of the specimens are exposed to the cleavage during the collision with each other and with chamber walls as well. The percentage of the fraction of more and less than 1 mm was determined in terms of total grinded mass. The reduction of the total mass of the specimens is on the average 0.07 g/pulse and an increase in the number of particles in this mass with the size less than 1mm is on the average 0.03 g/pulse. Approximately 70% of the mass of grinded particles is formed during the first 5 pulses. The comparison of the curve 4 with curves 1, 2, 3 shows that specific power inputs are equal to 0.43 kJ/g for the first packet of 5 pulses and are the lowest due to the intensive mass loss. Subsequent pulse packages require on the average 3.6 kJ/g.

Fig. 7 shows that the disruption in the volume No 2 occurs by all appearance by way of crushing, when the initial electrohydraulic pulse action results in the formation of the crack network in the major portion of the specimen volume. From our point of view this can be related to that the treated specimens are placed near each other and near spark channel specimens, which results in more intensive collisions. Structural and strength peculiarities must also be taken into account.

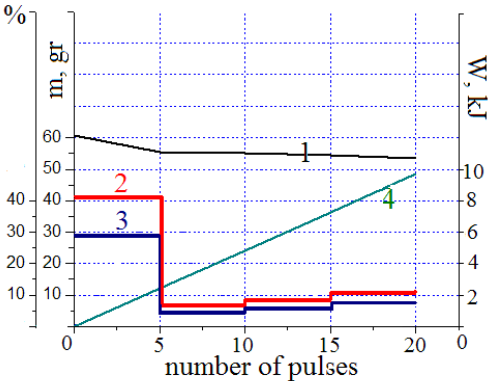


Fig. 6. Dynamics of the electrohydraulic pulse grinding of the specimens in the water, volume No 1:
1 – mass loss curve; 2 – the relationship of the percentage of particles with the size more than 1 mm in terms of grinded material as a function of the number of pulses; 3 – the relationship of the percentage of particles with the size less than 1 mm in terms of grinded material as a function of the number of pulses; 4 – total stored energy spent for the material grinding

The comparison of the curves 1, 2, and 3 shows that average specific energy inputs are equal to ~ 2.6 kJ/g. Subsequent pulse packets require on the average ~ 3.6 kJ/g.

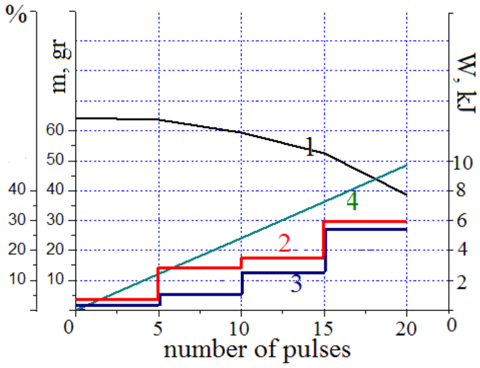


Fig. 7. Dynamics of the electrohydraulic pulse grinding of the specimens in the water, volume No 1:
1 – mass loss curve; 2 – the relationship of the percentage of particles with the size more than 1 mm in terms of grinded material as a function of the number of pulses; 3 – the relationship of the percentage of particles with the size less than 1 mm in terms of grinded material as a function of the number of pulses; 4 – total stored energy spent for the material grinding

The comparison of the amount of the glass mass obtained in the water with the amount of the rubber mass that was precrisped in liquid nitrogen and currently required for different technologies is of interest [4, 5].

It can be seen that the fractional yield with the size less than 1 mm is higher for the cases of the grinding of glass specimens considered in this scientific paper. The diagram shows the prevalence of fine grains for the electrohydraulic reactor design No 2 in comparison with No 1 in the case of rubber, after the packet of 25 pulses which corresponds to the total energy input of 15 kJ (Fig. 8).

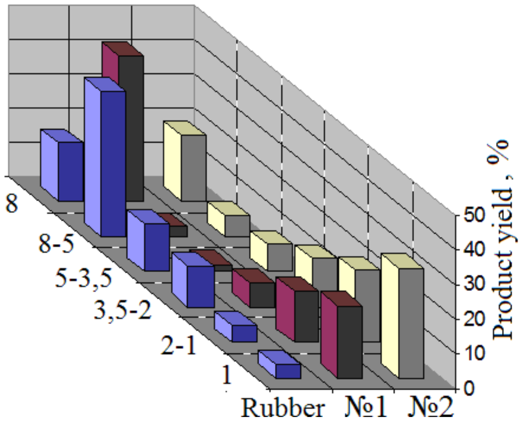


Fig. 8. The fraction distribution diagram of grinded glass specimens in the volumes No 1 and 2 and the rubber crumbs after 25 pulses

Output, kg/h	~ 18
Specific output, g/pulse	0.36…1.34
Particle size, mm	0.005…4
Liquid nitrogen consumption (rubber), l/kg	3
Power inputs for the electrohydraulic reactor , kW·hour	6
Discharge frequency, Hz	5

CONCLUSIONS

Microphotography patterns show that the electrohydraulic pulse method allows for the particle production of the materials that simulate the RAW of 10 µm, which should provide from our point of view an effective evaporation of fission products at a short-time heating of 1 to 10 s up to the temperature of 2000 °C. However, the search for new approaches to an increase in the efficiency of the electrohydraulic pulse method used for the grinding of the materials that simulate the solid RAW is required.

One of such approaches suggested in this scientific paper is the compact placing of the materials. A prerequisite for that is the placement of treated specimens near the spark channel with the possibility of motion to provide the collision of the specimens with each other and with the reactor wall. Two modes of the specimen grinding, in particular the cleavage and the crushing that sooner depend on the internal structure and the specimen composition then on treatment conditions have been established. The crushing turned out to be more efficient, because it provides a faster increase in the grinded mass. After some technological improvements we can assume that the electrohydraulic pulse method can be used as one of the options for the grinding of the solid RAW.

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ЭЛЕКТРОГИДРОИМПУЛЬСНОЕ ИЗМЕЛЬЧЕНИЕ МАТЕРИАЛОВ, МОДЕЛИРУЮЩИХ ТВЕРДЫЕ РАО

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Предложен способ измельчения материалов, моделирующих твердые РАО при помощи искровых разрядов в воде. Установлены два пути измельчения. Проведено сравнение потери массы измельчаемых материалов в зависимости от количества импульсов и размеров рабочего объема электрогидравлического реактора.

ЕЛЕКТРОГІДРОІМПУЛЬСНЕ ПОДРІБНЕННЯ МАТЕРІАЛІВ, ЩО МОДЕЛЮЮТЬ ТВЕРДІ РАВ

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Запропоновано спосіб подрібнення матеріалів, що моделюють тверді РАВ за допомогою іскрових розрядів у воді. Встановлено два шляхи подрібнення. Проведено порівняння втрати маси матеріалів, що подрібнюються в залежності від кількості імпульсів та розмірів робочого об’єму електрогідравличного реактора.