Influence of Density of Pyrotechnic Composition Samples (Ammonium Perchlorate + Superdispersed Aluminium) on Their Sensitivity under Action of Laser Pulse

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Abstract – Ignition of the pyrotechnic composition containing ammonium perchlorate + superdispersed aluminium, taken in a stochiometric ratio, by laser radiation with wave length of 1,06 μm and pulse duration of 4 ms is experimentally investigated in atmosphere of air. Factors of reflection, size of power thresholds and delays of ignition are measured at various densities of samples. Features of ignition and combustion of researched composition are considered.

1. Introduction

It is known, that radiation sensitivity of power materials depends on their density [1–4]. On the basis of pyrotechnic composition it is possible the creation of pyrocartridges and other means of ignition in which an initiating pulse is the laser pulse [5, 6]. Study of influence of density of pyrotechnic composition on power thresholds of ignition (PTI) therefore is of interest. Such works would allow optimizing of conditions of laser initiation of considered power materials.

Experimental methods

In this work in an atmosphere of air the ignition of mixture composition [ammonium perchlorate (AP) + superdispersed aluminium (SDA), taken in a stochiometric ratio] by laser radiation (LR) (λ = 1,06 microns) with a pulse duration $4\cdot10^{-3}$s was investigated experimentally. Preliminary the AP was reduced to powder in an agate mortar and it was sifted through a capron sieve with the average size of cells ~85×85 μm. The superdispersed powder of aluminium is obtained by electric explosion. Average diameter of particles made 0,25 μm, the form of particles was spherical, distribution of particles in the sizes submits to the normal – logarithmic law [7]. The sample with weight ~ 6 mg was filled up in a capsule from plexiglas with internal diameter 3 mm and depth 3 mm. Portion of powder with bulk density 0,27 g/cm^3 pressed by the piston in a capsule up to density no more than 0,82 g/cm^3. The whole of open face surface of samples was irradiated. Samples with density more than 1,27 g/cm^3 were made and tested in another way. Portion of powder with weight ~ 10 mg was filled up in a mold and pressed by the manual press up to the required density. Samples as tablets in diameter 4 mm turned out. The central part of a face surface of sample in diameter 3 mm was irradiated on a normal direction. Such change of a making technique of targets and a method of a laser irradiation is connected with the sample edges were pressed worse than the central part of sample that it could affect the measurement of PTI. As have shown preliminary experiments, reduction of diameter of an irradiation zone from 4 mm up to 3 mm does not result in change of PTI.

Radiation of neodymium laser generating quasi-rectangular and quasi-continuous pulse (depth of modulation no more than 30%) with duration 4 ms (multimoding generation) was used. Non-uniform light-striking of a face surface of sample irradiated on a normal direction has made no more than 20 %. The circuit of experimental set is resulted in work [8]. Transportation of LR from top to down was executed with the help of a rotational prism. The construction of pulse laser set and the form of a laser pulse are resulted in [9]. The magnitudes of PTI were determined by a technique described in [8]. In the beginning the probability charts of ignitions were plotted from 0 up to 100 % (P = quantity of ignition / quantity of experiments), as function P (E) from density of radiation energy E. A statistical set of 25 experiments was corresponded with every point of a chart at spread in indications of a calorimeter no more than 10 % from average value. Taking into account the character of probability chart the values of E_{50} were assumed the size of PTI at which ignition with probability P = 50 % was realized. In point E_{50} the small changes of E increment leads to the greatest change of P. Instead of a confidence interval which in these experiences has no clear a physical sense the probability ignition interval determined by cotangent (ctg α) of inclination angle of a tangent line to a probability curve in a point with ordinate P = 50 % was measured.

The reflection factors of samples on wave length of laser radiation were measured with the help of a integrating sphere photometer, more detailed measurement technique is resulted in [8]. Reflection factor was measured relative to an aluminium mirror.

3. Results and discussion

Results of studying are presented in the Table.

Table. The sizes of reflection factor R, thresholds *(E_{50})*, ignition delay of (τ_i) and ctg α at different of samples density ρ.

ρ, g/cm^3	R, a. u.	E_{50}, J/cm^2	τ_i, ms	ctgα, J/cm^2
0,28	0,12	1,16	4,0	0,27
0,54	0,12	1,16	4,0	0,27
0,82	0,15	1,43	4.0	0,27
1,27	0,26	3,2	3,5	0,45
1,4	0,30	4,5	3.0	0,6
1,64	0,43	6,5	2,5	0,9
1,9	0,56	7,9	1.8	0,9
2,1	0,65	16,1	1,5	1,8

According to the table the curve of dependences of size of an ignition threshold and reflection factor versus the samples density are plotted (Fig. 1). The samples silently flamed and burned out showing a flame in height more than 10 cm (Fig. 2).

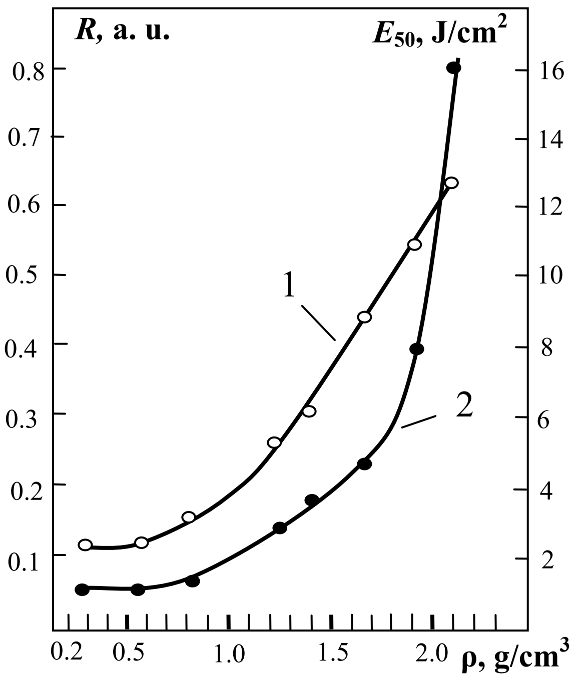

Fig. 1. Reflection factor *R* (curve 1) and ignition threshold of E_{50} (curve 2) versus the samples density ρ

In products of outburst the agglomerated particles of aluminium and aluminium oxide in diameter more than 0,1 mm were observed. For this purpose, on distance of 10 cm in parallel by a face plane of a sample the glass plate was located for precipitating of the particles. It was observed with the help of microscope MBS-9 (Fig. 3).

Fig. 1 shows that the curves 1 and 2 qualitatively coincide. Therefore it is possible to assume, that first of all the growth of ignition thresholds is connected to increase in reflection factor instead of with reduction of quantity and the size of pores in process of growth of samples density. The initial parts of curves indicates in favor of it (ρ from 0, 28 up to 0,54 g/cm^3) where the reflection factor and a ignition threshold E_{50} are constant. In this range of samples density the color of samples is dark grey. At ρ ≥ 0,82 g/cm^3 the metallic lustres appear on a face surface which quantity grows in process of increase in compacting pressure. At ρ = 1,27 g/cm^3 the surface becomes matte and has dark – silvery color. At ρ ≥ 1,64 g/cm^3 the surface becomes glossy and has bright silvery color. Apparently such metamorphosises are connected with forming a metallized superficial layer due to the aluminium is gathered near surface at growth of pressing. At a break of samples with ρ ≥ 1,64 g/cm^3 on a fracture the surface remained dark grey with fine specks of SDA. Apparently, with growth of pressure of pressing the metallized superficial layer becomes stronger. For the benefit of such assumption specifies more steep curve of E_{50} (ρ) versus *R* (ρ).

Fig. 2. Photo of a flame of a burning sample

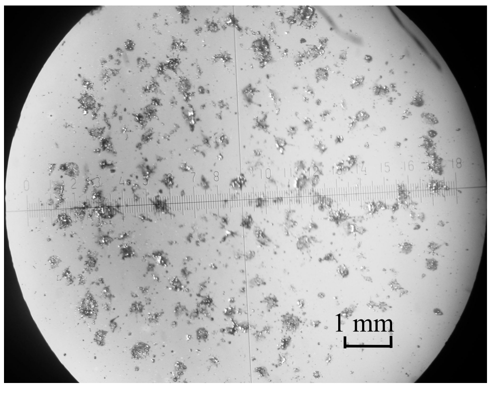

Fig. 3. Photomicrography of the precipitated particles

At energy densities close to thresholds the refusals are observed. At ρ from 0, 28 up to 0,82 g/cm^3 the surface visually did not change the color and structure. At ρ from 1, 27 up to 1,9 g/cm^3 the surface became matte, at a repeated of irradiation some decrease in thresholds was observed. At ρ = 2,1 g/cm^3 the metallized surface destroyed and the photodetector registered flash with a delay 1 – 2 ms and duration 8 – 20 ms. The irradiated zone had dark grey color and porous structure with metallized impurities (Fig. 4).

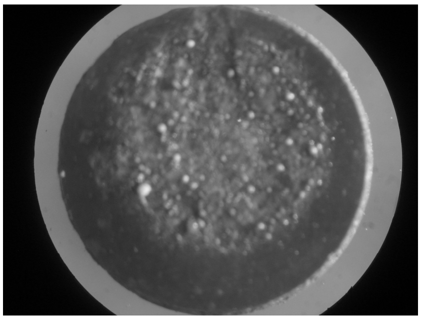

Fig. 4. Photo of an irradiation zone for samples with ρ = 2,1 g/cm^3 after laser pulse exposure with E = 15 J/cm^2

At a repeated of irradiation the ignition threshold was reduced approximately twice. Similar decrease in thresholds was observed at laser ignition of gunpowders by a millisecond laser pulse [8].

4. Conclusions

1. At increase in density of mixture composition (ammonium perchlorate + superdispersed aluminium) the thresholds of laser ignition grow that is connected with increase in reflection factor of a samples surface.
2. In a range of density from 1,27 up to 2.1 g/cm^3 the ignition thresholds are reduced after an irradiation by laser pulses with prethresholds of energy densities.

Acknowledgement

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