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AN AXISYMMETRIC EXPLOSIVE ACCELERATOR WITH A CONICAL RECESS FILLED WITH POWDER

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Results of a numerical analysis of the main stages of development of a powder flux formed by a cylindrical explosive accelerator with a coaxial conical recess in the lower part, which is filled with the powder, are presented. The theoretical data are directly compared with experimental data obtained by the methods of pulsed x-ray photography.

Investigations of processes related to detonation deposition of coatings and superdeep penetration [1, 2] have raised interest in the study of the parameters and regularities of formation of powder fluxes by explosive charges. In the present work we analyze the development of the flow of a powder jet generated by an axisymmetric explosive accelerator with a conical recess in the lower part (Fig. 1). A numerical calculation of the acceleration process was performed using the computational scheme of the method of large particles [3, 4] with a uniform grid under the condition that there is no flow [3] on the axis of symmetry (on the remaining free surfaces of the scheme, the conditions of flow into a vacuum were used). The calculation scheme is a Windows modification of the program used in [5]. The equation of state of the powder (TiCN) was specified in the Tait form [6], while the equation of state of the explosive (trinitrotoluene) was specified in the form proposed in [7]. The results of the calculation were compared with data of pulsed x-ray photography (Fig. 2). Today's computers make it possible to perform this comparison in the most illustrative way. The images on the photographs (Fig. 2) were rectified, fitted with a grid, and converted to adequate contour patterns (on them, the contours of the flow formed are marked by a heavy solid line). Isolines of density (Fig. 3) and longitudinal velocity (Fig. 4) calculated on the basis of the above-mentioned difference scheme and plotted in the same scale and for the same time intervals were directly superimposed on the experimental contours obtained.

In Fig. 3a, calculated density isolines (a scale of 1 : 1) obtained at t = 10 and 30 μsec are superimposed on experimental contours of the powder flux (heavy line). It is seen from Fig. 3a, where good agreement between the theoretical and experimental data is exhibited, that the acceleration process begins with formation of a high-speed gas-powder jet. Its velocity at 30 μsec can be determined by the computational procedure as 0.2 (~1600 m/sec in terms of the dimensional quantity) (Fig. 4a). The experimentally determined value falls within the range of 1000–1500 m/sec (everywhere hereinafter, the values D = 8000 m/sec and ρ_0 = 1000 kg/m^3 are taken as the unit of measurement of velocity and density). The marker that corresponds to 10 μsec indicates that the formation of the high-speed jet is preceded by axisymmetric compression of the recess filled with the powder with indications of initiation of a high-speed axial flow (the initial velocity is 700–800 m/sec). The process of formation of the flow is just beginning.

In Fig. 3b, calculated density and velocity isolines are superimposed on experimentally determined contours of the recorded position of the jet at t = 50 μsec. A certain advance shown by the calculated parameters should be attributed to dissipative processes that were not taken into account in the modeling (internal friction, blowing of a gas through the powder, and so on). Otherwise the numerical and experimental patterns of the flow correspond to each other. The development of the flux leads to elongation of both the high-speed (jet) and slow (pestle) parts of the flow. Here, judging from Fig. 4b, the velocity of the jet remains equal to 0.2

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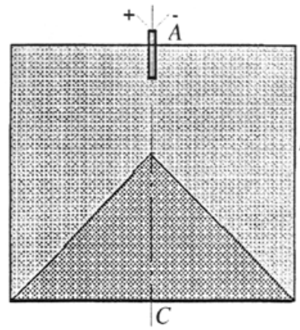

Fig. 1. Schematic of an explosive accelerator of powder particles with a conical recess: A) electrodetonator; B) explosive charge; C) conical recess filled with powder.

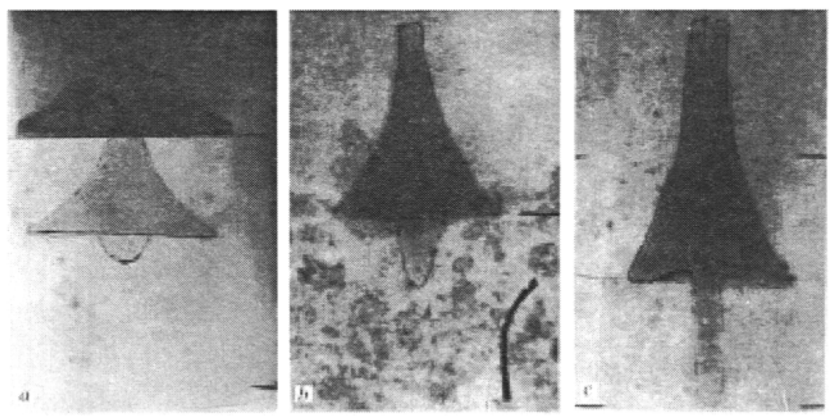

Fig. 2. Development of a particle flux (pulsed x-ray photography): a) 10 and 30 μsec; b) 50 μsec; c) 90 μsec.

(~1600 m/sec) as before, while the velocity of the pestle amounts to ~0.05 (~400 m/sec). The velocity of the main mass of the material turns out to be equal to ~0.1 (~800 m/sec). The experimental data are in good agreement with the theoretical ones: the jet velocity is ~1550 m/sec, the pestle velocity is 350–450 m/sec, and the main-mass velocity is 1100–1200 m/sec.

Figure 3c shows the superposition of calculated density isolines on an experimentally obtained contour at a moment when the development of the flow is predominantly determined by the inertia and the velocity gradient along the flow causes significant elongation. The calculation gives the following velocities of the principal parts of the flow: 1200–1400 m/sec for the jet, 400–500 m/sec for the pestle, and 900–1000 m/sec for the main part (Fig. 4c). The experimentally determined values are as follows: ~1125 m/sec, ~410 m/sec, and ~715 m/sec for the jet, pestle, and main part, respectively.

Thus, based on a comparison of the calculated data with the experimental ones, it can be inferred that the development of the flow in the acceleration of the flux by an axisymmetric explosive accerator of the type shown in Fig. 1 occurs in three main steps:

1) formation of a high-speed dense jet of the working material of a relatively small diameter (up to 10 mm with an initial diameter of 40 mm and a recess height of 20 mm in the scheme used in the experiment) containing approximately 10–12% of all the working material placed in the conical recess;

2) formation of a flux consisting of three component parts: a high-speed jet (7–8 mm in diameter and 10–12 mm in length, containing up to 11% of all the material), a slow pestle (up to 7–12 mm in diameter and 23–25 mm in length, containing about 27% of all the material), and the main mass of the material (up to 35 mm in diameter and ~15 mm in length, containing 62% of all the material) moving with a velocity intermediate to the above two velocities;

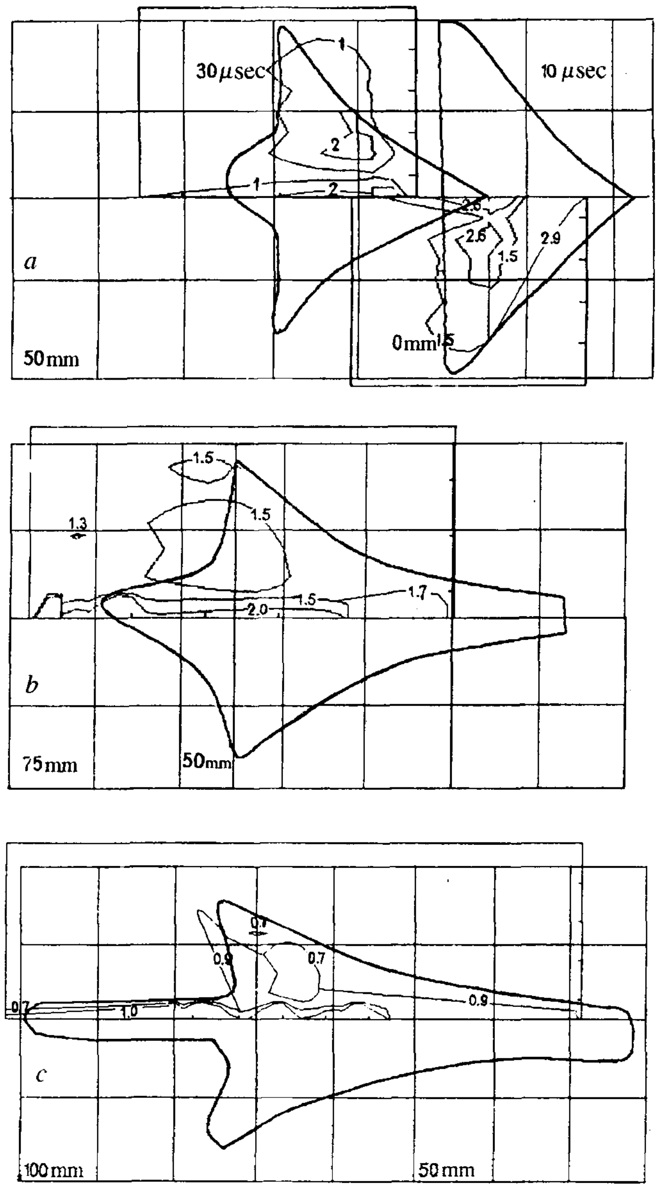

Fig. 3. Calculated flux-density isolines superimposed on experimental contours of the flow: a-c) the same as in Fig. 2.

3) inertial motion where the development of the flow is determined only by the velocity gradient along the flux, the jet length increases to 25 mm as the diameter decreases to 5 mm (the total content of the material remains practically constant – 10%), the diameter of the pestle changes slightly (10–15 mm) although its length increases to 30 mm (it corresponds to 33% of the entire volume), and the length of the main mass of the flux increases to 25 mm with a simultaneous decrease in the diameter to 20–30 mm (~ 57% of the entire volume).

In features of the development and in general appearance, the formation of the flux is very similar to the processes of formation of cumulative jets [8]. The resulting flow contains all the classical elements that are characteristic of cumulation (jet, pestle, and main mass, sometimes called the funnel).

All the experimental data were obtained on equipment of the branch of the Institute of Chemical Physics in Chernogolovka. The authors express their gratitude to A. N. Mikhailov for active and direct participation in the experiment.

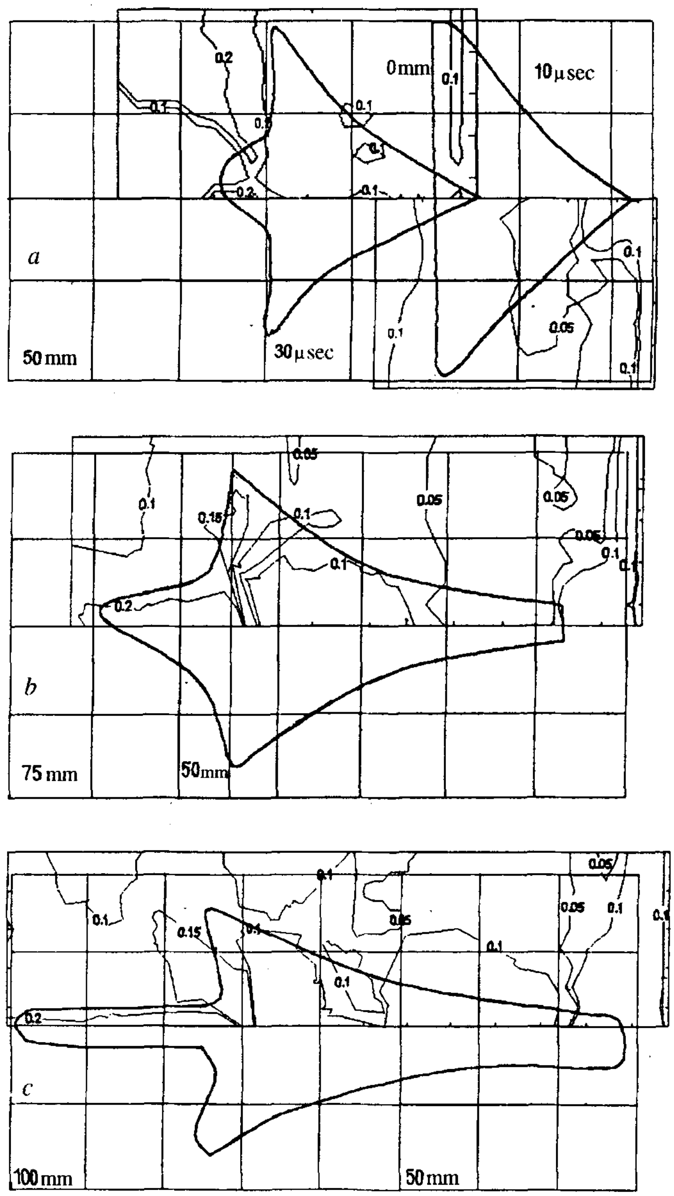

Fig. 4. Calculated flux-velocity isolines superimposed on an experimental contour of the flow: a-c) the same as in Fig. 2.

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