ASSESSMENT OF THROWING CAPABILITY OF DESENSITIZED HIGH EXPLOSIVES

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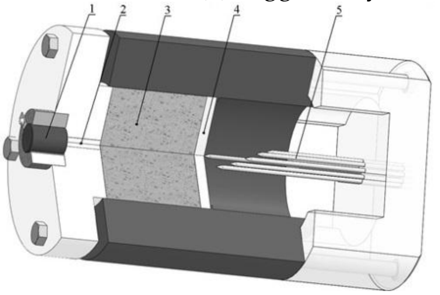
The experimental setup that uses different explosive materials to accelerate flyers is widely accepted for assessing the energy parameters of explosives, as well as for obtaining the data needed for numerical simulation of detonation. So, numerical simulation needs the equation of state of explosion products, which, together with the Jouget parameters, determines the explosion-products-expansion isentrope going through the Jouget point. The isentrope of explosion products expansion determines initial parameters of a shock wave and also the work done by the expanding explosion products. And this determines propellant action of explosives.

The goal of this effort is the experimental-and-computational study of the process when a steel plate is accelerated by a charge of a phlegmatized RDX-based explosive with the ~10% content of the inert phase. Experiments used the M-60 technique to study the flyer acceleration process as this method is traditionally used to estimate the propellant action of explosives. GRAD software system [1] was used for calculations by the model that takes into account kinetics of explosion products from the test HE [2,3].

According to the M-60 technique [4], the electrical contact pins are used to record velocity of the (∅60×5) mm steel plate made from the 12Kh18N10T stainless steel, which is accelerated by a (∅60×50) mm cylindrical HE sample. In addition to the electrical contact technique, this effort also used the "noninvasive" radio-wave technique.

In three experiments, we used the radio-wave technique and in five experiments – the electrical contact technique of registration.

Figure 1 shows the experimental setup wherein the electrical contact pins (5) recorded parameters of the flyer movement (4) according to the M-60 technique. The test HE sample (3) was initiated by the (∅5×17) mm plasticized HE rod (2) triggered by an electric detonator (1).



1 Electric detonator
2 HE rod, (∅5×17) mm
3 HE sample, (∅60×50) mm
4 Steel flyer, (∅60×5) mm
5 System of electric contact pins

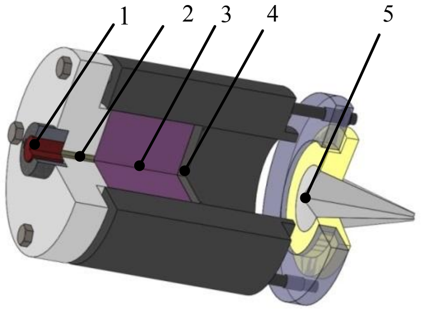
Figure 1. Schematic experimental assembly with electric contact pins according to the M-60 technique

The HE charge is placed inside a thick-walled metal body to reduce the effect of side release waves. The steel plate driven by the expanding explosion products alternatively closes spaced electrical contact pins and as a result, we obtain the *x-t* diagram of flyer movement.

The system of electrical contact pins has the following drawbacks [5]:

- Continuous registration of the flyer acceleration within the entire measurement range is impossible;
- The recording system impacts the flyer movement process.

The use of the radio-wave technique to record the flyer movement process eliminates the above drawbacks. In order to record the flyer movement, the radio interferometer with the 3-mm wavelength of the probing radiation was used in this work. The schematic experimental setup is given in figure 2.



1 Electric detonator
2 HE rod, (∅5×17) mm
3 HE sample, (∅60×50) mm
4 Steel flyer, (∅60×5) mm
5 Aerial of radio interferometer

Figure 2. Schematic experimental assembly with the radio interferometer according to the M-60 technique

A conical irradiator was specially designed for this assembly to serve as the irradiator in the antenna-feeder path of the interferometer. In the experiment, the irradiator is positioned at the distance of 70 mm from the flyer and the informative basis of the plate flight is about 60 mm.

The areal is responsible for the wave beam focusing needed to record the flyer movement. A drawback of the radio interferometric method is a rather large area of the flyer surface whereat the wave beam is recording flyer's movement compared to the area of the surface whereat recording is performed with the help of the electrical contact pins. Actually, probing is performed (though with power distribution being different) over the whole flyer surface and this, taking into account two-dimensionality of this experimental setup, can have an impact on the accuracy of velocity registration.

A special software system helped to process results given by the radio-wave technique. We determined the *V-t* and *V-X* relationships that describe the flyer movement in time and in space.

In Figures 3 and 4, red line shows the typical *V-t*, *V-X* diagrams of the free surface movement. These diagrams are the result of radio-interferometric measurements. For comparison, the diagrams have experimental points given by five experiments with the use of electrical contact method of registration.

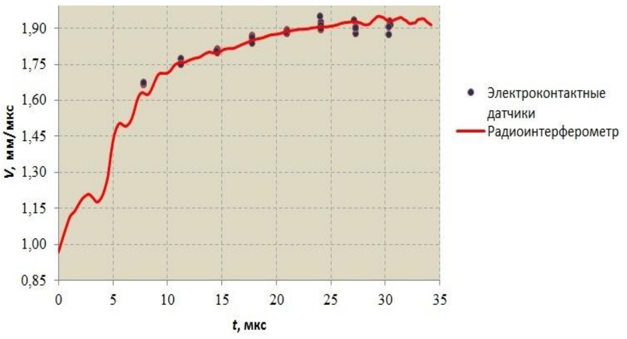


Figure 3. *V-t* diagram for the movement of the flyer accelerated RDX-based HE explosion products

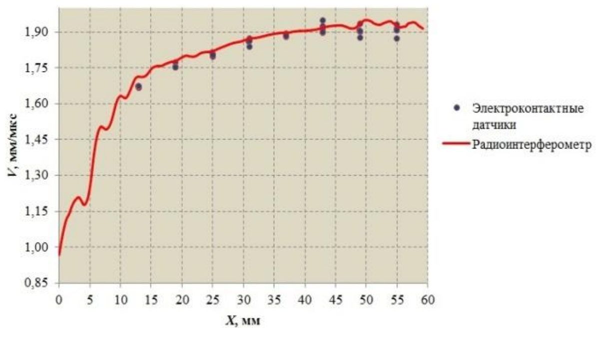


Figure 4. *V-X* diagram for the movement of the flyer accelerated RDX-based HE explosion products

The recorded diagrams demonstrate good agreement between experimental data given by two methods, though the radio-wave data are more informative. The radio interferometric readings in Figure 4 also demonstrate that at the up to 15 mm flight base, flyer acceleration is of stepped nature due to circulation of shock waves in the flyer. At the base light of 20-45 mm, where the moving velocity is smoothly increasing, readings of electrical contact pins are in good agreement with the radio-interferometric measurement data (velocity values practically coincide). However, at the more than 45 mm flight base, readings of electric contact pins demonstrate a tendency towards decrease in the flyer velocity, probably, due to flyer deceleration against pins. Velocity oscillations observed at the more than 52 mm flight base are likely to be due to fly-out of the plate from the body of the experimental assembly.

Figure 5 shows the initial calculated setup of the numerically simulated experiment wherein the flyer is accelerated according to the M-60 technique.

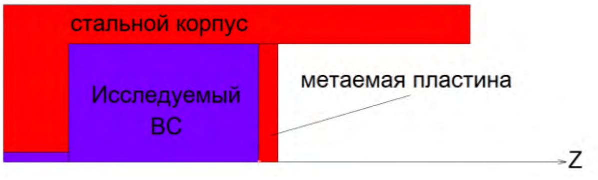


Figure 5. Initial calculated setup of the numerically simulated experiment

Detonation of the test HE was simulated with the help of the model [2,3] that considers kinetics in explosion products. Simulation of the experiment in the setup according to the M-60 technique took into account the following:

1. The gasdynamic flow is tangibly two-dimensional. The flow process demonstrates a complicated pattern of interaction between the detonation wave and shock waves reflected from the body.

2. Account must be taken of spallation and body expansion in order to have a correct description of the experimental data.

For the steel body, we used the Mie-Gruneisen equation of state with the following parameters

$\rho_0 = 7{,}8$ г/см^3, $C_0 = 4{,}266$ км/с, $n = 4$, $\gamma = 2{,}333$, $\sigma_{отк} = -4$

The tabular equation of state of the material was used to model the flyer made of stainless 12Kh18N10T steel and the instantaneous spallation model was used to simulate spallation.

For the elastic-plastic properties of the body and the flyer to be taken into account, the GRAD software system used the Wilkins model wherein the yield stress is the function of pressure and thermal energy:

$$Y = min\left\{(Y_0 + Y_1 \cdot P)\left(1 - \frac{E_t}{E_{pl}}\right)^{At}, Y_{max}\right\}, \quad (1)$$

where Y_0, Y_1, Y_{max}, E_{pl}, and A_t – are constants.

Parameters of the elastic-plastic model are given in Table 1. The 0.2 x 0.2 mm computational grid was used for simulation.

Table 1. Parameters of the elastic-plastic model for the body and flyer in the GRAD software system

υ	*Y0, GPa*	*Y_1*	*Y_{max} ,GPa*	*At*	*E_{PL} ,kJ/г*	*σ_{kp}, GPa*
0.28	0.45	1.0	1.5	0	0.277	4.0

Figure 6 shows evolution of the gasdynamic flow in the simulated experiment at different times from the instant of initiation onset. Coloring is according to the pressure scale (GPa).

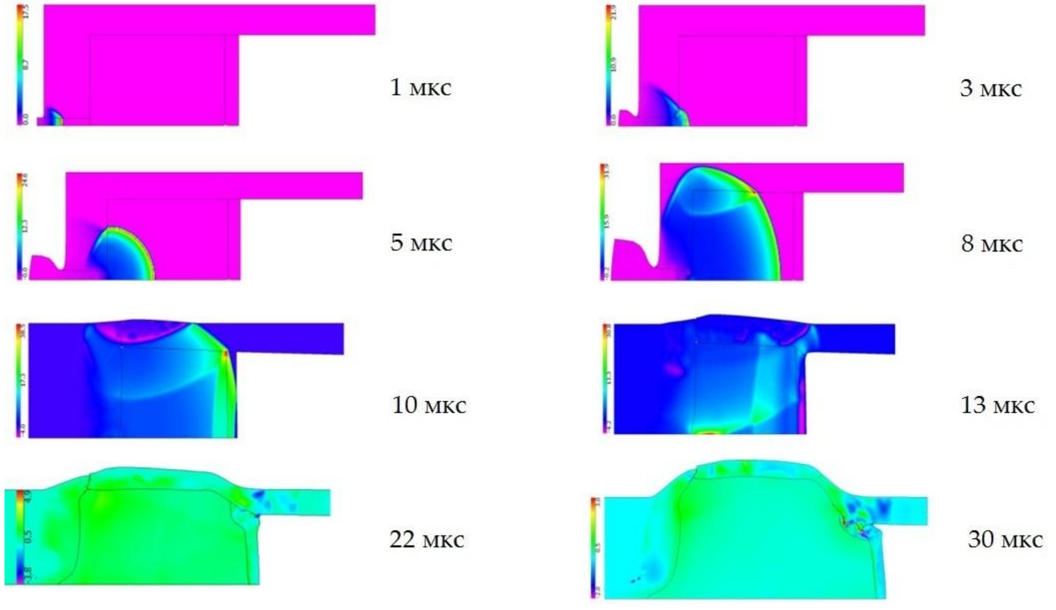


Figure 6. Evolution of gasdynamic flow at different instants of time

Figure 7 presents spallation of the body and closure of spalls. Coloring is according to the density scale (g/cm^3).

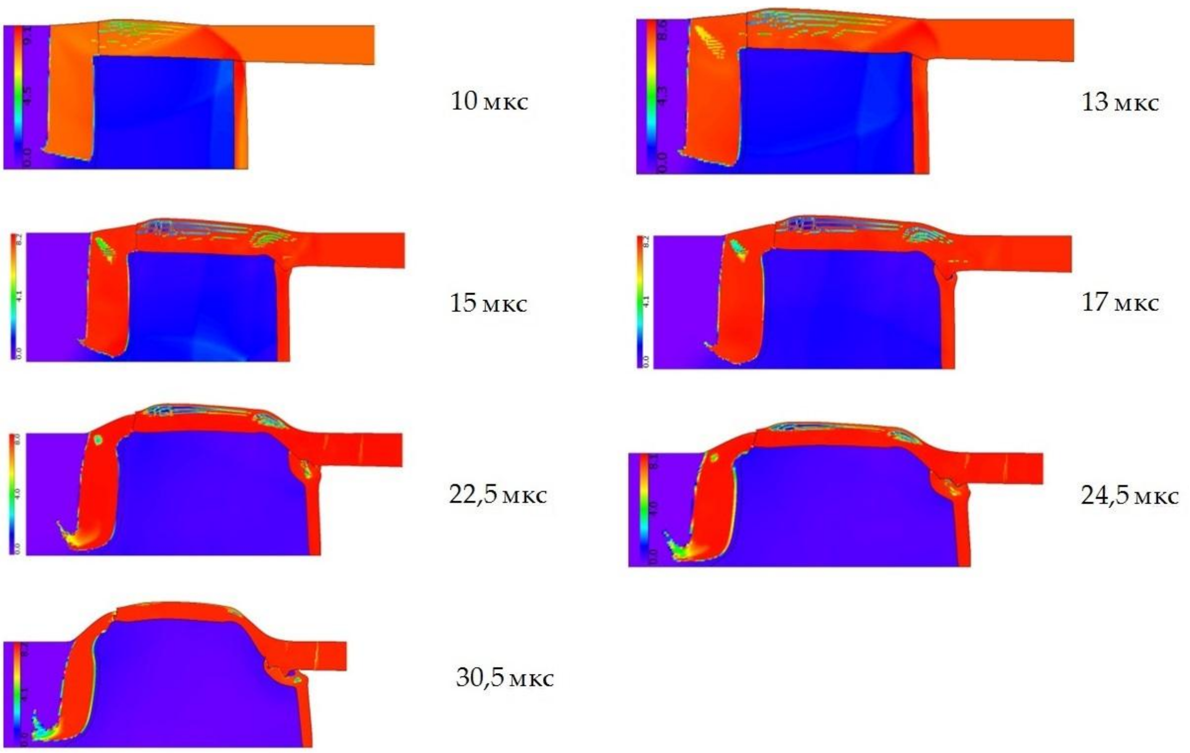


Figure 7. Spallation of the body and closure of spalls

Figures 8 and 9 show plotted computational and experimental relationships "flyer velocity (*V*) versus time (*t*) " and "flyer velocity (*V*) versus coordinate (*X*)".

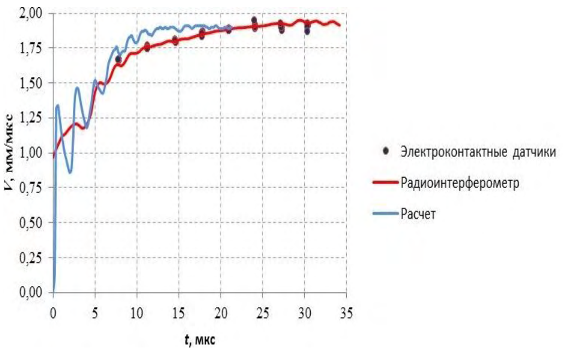


Figure 8. Flyer velocity versus time

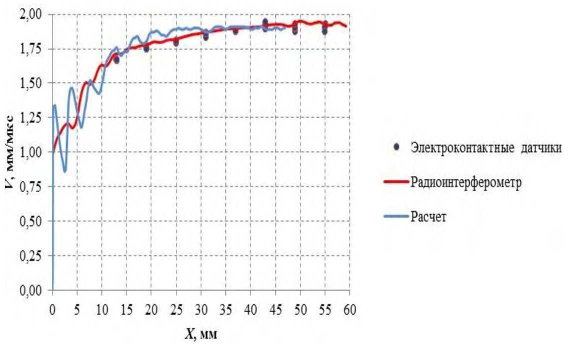


Figure 9. Flyer velocity versus coordinate

The above diagrams of the flyer velocity demonstrate good qualitative agreement between the computational and experimental data. However, discrepancy in computed and experimental time and amplitude of flyer velocity oscillations is also noted. Apparently this is associated with the «averaging» of these parameters in the case of radio-wave recording because of a large probing area in this tangibly two-dimensional setup.

Conclusions

Good agreement between the calculated and experimental data suggests that the phlegmatized HE detonation model is correct. Calculations give flyer velocity oscillations induced by the shock wave reflection in the plate itself and these oscillations are the same as in the experiment. Certain discrepancies in the calculated and experimental flyer velocity can be due to inadequate choice of the equation of state for the flyer material.

More correct simulation of spallation processes requires updated models capable to consider kinetics of both spallation and compaction.

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