ACCELERATION OF FRAGMENTS FROM CYLINDRICAL SHELLS BY DETONATION PRODUCTS OF HE CHARGES

E.F. Gryaznov[1], S.I. Voronkov[2], V.N. Okhitin[1], A.I. Sporykhin[2]

[1] *Bauman Moscow State Technical University, Russia, 105005, Moscow, 2-nd Baumanskaya Str., 5.*
[2] *FGUP Scientific-Research Institute of Applied Chemistry (NIIPKh), Russia, 141300, Sergijev Posad, Silina Str, 3*

The paper dwells upon the study of behavior of fragments of steel cylindrical shells loaded by detonation products.
From the modern viewpoint a shell is accelerated by products of explosion to its breakup, and the maximum velocity of fragments is the velocity of shell at breakup. The behavior of fragments in the cloud of detonation products has not been practically studied.
In order to measure the velocity of the shell and its fragments at the distance to 2…3 m one proposed a simple and reliable method with the help two types of electric-contact sensors: nail-type sensors to measure the velocity of the shell, and plane sensors to measure the velocity of fragments.
Tests have been done on steel shells and two types of explosives: phlegmatized RDX and very phlegmatized RDX with aluminum.
Test show, when using phlegmatized RDX the maximum velocity of fragments is achieved at the distance to $r \approx 10r_0$ (r_0 is the initial radius of the shell), and when using metallized explosive (RDX with aluminum) at the distance to $r \approx 30r_0$.

INTRODUCTION

At explosion of charges, confined by metal shells, a number of fragments are formed, which are accelerated by the detonation products with velocity from some hundreds to some thousands meters per second.

Air drag, acting on the fragments, causes the decrease of velocity of fragments, thus, the change of velocity is described by the formula

$$V = V_0 e^{-Ax}, \qquad (1)$$

where x is the distance, A is the ballistic coefficient, and V_0 is the initial velocity of the fragment.

The velocity, which the shell has at the moment of separation into single fragments, is usually taken as the initial velocity.

Approximately the initial velocity of the fragments V_0 can be asses using Pokrovsky-Garni formula. More accurate value V_0 can be assessed from tests. In laboratory conditions when testing relatively small shells in order to measure V_0 one uses either high-speed optical filming, or multiple impulse X-raying. Shells of greater sizes, containing considerable explosive charge are usually exploded in the open places, equipped with thin metal screens-targets. When fragments perforate the targets, the optical filming records the moment of perforation. In such tests the average value of fragment velocity is measured for the distance from the explosion point to the targets, then using formula (1) one calculates the value V_0.

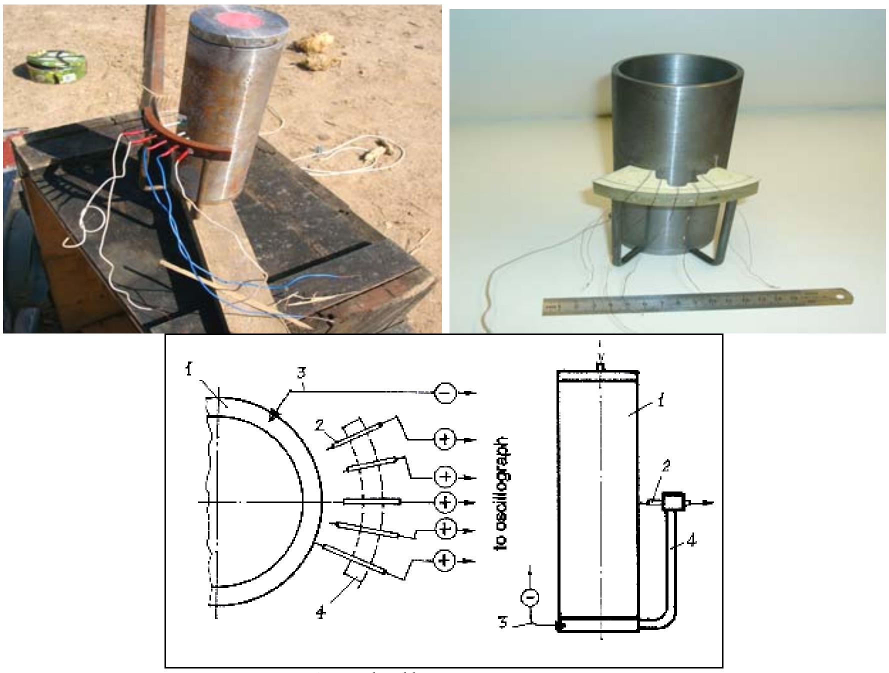
The shields-targets are installed at the distance $x \geq 100r_0$ for these tests. The distance of the shell collapse (destruction) is $r_f \approx (1.3...1.7)r_0$. The behavior of the fragments at the distance $r_f < x < 100r_0$, i.e. in the near explosion zone was not been studied.

METHOD OF MEASUREMENT

In order to test the behavior of fragments in the near explosion zone, described in the paper, the known method to measure velocity of bodies using contact sensors has been used; velocity of both of the shell itself, and separate fragments has been measured.

At the stage of shell expansion (to $\approx 1.5r_0$) pin-like sensors were used as a whole block at the center of the shell, as shown in Fig. 1. On the shell 1 at the center along the axis the contacts 2 of the sensors are located at different distances from the surface, at that one of the contacts (number zero) contacts with the shell through an insulating lining (thickness of ~0.01 mm). Contact 3 is set on the shell itself at its base. Voltage is applied to contacts 2 and 3. When the shell is expanding, the contacts 2 are closed in series, and the moments of contact closure are recorded using the oscillograph.

In order to measure the velocity of fragments one uses plane electro-contact sensors, which are actuated when the measurement circuit is completed by the fragments. The electric contacts of the sensors are located on a massive plate (Figure 2) and are protected from detonation products by a shield. The sensors are located at



1 – shell;
2 – contacts "+" of sensors;
3 – contacts "–" of sensors;
4 – unit of attachment of contacts

Figure 1. Shells with contact sensors and geometry of installation

different distances at the equatorial plane of the shell center perpendicular to the shell axis, taking into account the declination of fragment trajectories. In order to prevent the sensors from displacement by a shock wave and detonation products the plane sensors are located on massive props. The moments of closure of the electric contacts of the plane sensors are recorded using an oscillograph.

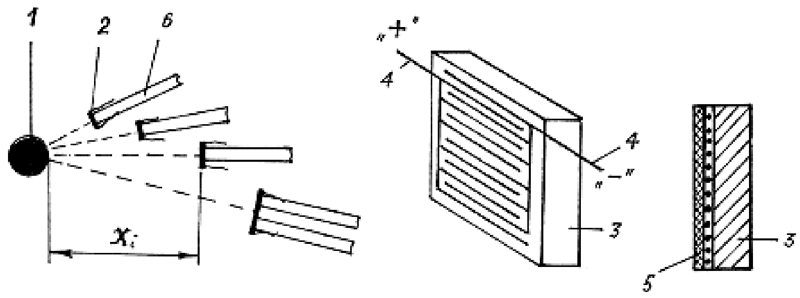
Thus, the velocity, assessed using the presented method, is

$$V_i = \frac{x_i - x_{i-1}}{\tau}$$

where x_i, x_{i-1} – are distances of i-th and ($i-1$)-the contacts,

τ – time interval.

The obtained values of V_i allow to see the acceleration of the shell and fragments, i.e. to obtain the function $V_i(t)$ or $V_i(x)$, at that the increase of the number of contact sensors increases the accuracy of functions $V_i(t)$ and $V_i(x)$. In practice the number of sensors is limited, usually, by the capabilities of the



a *b*

(*a* – sensor installation; *b* – sensor design)
1 – shell
2 – plane sensor
3 – plate
4 – electric contacts
5 – protective shield
6 – prop

Figure 2. Geometry for measuring velocities using plane sensors.

measuring equipment. In the study the number of simultaneously used sensors was to ten for different types.

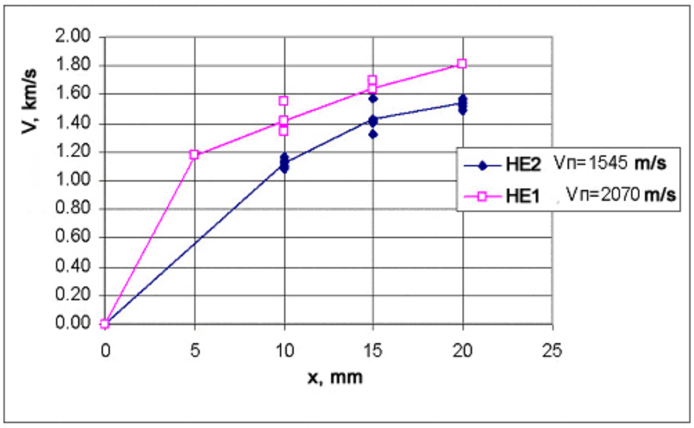
The measuring equipment used in the study, has the following parameters:

- voltage of source of current is from 3 to 80 V;
- oscillographs of type “Tektronix” are used to record the moment of contact closure with time resolution 0.01…0.05 microseconds;
- accurate measurement of distances of the sensors are made just before explosion; special nonius measuring device is used for pin-like sensors with accuracy ± 0.01 mm, and for plane sensors the measuring accuracy is ± 0.5 mm.
- early estimation of the accuracy of the method shows, the mean-square error for measuring the velocity of the leading fragments doesn’t exceed 3.5%.

TEST RESULTS

The described method has been used when testing a number of steel cylinders with internal diameter of 60…120 mm and relative thickness of the wall $\bar{\delta}_0$=0.03..0.1 ($\bar{\delta}_0 = \delta_0 / D_0$, where δ_0 – is the wall thickness, D_0 – is the external diameter). The comparative tests have been conducted for two types of explosives: HE1 – phlegmatized RDX (density 1.64 g/cm^3, detonation speed 8300 m/s) and HE2 – very phlegmatized RDX with additive of 20% aluminum (density 1.62 g/cm^3, detonation speed 6000 m/s).

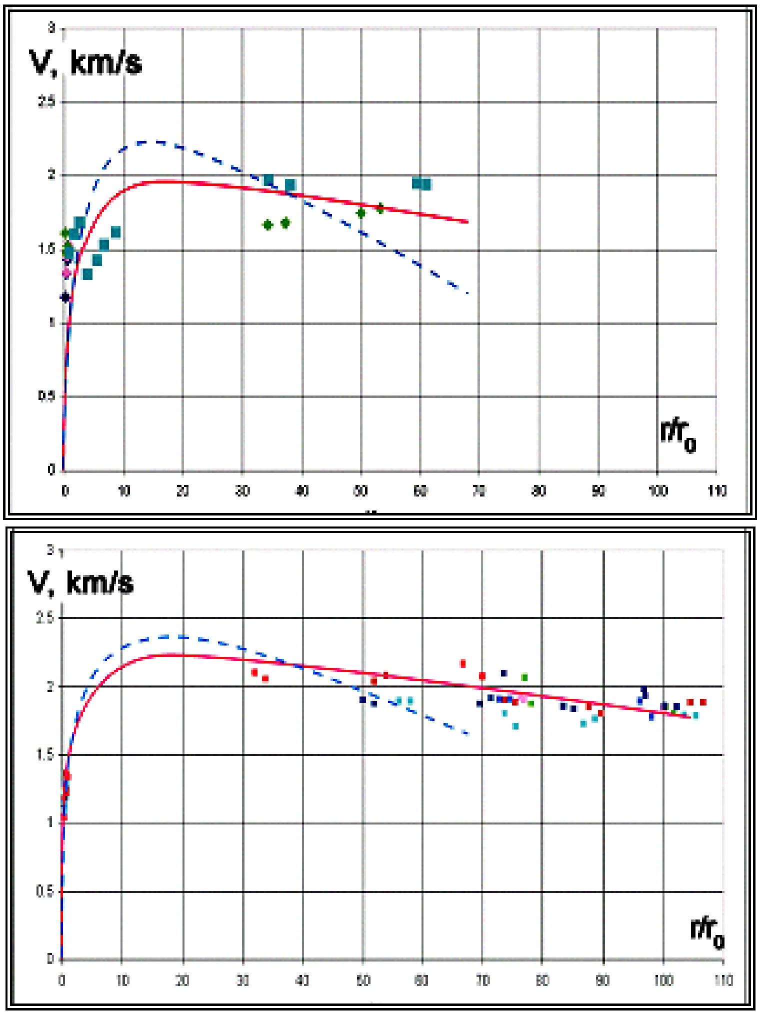
The reliable functions $V_i(t)$ and $V_i(x)$ have been obtained as a results of test studies; the formulas have just the same qualitative form in all tests. As an example, Figure 3 shows the results of measurements of shell velocity using the pin-like sensors at the radius increase in ~ 1.6 times. As Figure 3 shows, the use of the pin-like sensors allow to see the acceleration of the shell, and just all the results of measurements are very stable. The obvious fact is that at *x*=20 mm the maximum velocity is not achieved. Figure 3 shows the more powerful HE1 gives higher velocities (~15%) in comparison with HE2, that is connected with higher level of detonation characteristics of HE1.



External diameter is 60 mm, wall thickness is 4 mm
Figure 3. Velocity growth in shell acceleration zone

The test results on the fragment velocity of the same steel cylinders are shown in Figure 4. One should note the data on the fragment velocity differ in some greater dispersion in comparison with the data on velocity of shells, that in turn called for more tests and corresponding statistical processing.

The main feature of the obtained results is that the maximum level of the fragment velocity, accelerated by low-brisant composition HE2 is approximately equal, and in some tests exceeds the corresponding level of fragments in tests on high-brisant explosive HE1. The increase of the wall thickness increases the maximum fragment velocity in obviously higher: approximately 15…20% in comparison with HE1.



HE1

HE2

Figure 4. Velocity of fragments versus reduced distance (r/r_0)

The analysis of the results allows making one more important conclusion: the maximum values of the fragment velocity is achieved not at the stage of the shell expansion, but considerably later and at distances, considerably exceeding the shell collapse (breakup) radius. For high-brisant HE1 the distance is about $10\,r_0$, and for low-brisant HE2 it is about $(20\ldots30)\,r_0$, at that the maximum velocity of the fragments in comparison with the measured velocity of the shell grows approximately in 10% 10% for HE1 and (25…40)% for HE2.

The reason of additional acceleration of fragments is, apparently, connected with ram of detonation products and their viscous friction when flowing around the fragments (Figure 5).

For HE2, when the detonation products are the most dense due to non-reacted aluminum particles, the effect, noted above, is more visible.

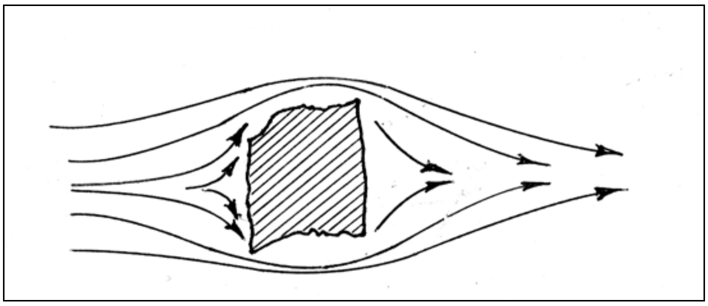


Figure 5. Detonation products flowing around fragment

The comparison of the obtained test data with the calculation results of projection velocity using Pokrovsky-Garni formula V_P (the values V_P are presented in Figure 3) shows the acceptable accuracy of Pokrovski-Garni formula (or other similar ones) to asses velocity of a shell, filled with explosive like HE1 (difference between calculated and test data doesn't exceed 10%). For shells, filled with explosive with aluminum, Pokrovsky-Garni formula underestimates the velocity V_0 (to 40%).