# MODELLING THE PROCESS OF FORMING THE INITIAL KINEMATIC PARAMETERS OF THE FRAGMENTATION FIELD

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***Abstract:*** *A quasi two-dimensional mathematical model describing the process of forming the initial kinematic parameters of the fragmentation field was developed. It has been shown that the use of the continuous explosive initiation system allows for increasing the relative area of the target damage with up to 23% with varying degrees of damage.*

**Keywords**: FRAGMENTATION WARHEAD, INITIAL KINEMATIC PARAMETERS OF FRAGMENTATION FIELD, IMPACT-WAVE PICTURE

## *Introduction*

The theory of the destruction and ejection of plates under the impact of explosive detonation products (DP) at the present is a separate section within the physics of the explosion, which is often used as explosive ballistics. As a result of the development of experimental techniques and the widespread application of non-standard methods of gas dynamics, dynamic plasticity, solid state physics and fracture theory, theoretical and experimental material on this issue has been accumulated and a great number of research and scientific papers have been published.

One of directions for the improvement of the fragmentation warhead of different purpose ammunitions is increasing the efficiency at the expense of the predetermined distribution of the fragments field within the area of action.

In practice, during the phase of design and impact analysis of the fragmentation ammunitions explosive devices, the first step is solving the problem of determining the initial kinematics parameters of the fragmentation field.

## *Development of a mathematical model for determining the initial kinematic parameters of the fragmentation field*

Within the above framework, all tasks can be provisionally divided into complex of items connected to: one-dimensional movement of the body under the impact of DP [1]; two-dimensional movement of the body under the impact of DP [1].

When developing one-dimensional models, the following are generally used:

- assumption of instantaneous detonation of the explosive;
- the energetic, kinematic approach of Gorni-Staniukovic-Pokrovsky;
- various proposals for the mechanism of distribution of the explosive mass in the direction of scattering - the concept of active masses.

As the analysis of one-dimensional body motion models shows, the one-dimensional radial solutions give the law of movement and the kinetic velocity of infinitely long charges. It is definitely impossible to proceed with charges of a certain length within the one-dimensional task.

On the other hand, the two-dimensional solution of the task allows to adequately determine the process of the body dynamic loading, but the model under consideration is rather complex and its application at the stage of ammunition experimental design, when it is necessary to compare a large number of design variants of technical solutions, is problematic.

In this regard, development of methods for calculating and determining the direction of the fragments velocity along the body in a quasi two-dimensional setting, based on the flat sections method, is relevant. It is appropriate to present the process of accelerating the body in two phases:

- wave stage (impact acceleration), depending only on the properties of the explosive, the metal, the body configuration and the means for initiating the explosive;

- ballistic stage, defining the configuration of the bursting charge, the properties of the explosive and the body structural characteristics.

The following assumptions are made during developing the model for the movement of an axis-symmetrical elastic-plastic body:

- The fragments scattering is taking place within the framework of the flat sections hypothesis, i.e. the axis coordinate of the section is not changed during the acceleration process;
- The pressure acting on the body is defined as a multiplicative function of pressure at axial and radial scattering of DP;
- The entropy index of the DP is assumed to be equal to 3 [2];
- The DP pressure is averaged over the cross section and the mass velocity of the DP flow is proportional to the radius;
- The process of scattering the parts of the body is considered in a two-stage approximation: the first stage of the body acceleration occurs under the action of the shock wave and the unloading wave (UV), and in the second stage - under the action of expanding DP.

These assumptions are widely used in the course of developing various models at ejecting metal plates by the DP and their relevance is proven in the scientific labor of V.A. Odintsov, V.V. Silivanov, TG Statsenko and other authors [3, 4].

At the first stage, the parameters of the velocity field of various points under the impact of the falling shock wave and the UV will be determined.

An axis-symmetrical charge with mass of $M = \int_0^{h_3} m(x)dx$, radius $z_o$ and length $h$, on the side surface of which there is a throwing plate, part of the body with thickness $\delta(x)$ is considered. Generally, the initiation of the explosive charge can be continuous or discrete, which also determines the angle of the detonation wave approach to the body $\propto (x)$.

The parameters of the field of velocity in the first stage of the body acceleration under the action of the shock wave and the unloading wave will be determined. *Fig.1* shows an impact-wave pattern in the body in a mobile coordinate system associated with the point of intersection of the detonation wave (DW) and the body.

The assumption is made that after completing the first stage at the acceleration of the body elements remains unchanged, at the same time the body is unloaded to its initial state, i.e. the condition for velocity continuity of the forming flow and the flow after the transition by the shock wave front and the discharge wave is fulfilled $|\overline{q_1}| = |\overline{q_2}|$ . The following ratios are obtained from the shock-wave picture analysis:

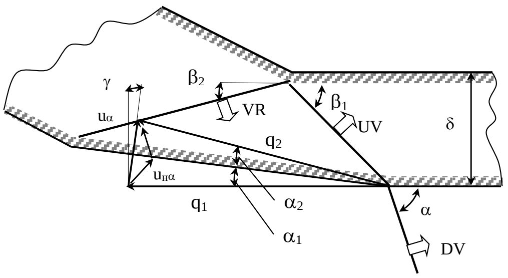


***Fig.1 .*** *Impact-wave picture in the body at the shock wave approach.*

$$\beta_1 = \arcsin \frac{C_0 + \lambda u_{H\propto}}{D} sin \propto$$

$$\beta_2 = \arcsin\,[C_0 + (\lambda - 1)u_{\propto}]\sqrt{1 + 2u_{\propto}\,\lambda / C_0}\;\frac{sin \propto}{D}$$

$$\gamma = \frac{\propto_1 + \propto_2}{2}\;; \quad u_{\propto} = 2u_{H\propto}\,\frac{\cos(\beta_1 - \propto_1)}{\sin(\propto_1)}\,\sin(\gamma)$$

where: $C_0, \lambda$ are constants of the shock adiabatic of the type $D = C_0, +\lambda u_x$; $u_{H\propto}$ - flow velocity in the body behind the shock wave front; $u_{\propto}$ - velocity of the body element after completing the shock-wave stage of acceleration; $\beta_1 \beta_2$- angles of the slope of the shock-wave and sound lines; $\propto_1 \propto_2$ - angles of flow divergence behind the shock wave front and the UW.

The following equations are used to determine the shock wave attenuation in the body material [5]:

$$p \approx p_0 \left(\frac{m_0^{'}}{M}\right)^{n_1};\; u \approx u_0 \left(\frac{m_0^{'}}{M}\right)^{n_1},$$

where: $M$ - mass of substances covered by the shock wave; $m_0^{'}$ - characteristic (active) mass of the explosive.

The nature of the shock wave waves depends on the choice of the characteristic (active) mass of the explosive $m_0^{'}$, which can be represented with a characteristic scale in mass Lagrange coordinates; a mass of the explosive charge which is not covered at the moment of the detonation wave exit at the boundary of „explosive-body“ contact can be chosen for $m_0^{'}$. Then:

$$M = m_0^{'} \int_{z_1}^{z_2} dm = m_0 + \rho_n \delta_0$$

$$u_{\propto} = \frac{u_{H\propto}}{\left[1 + \frac{\delta}{H^{'} cos\beta_1}\,(\frac{3\rho_n}{4\rho_{expl}})^{k/7}\right]^{\frac{2n}{k+1}}},$$

where $H^{'}$ - the characteristic size of the system determining the characteristic (active) mass $m_0^{'}$ $\left(H^{'} = m_0^{'}/\rho_{expl}\right)$, where: $\rho_x, \rho_{expl}$ - density of the body material and the explosive substance; $n$ - indicator of symmetry: $n = 1,2,3$ for flat, cylindrical and spherical shape, respectively.

The initial velocity on the boundary „explosive-body“ at obliquely impact of the DW is determined by solving the task of reflecting the falling DW from the moving wall using the known ratio of the contact surface decomposition and the equation of the body material dynamic contraction of the type:

$p = A.(\frac{\rho}{\rho_0})^n + B$ ,

In this way, the calculation of the velocity of the body element $u_H$ will allow to calculate the values of the kinematic parameters of the body at the first wave stage, which is also the initial condition for the second gas-dynamic phase [6, 7].

### *System for continuous initiation of the explosive substance*

A flat deformation of a cylindrical body will be considered – *Fig.2*.

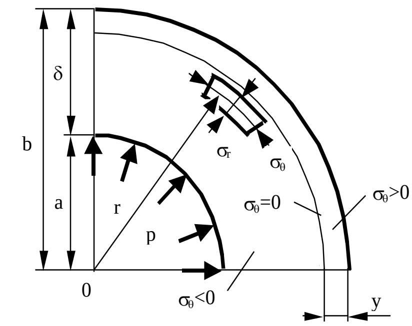


***Fig.2.*** *Stressed state of the body under detonation products impact.*

By using the equation of the body motion in the shape of Euler and taking into account the continuity of the body material equation and the plasticity conditions of Saint Venant - Tresca, it is obtained:

$$\frac{dv_a}{dt} = \left(\frac{1}{2a.\,ln\,b/a} - \frac{a}{2b^2.\,ln\,b/a} - \frac{1}{a}\right)\left(\frac{da}{dt}\right)^2 + \left[\frac{P}{a.\ln b/a} - \frac{xY}{a}\right].\frac{1}{\gamma_0}$$

where: $b = (b_0^2 - a_0^2 + a^2)^{1/2}$ - current radius of the body on the outer surface; $Y$ - dynamic yield boundary of the body material; $a$ - current radius of the inner surface of the body; $r$ - radial Euler coordinate.

The pressure $P$, is represented in the form of multiplier function

$$p = p_m \bar{p}(r,t)\bar{p}(x,t),$$

where: $\bar{p}(r,t)$ - dimensionless pressure, taking into account the pressure variation in radial direction at the expense of the DP expansion and the movement of the expanding body; $p_m$ - amplitude pressure on the detonation wave front; $\bar{p}(x,t)$ - dimensionless pressure, determined by the ratio of the axial one-dimensional flow of the DP; $p_m$ - amplitude pressure at the DW front.

In order to determine the $\overline{p_x}(x,t)$, the diagram of the wave process in the DP, shown in *Fig.3*, is examined [8].

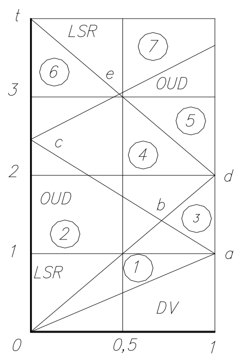


***Fig.3.*** *Phase diagram for the movement of the detonation waves and the unloading waves at one-dimensional flow of the DP.*

The parameters of the gas behind the DW front are determined after solving the gas dynamics equations (zone 1); in the unloading waves they are determined by a common solution (*Fig.4*).

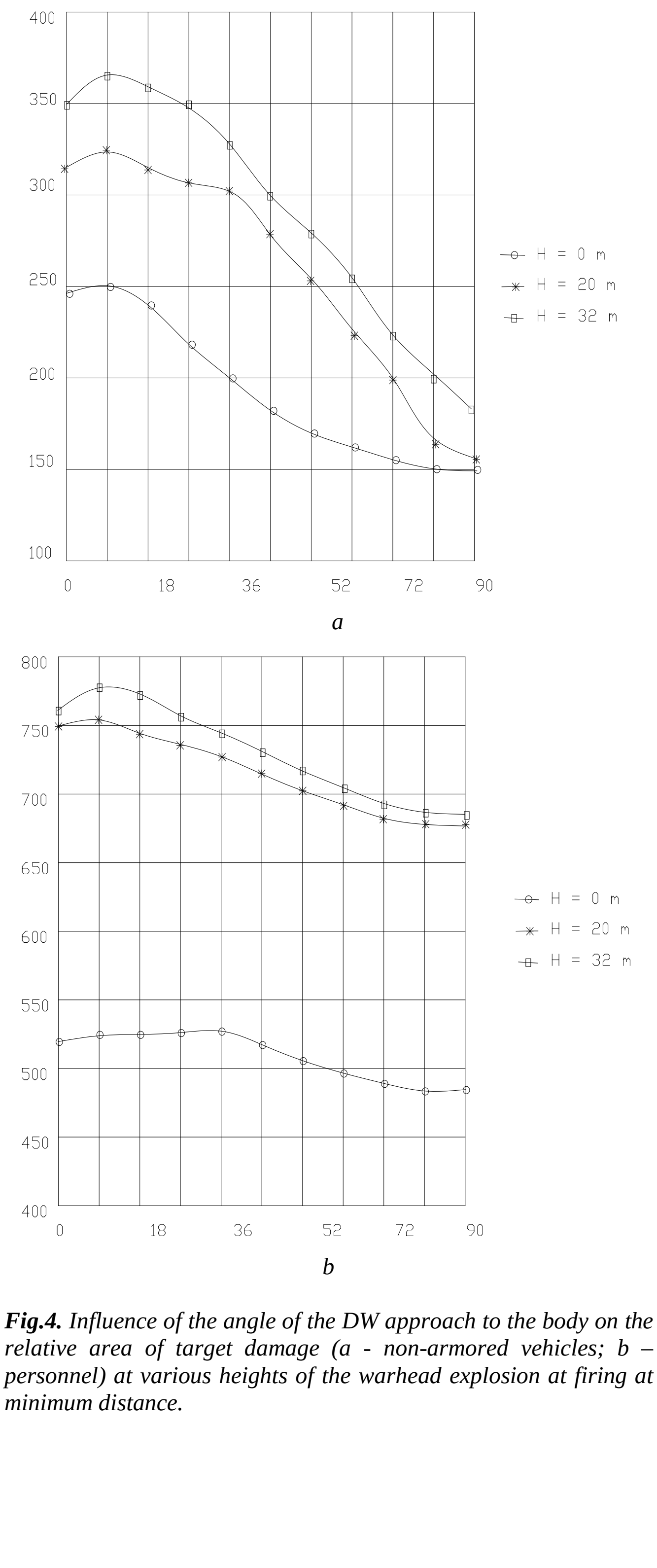


***Fig.4.*** *Influence of the angle of the DW approach to the body on the relative area of target damage (a - non-armored vehicles; b – personnel) at various heights of the warhead explosion at firing at minimum distance.*

## *CONCLUSIONS*

1. A quasi two-dimensional mathematical model is developed for the process of forming the initial kinematic parameters of the fragmentation field.
2. It is shown that the use of the system for continuous explosive initiation allows up to 23% increasing the relative area of the target damage with varying degrees of damage.

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