NUMERICAL SOLUTION OF THE TWO-DIMENSIONAL UNSTEADY-STATE PROBLEM OF THE MOTION OF A SHELL UNDER THE ACTION OF THE PRODUCTS OF AN AXIAL DETONATION

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A numerical solution is obtained to the problem of the motion of an incompressible cylindrical shell with a charge of explosive, with excitation of the detonation simultaneously along the whole axis of the charge. The strength of the shell is not taken into consideration. A three-term equation of state is adopted for the products of the detonation. In [1] a numerical solution is obtained to the problem of the one-dimensional motion of a shell with the axial detonation of a charge of explosive.

We consider a cylindrical shell with a charge of explosive. With the excitation of a detonation simultaneously along the whole axis of the charge, an outgoing cylindrical detonation wave is formed in the charge. The detonation products go out into a vacuum from the faces of the charge. Up to the moment when the detonation wave reaches the shell, the motion of the detonation products in the end zone is self-similar. After the impact of the shock wave on the shell, a reflected shock wave arises in the detonation products, going out toward the axis of symmetry, as a result of which the subsequent motion of the gas is nonisentropic. With the adopted equation of state of the detonation products, the determining parameters of the problem will be

$$\lambda = L / 2R_0, \ \mu = m / M$$

where m is the mass of the charge; M is the mass of the shell; L is the length and R_0 the initial radius of the charge.

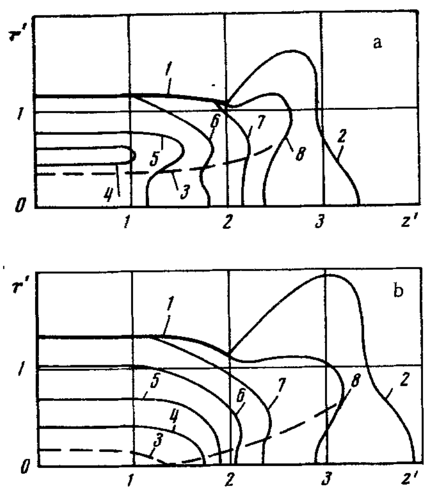

Fig. 1

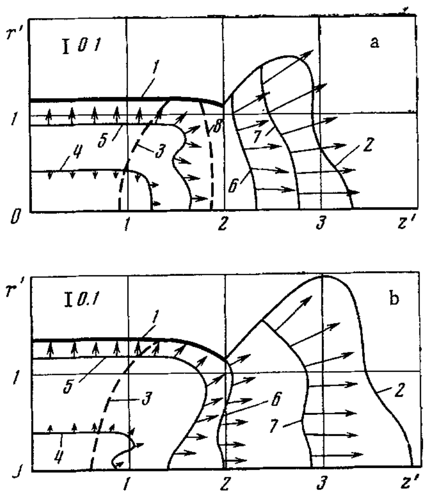

Fig. 2

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The explosive used was pentolite (a melt of Trotyl and Pentrite 50:50) with an initial density $\rho_0 = 1.65$ g/cm^3, a heat of explosive conversion Q = 0.0536 mbar · cm^3/g, and a detonation rate D = 0.7655 cm/μsec.

The dimensionless variables are introduced in such a manner that the form of the equations of motion does not change

$$p' = p / \rho_0 D^2,\ \rho' = \rho / \rho_0,\ w' = w / D,\ v' = v / D,\ u' = u / D,\ c' = c / D$$
$$e' = e / D^2,\ r' = r / R_0,\ z' = z / R_0,\ t' = tD / R_0$$

Here p is the pressure; ρ is the density; w is the mass velocity; v is the axial component of the velocity; u is the radial component of the velocity; c is the velocity of sound; e is the internal energy; r is the radial coordinate; z is the axial coordinate; t is the time.

The following equation of state is adopted for the detonation products [2]:

$$p' = A\rho' e' + B\rho'^4 + C \exp(-k / \rho')$$
$$A = 35 \cdot 10^{-2},\ B = 1659 \cdot 10^{-5},\ C = 2147 \cdot 10^{-3},\ k = 3636 \cdot 10^{-3}$$

The initial distribution of the parameters of the detonation products was given at the moment of time t' = 0.1. In the region not affected by the face rarefaction wave, a one-dimensional self-similar distribution was used behind the front of the outgoing cylindrical detonation wave. In the zone of the action of the rarefaction wave, linear approximations were used.

The boundary conditions of the problem are described in [3]. The finite-difference approximation of the equations of motion of the detonation products was constructed using a two-interval scheme of the second order of exactness [4]. The calculations were made in a BÉSM-6 digital computer, on a grid of 37 × 25.

The shell (1), the front of the outgoing detonation products (2), and the front of the reflected shock wave (3) are shown at different moments of time on Fig. 1 (*a* corresponds to the moment of time t' = 1.926, b to t' = 2.735). Lines 4-8 show the isobars. Line 4 on Fig. 1 corresponds to the pressure p' = 0.1, and lines 5, 6, 7, 8 to the pressures p' = 0.05, 0.018, 0.003, 0.001. On Fig. 1b, line 4 corresponds to the pressure p' = 0.044, and lines 5, 6, 7, 8 to the pressures p' = 0.02, 0.01, 0.005, 0.0004, respectively.

Figure 2 shows lines of equal velocities (4-7) at the same moments of time; the arrows indicate the vectors of the velocities of the detonation products to scale. Line 3 corresponds to the front of the face rarefaction wave, line 8 to the sonic surface (c = w).

The following special characteristics of the flow were followed: the presence of a one-dimensional zone in the middle part of the charge, not affected by the face rarefaction waves; the intense unloading of the detonation products in the region of the faces, the curvature of the reflected shock wave in the detonation products; the motion of the sonic surface inside the shell; the strong damping of the reflected shock wave; the absence of any appreciable "flowing-in" of the reaction products to the shell.

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