A CYLINDRICAL DOUBLE EXPLOSION

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The problems pertaining to a double point explosion in a gas, which were dealt with in [1, 2], serve as an important fragment in the problem of controlling an explosion. The solution here depends on two control parameters: the ratio of explosion energies $\lambda = E_2^0/E_1^0$ and the time t_0 separating one explosion from the other. A powerful double explosion has been studied in [1], with no provision made for the counterpressure of the ambient atmosphere. A numerical study was undertaken in [2] of the problem dealing with a double point explosion in a spherical—symmetrical formulation for a broad range of changes in pressure, i.e., from the powerful stage to the quasiacoustic asymptote; here studies were also undertaken of the unique features involved in the behavior of the solution, in dependence on the dimensionless time t_0 for a fixed value of the parameter $\lambda = 1$.

In the present paper the results of [2] are generalized to the case of a cylindrical dual explosion, and we also examine the relationship between the solution and the parameter λ for a fixed value of the duration t_0' between the explosions and the fixed total explosion energy $E_1^0 + E_2^0 = \text{const}$.

Let us examine a cylindrical double explosion in a gas with counterpressure p_0 and density ρ_0. The explosions correspond to the instantaneous release of energy with constant linear densities E_1^0 and E_2^0 along one and the same axis $r = 0$. The first explosion occurs at the instant of time $t = -t_0$, with the second explosion occurring at $t = 0$. Viscosity and heat conduction have not been taken into consideration. The flow of the gas behind the shock waves are adiabatic, and subject to the equation of state $\varepsilon = p/(\gamma - 1)\rho$ for an ideal gas, with an adiabatic exponent $\gamma = 1.4$.

For the scales of time and distance we have taken $t^0 = r^0/(p_0/\rho_0)^{1/2}$, $r^0 = (E^0/p_0\alpha_0)^{1/2}$ ($\alpha_0 = 0.984$ is a self-similar constant). The original system of gasdynamic equations, describing the cylindrical—symmetrical flows, are made dimensionless by means of the parameters t^0, r^0, p_0, and ρ_0, with the dimensionless quantities subsequently identified as prime. The S. K. Godunov [3] method was used numerically to solve this system of equations, and the unique features of the flows, i.e., the shock discontinuities, were identified. The unique nature of the application of this method to the problem of a double point explosion has been described in [1, 2]. We note that as $t_0 \to 0$ the solution of the problem regarding the double explosion changes into a solution of the problem for a single explosion with energy $E_1^0 + E_2^0$.

The results from the calculations can be seen in Figs. 1-3 ($\gamma = 1.4$). Qualitatively the nature of the interaction between the shock waves (SW) depends on the relationship between the dimensionless delay time $t_0' = t_0/t^0$ and the duration of the positive phase of the excess pressure in the first SW $\Delta t_p'(0) \approx 0.15$. With $t_0' \sim \Delta t_p'(0)$ the second SW is propagated through the compression phase behind the first shock wave. The interaction of these waves here is such that one wave overtakes the other: at some distance from the axis the SW merge one into the other. Figure 1 shows the merging distance r_m' as a function of λ for a fixed delay between the explosions, i.e., $t_0' = 0.02$. The function $r_m'(\lambda)$ is obvious: with an increase in λ, r_m' monotonically tends to zero.

The interaction of the waves from the explosions of approximately equal energies $\lambda \sim 1$ when $t_0' < \Delta t_p'(0)$ produces a cumulative effect: an increase in the amplitude of the pressure in the merger region exhibiting a characteristic dimension on the order of the width of the shock peak (analogous to a spherical double explosion) and to a positive-phase pulse of excess pressure in the interval from $r' \approx 0$ to $r' \approx r_m'$, in comparison to the single explosion with the same total energy. When $r' > r_m'$ the momentum of the double explosion tends monotonically to that of a single explosion exhibiting the total energy.

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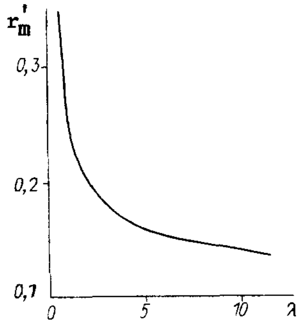

Fig. 1

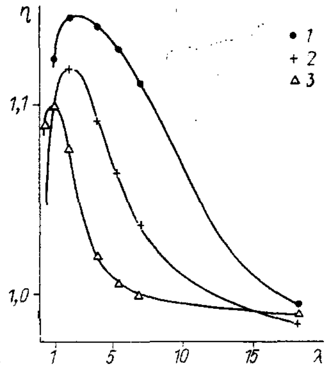

Fig. 2

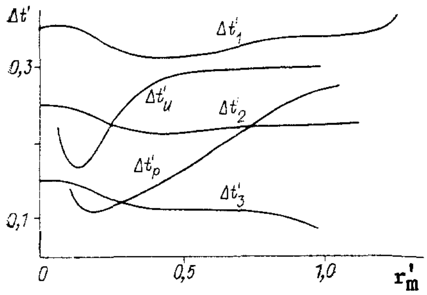

Fig. 3

It is physically obvious that as $\lambda \to 0(\infty)$ and $E_1{}^0 + E_2{}^0 = \text{const}$ the momentum of the positive phase for the excess pressure $I_p^+ = \int\limits_{\Delta t_p} (\Delta p' - 1)\, dt'$ tends toward the momentum of the single total-energy explosion for any fixed radius $r' > 0$. The existence of the cumulative effects in this case in the intermediate region $\lambda \sim 1$ suggests the possibility of maximizing the momentum at the given dimensionless distance through selection of the explosion energy ratio λ (with a fixed total energy $E_1{}^0 + E_2{}^0 = \text{const}$). The results from that series of calculations carried out for a fixed dimensionless delay $t_0' = 0.02$ (Fig. 2) confirms this. In Fig. 2, $\eta = I_p{}^+/(I_p{}^+)_{sin}$ is the ratio of the momentum of the double explosion to the momentum of the single explosion with energy $E_1{}^0 + E_2{}^0 = 2E^0$, with points 1-3 corresponding to the dimensionless radius $r' = 0.13$, 0.15, and 0.18. We can see from Fig. 2 that the energy ratio $(\lambda)_{max}$, corresponding to maximum momentum, depends, generally speaking, on the radius r' and does not correspond to the double explosion with equal fractions of energy (i.e., $\lambda = 1$). For the delay time which we have chosen in our calculations, with an increase in r', $(\lambda)_{max}$ increases.

Let us examine the case in which $t_0' > \Delta t_p'(0)$, i.e., the delay time between the explosions is greater than the time required for the formation of the negative phase behind the first SW. The second shock explosion will then be propagated through the rarefaction phase, which leads to its additional attenuation. When $\lambda \lesssim 1$ this circumstance, as in the spherical case, leads to the existence of a critical delay time $(t_0)_*$ such that when $t_0 > (t_0)_*$ the second shock explosion cannot overtake the first.

The distance of the interaction in the second explosion with the rarefaction phases can be determined from the intersection of the curve $\Delta t'(r')$ with $\Delta t_p'(r')$ and $\Delta t_u'(r')$ in Fig. 3, which has been plotted for $\lambda = 1$. Here $\Delta t'(r')$ is the time interval (spacing) between the arrival of the first and second shock explosions at a given Euler coordinate; $\Delta t_p'$ and $\Delta t_u'$ are the durations of the positive excess-pressure phases and the duration of the first SW.

The subscripts 1, 2, and 3 with $\Delta t'$ correspond to delay times $t_0 = \Delta t'(0) = 0.35$, 0.25, and 0.15. Figure 3 shows that for a cylindrical double explosion, analogous to a spherical explosion in the quasiacoustic stage, it is possible to have formation of double wave configurations with quasiconstant duration over some range of distances between the explosions, i.e., for $r' \in (r_1', r_2')$ we have $d(\Delta t'(r))/dr' \ll 1$ and $\Delta t'(r', t_0) \simeq T(t_0) = \text{const}$. The formation of such a configuration of explosions comes about without reference to whether or not the second explosion (i.e., the shock front) overtakes the first explosion on the asymptote or not. The amplitude of the excess pressure in the first SW at distances of r_1' from the axis corresponds approximately to 1.0, i.e., at distances of $r' > r_1'$ the evolution of the double wave truly corresponds to the quasiacoustic stage.

Within the scope of approximating nonlinear acoustics it is demonstrated analytically in [2] that the formation of double SW configurations with constant time spacing T = const between the fronts is associated with the specific agreement of the amplitudes and profiles of the two waves at the point $r' = r_1'$.

Thus, we can see from these calculations that for a cylindrical double explosion, as well as for a spherical explosion, there exists a region of control-parameter values t_0, λ in which the second wave, within the period of evolution from $r' = 0$ to $r' = r_1'$, "positions" itself with respect to the first wave in a manner such that it becomes possible to form two-wave configurations with quasiconstant spacing T between the fronts. The spacing T and the interval $\Delta r' = r_2' - r_1'$ depend exclusively on λ and t_0 and can be determined only as a result of a numerical solution for the problem of a double explosion.

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MICROSCOPIC CONDITIONS FOR THE EXISTENCE OF RAREFACTION SHOCK WAVES IN SOLIDS

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The existence of rarefaction shock waves in a substance near the critical point of the Ist kind of phase transition was predicted by Zel'dovich [1] and observed experimentally [2-4].

Let us examine the conditions for the existence of rarefaction shock waves, such as are associated with phase transition of the IInd kind.

In some manner let us initiate a multilateral rarefaction wave of amplitude P in a material subjected to preliminary stress, said wave of rather limited width such that the time required for a change in pressure is smaller than the stress relaxation time within the material. It is assumed that the body in the solid state with expansion such that $\Delta V = V_L - V_m$ (V_L, V_m is the volume of the body in the liquid and solid phases, respectively) makes the transition to the metastable state [5]. In this case, if the body remains in the solid phase, the new state may be amorphous [6]. With such transitions the body undergoes continuous changes of state, whereas the symmetry undergoes sudden jumps. We know that an amorphous structure is, in and of itself, more symmetrical than any ordered structure. The process involved in the formation of a new structure under the action of a rarefaction wave proceeds through a series of intermediate structures whose crystallographic symmetry covers more than 230 spatial groups [7], i.e., the transition process is represented by a sequence of states with ever-broader classes of symmetry. The conclusion of this process is found in the transition of the material into a fully amorphous state (a phase transition of the IInd kind [8]).

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