The dispersion of detonation products of a condensed explosive charge is numerically investigated; the charge is spherical and contains chemically inert solid particles uniformly distributed throughout its volume. The calculations are based on a two-speed, two-temperature model of interpenetrating continua, one of which consists of the gaseous detonation products or the atmosphere, while the other is the medium corresponding to the chemically neutral heavy particles.

The dispersion of detonation products (DP) from a condensed explosive charge is considered; the charge is spherical (radius $R_*$) and includes chemically inert solid particles uniformly distributed over the volume. Detonation is initiated at the center and propagates to the periphery of the charge.

The detonation wave is assumed to be infinitely thin. In accordance with [1], the DP are represented as a perfect gas with an adiabatic index $\gamma_1$, which is calculated from the density $\rho$ (g/cm$^3$) [2]: $\gamma_1 = 1 + (0.09 + 2\rho^2)/(0.3 + \rho^2)$. The viscosity and thermal conductivity $\lambda$ of the gas are only taken into account in calculating the phase interaction. The particles are assumed to be spherical (diameter $d$), and their internal state is described by a temperature $T_s$, which is constant within each but differs from the gas temperature $T$ in the general case.

On passing from the charge to the atmosphere, the detonation wave (DW) is converted to a shock wave. The contact-charge surface following the wave separates the expanding gaseous detonation products from the gas surrounding the explosive. The development of the explosion depends, in particular, on the properties of the explosive itself (its density $\rho_0$ and calorific value $Q$), the size of the charge, the total mass of inert inclusions, the particle size, the true density $\rho_s^0$, and the specific heat $c_s$ of the particle material.
In the present work, the propagation of the detonation within the explosive and the dispersion of its products in the atmosphere is investigated numerically on the basis of a two-speed, two-temperature model of interpenetrating continua, one of which consists of the gaseous detonation products or the atmospheric gas, while the other is the medium corresponding to the chemically neutral heavy particles. The equation of motion of this two-phase medium behind the principal detonation or shock wave when the specific volume of dispersed phase is small in comparison with the specific volume of gas may be written in the form [3]

\[ \frac{\partial \rho_1 u^v}{\partial t} + \frac{\partial \rho_1 \rho_1 u^v}{\partial r} = 0, \]

\[ \frac{\partial \rho_2 u^v}{\partial t} + \frac{\partial \rho_2 \rho_2 u^v}{\partial r} = 0, \]

\[ \frac{\partial \rho_1 u^2}{\partial t} + \frac{\partial \rho_1 \rho_1 u^2}{\partial r} = - \left( f + \frac{\partial \rho_1}{\partial r} \right) \rho_1 u^v, \]

\[ \frac{\partial \rho_2 u^2}{\partial t} + \frac{\partial \rho_2 \rho_2 u^2}{\partial r} = - \left( p \frac{\partial u}{\partial r} - f (u - v) + q \right) \rho_2 u^v, \]

\[ f = \frac{\rho_1 (u - v)}{\tau_u}, \quad q = \frac{\rho_0 c_s (T - T_s)}{\tau_h}, \]

\[ \tau_u = \frac{4}{3} \rho_1 |u - v| \tau_s, \quad \tau_h = \frac{\rho_0 c_s \tau_s}{\epsilon N_u \lambda_1}, \]

\[ e_1 = \frac{4}{(\gamma_1 - 1)} \frac{p}{\rho_1}, \quad e_2 = c_s T_s, \quad p = \frac{R}{\mu_i} \rho_1 T, \]

\[ \mu_i = \frac{\mu_1^0}{1 + \frac{\mu_2}{\mu_1}}, \quad \beta_2 = 0, \quad \beta_1 = 4 \beta_1 \]

(\( \rho_1 \) is numerically equal to \( \rho_1, \) g/cm³ [2]). Here \( p, \rho_1, u, c_1, \mu_1, \gamma_1 \) are the pressure, density, velocity, internal energy, molecular weight, adiabatic index, and thermal conductivity of the gaseous detonation products (\( i = 1 \)) and the atmospheric gas (\( i = 2 \)); \( n, v, c_s \) are the concentration, velocity, and specific heat of the particles; \( \rho_s, e_s \) are the mass density and internal energy of the disperse phase; \( \nu \) is the spatial symmetry parameter: \( \nu = 0, 1, 2 \) for the plane, cylindrical, and spherical cases, respectively. The dependence of the interphase friction coefficient \( C_d \) and the Nusselt number \( Nu \) on the Mach number \( M_{12} \) and the Reynolds number \( Re_{12} \) of relative motion of the phases \( - M_{12}^2 = (u - v)^2/(\rho_1 \rho_2) \) and \( Re_{12} = \rho |u - v| d/\eta \) are taken from [4, 5].

Initially \( (t = 0) \), the particles are assumed to be motionless \( (v = 0) \) and cold \( (T_s = T_0) \); their concentration is assumed to be constant over the charge volume \( (n = n_0) \). The surrounding space does not contain particles. The dispersion of a compressed volume of gas suspension was considered in a similar formulation in [6].

The numerical approach is based on the Godunov method [7], with the isolation of the principal discontinuity and the contact surface, as developed for the case of a two-phase medium [8]. The following fixed parameter values are adopted: \( \nu = 2, \rho_{10} = \rho_1(0) | t = 0 = 1500 \text{ kg/m}^3, \rho_{20} = \rho_2(0) | t = 0 = 1 \text{ kg/m}^3, R_s = 0.5 \text{ m}, T_0 = 293 \text{ K}, \gamma_1 = 2.8, \gamma_2 = 1.4, c_i = 1700 J/\text{kg.K}, \mu_1 = \mu_2 = 30, \lambda_1 = \lambda_2 = 2.44 \cdot 10^{-2} (T/273)^0.82 \text{ N/see K}, \eta_1 = \lambda_1 \Pr/cp_1 = [\gamma_1/(\gamma_1 - 1)] (R_0/\mu_1), \Pr = 0.75, d = (5 \cdot 10^{-5})-(5 \cdot 10^{-4}) \text{ m}, \) the mass density of the solid inert phase \( \rho_{0s} = 150-750 \text{ kg/m}^3, \) and the true density of the particles \( \rho_{0s} = 2700-5000 \text{ kg/m}^3. \) The detonation rate \( D_j = 5900 \text{ m/sec}\) is determined by the heat liberation \( Q = 4.2 \text{ MJ/kg}. \)