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EFFECT OF THE LOWER SURFACE ON A CLOUD OF PARTICLES MOVING BEHIND A SHOCK WAVE

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The results of numerical solution of the problem of the interaction of a shock wave (SW) with a cloud of particles located at height H above the surface are presented in the paper. It is shown that the presence of the surface causes asymmetry of cloud motion, and, at $H \sim 0.25$–0.5 m, break-up of the cloud of particles.

Let us consider a cloud of spherical particles which occupy region Ω_2 at height H above a flat surface (Fig. 1) with an SW incoming from the left. Let us examine the gas and particle flows in this case. The gas flow in Ω_1 is described by the Euler equations. In Ω_2, the particle motion is simulated by a collisionless kinetic equation, and the gas motion is modeled by the equations of a dusty gas. This model and its numerical realization were described in detail in [1, 2]. The rigid wall condition was set for γ_1, and the condition of a zero gradient of gasdynamic functions for γ_2, γ_3, and γ_4 as the boundary conditions for the gas. The specular reflection condition was set for the particles on γ_1, and particle absorption was assumed for γ_2, γ_3, and γ_4.

The gas ahead of the SW had density $\rho_0 = 1.3$ kg/m^3, pressure $p_0 = 1$ atm, and velocity $v_{1x} = v_{1y} = 0$ (normal atmospheric conditions), and the gas parameters behind the SW were determined from the Hugoniot relation. The SW Mach number was $M_0 = 3$, and the specific heat ratio was $\gamma = 1.4$. The cloud consisted of Plexiglas particles. The particle diameter was $d = 4 \cdot 10^{-3}$ m, the volume concentration was $m_2^0 = 10^{-2}$, and the cloud size was $L_y \times L_x = 0.65 \times 1.4$ m.

The problem is solved in the system of the center of mass of the cloud of particles. Calculations were performed for various initial cloud heights H above the surface ($H = 0$, 0.25, 0.5, and 1 m). The results of the study show that the lower wall has a considerable effect on cloud motion for $H \leqslant 0.5$ m.

Figures 2–4 show the computation results for $H = 0.25$ m: isobars $p(x, y)$ [atm] at $t = 8 \cdot 10^{-3}$ sec (Fig. 2), particle velocity field at $t = 1.2 \cdot 10^{-2}$ sec (Fig. 3), gas velocity field at $t = 2 \cdot 10^{-2}$ sec (Fig. 4), and the dashed curves indicate the cloud contours.

As follows from Fig. 2, a reflected SW forms upstream of the cloud, and the gas streamlines curve upward behind it and entrain the major portion of the particles (Fig. 3). The streamlines near the lower surface of the cloud curve downward, and, therefore, the particles here move toward the lower surface. Entering the external flow in which the gas velocity is higher, the particles start to move more rapidly; as a result, the cloud takes the shape of a comet [2] with a dense core and an extended tail.

Inside the cloud a rarefaction wave forms that works opposite to the forces of viscous interaction between the gas and particles. The rarefaction-wave isolines leave the cloud and either are closed on the reflected-wave isoline or reach the wall (Fig. 2). The gas flowing around the cloud from below and from above is accelerated in the rarefaction wave. The lower wall prevents free expansion of the gas, and, therefore, the rarefaction wave is less expanded near the lower wall than in the upper part of the computation domain. The absolute value of the pressure gradient is higher here ($\nabla p < 0$), and the gas acceleration below the cloud is greater than that above it. This makes the particles in the lower part of the cloud move more rapidly than in the upper part.

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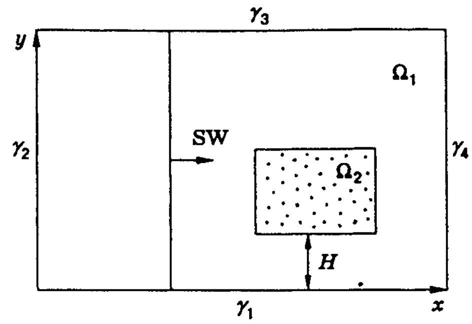

Fig. 1

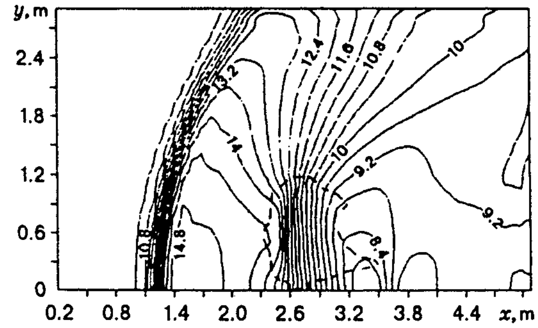

Fig. 2

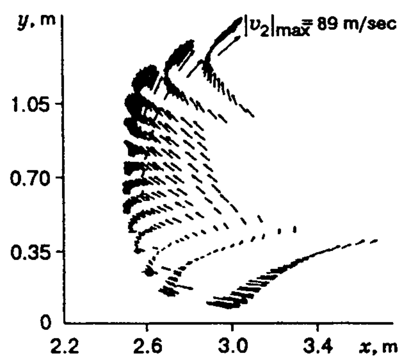

Fig. 3

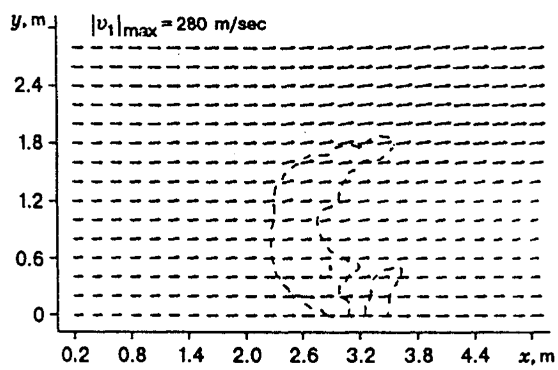

Fig. 4

In the course of time, as a result of expansion the cloud overlaps the gap between the cloud and the surface. The gas is abruptly decelerated by the friction forces, and the particles entering this region do not move as fast as the particles that have passed through this cross section previously; as a result, the cloud of particles breaks (Fig. 4). The overlapping of the gap causes the particles ejected from the upper part of the cloud to move more rapidly than the lower particles, and to overtake them. The calculations show that the effect of break of the cloud disappears when the cloud moves at the surface level ($H = 0$).

REFERENCES

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