ON SOME MOTIONS OF AN AEROSOL

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Abstract

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HYDROMECHANICS

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An aerosol is a fine suspension of solid particles or droplets of liquid in a gas. Let us assume that the particles are small and light, that their motion relative to the gas is absent, and that in the volume under consideration the density of particles is high, which increases the inertia of the medium (indeed, in 1 cm^3 of air in a large industrial city there are on the average 20,000 dust particles; in 1 cm^3 of clouds or fog there are 100–600, and sometimes as many as 1400 droplets). The density of an aerosol may be written in the form

$$\rho = \rho_0(1+k) \quad (k > 0),$$

where ρ_0 is the density of the gas, and k is a constant.

The system of dynamical equations of hydromechanics for an aerosol has the usual form. The equation of continuity for a gas of density ρ_0, when multiplied by the constant quantity $(1+k)$, is brought to the analogous form for an aerosol of density ρ. This assertion remains true for a viscous gas as well. The adiabatic equation in the medium under consideration gives the relation

$$\rho_0 c_v dT + ck\rho_0 dT + \rho p\, d\left(\frac{1}{\rho}\right) = 0,$$

where c is the heat capacity of the particles, assumed constant, and c_p and c_v are the specific heats of the gas. After integration we obtain:

$$p = A\rho^{\frac{c_p+kc}{c_v+kc}},$$

where A is a constant depending on the aerosol particles. We denote the expression

$$\frac{c_p+kc}{c_v+kc}$$

Fig. 1

Figure 1: Fig. 1

by γ'. Thus, the adiabatic equation has the usual form. In this case $1 < \gamma' < \gamma$ and $\gamma' \to 1$ as $\frac{kc}{c_v}$ increases, i.e., as the content of particles and their heat capacity increase. γ' is the ratio of the specific heats of the aerosol:

$$\gamma' = \frac{c'_p}{c'_v}, \quad \text{where} \quad c'_p = \frac{\rho_0 c_p + k\rho_0 c}{\rho_0 + k\rho_0}, \quad c'_v = \frac{\rho_0 c_v + k\rho_0 c}{\rho_0 + k\rho_0}.$$

Likewise, the conditions of conservation of mass and of the quantity of motion when passing through a shock wave do not change their form. The third condition–the condition of conservation of energy flux through the shock wave–is also preserved in the most general form. This is connected with the fact that the aerosol density ρ and the specific internal energy enter into it, the latter for an aerosol being written as

also as for an ideal gas with heat-capacity ratio γ'. Indeed:

$$d\varepsilon\rho_0(1+k) = c_v\rho_0 dT + ck\rho_0 dT,$$

where

$$\varepsilon = \frac{c_v + kc}{1+k}T = c'_{vT} = \frac{1}{\gamma' - 1}\frac{p}{\rho}.$$

It may be concluded that in all problems of gas dynamics a medium containing a large number of particles behaves like a gas with heat-capacity ratio γ' smaller than that for a pure gas.

Let us consider the question of a strong explosion in an aerosol. We shall determine the change in the intensity of the blast wave in such a medium. From the solution of the problem of a strong explosion ([1]) we find that the pressure at the shock wave is determined by the formula

$$p_2 = \frac{8}{(\nu+2)^2(\gamma'+1)\alpha(\gamma')}\frac{E_0}{r^\nu},$$

where ν is equal to $1, 2, 3$, respectively, for plane, cylindrical, and spherical explosions; E_0 is the energy released in the explosion; $\alpha(\gamma)$ is a complicated function, whose dependence on γ is given graphically ([1]).

Fig. 1

Let us consider two spherical explosions with one and the same released energy E_0 and estimate p_2 at one and the same distance from the center of the explosion. From the graph of the function $F = (\gamma + 1)\alpha(\gamma)$ (see Fig. 1) we see that F increases as γ decreases, i.e., the pressure at the shock wave falls. This means that the presence of fine particles in the air reduces the pressure at the shock wave. If γ were reduced to 1.2, then F would increase by approximately a factor of 2, and p_2 would correspondingly decrease by the same factor. However, this requires a very high aerosol density (0.888 kg of dust in 1 m^3 of air). To reduce p_2 by 10%, a dust density of 0.12 kg/m^3 is sufficient. The dustiness of the air in an industrial city corresponds to a 2% decrease in p_2 compared with the pressure at the shock wave in clean air.

In the same way one can consider a number of other problems of aeromechanics and gas dynamics and estimate in them the influence of dustiness. In considering the flow past bodies of revolution, one can obtain that the intensity of the resulting frontal shock and the pressure at the front point of the body decrease. Flow past a wing by a plane-parallel supersonic dusty stream leads to a decrease of pressure on the wing contour.

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CITED LITERATURE

1. L. I. Sedov, *Methods of Similarity and Dimensionality in Mechanics*, 1954.

This page contains no visible text, formulas, tables, or figures to translate.

Note: Figure translations are in progress. See original paper for figures.