SOME STUDIES OF THE FLOW OF A TWO-PHASE MEDIUM WITH SOLID PARTICLES AROUND BODIES WITH A SIGNIFICANT CONCENTRATION OF PARTICLES

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This paper proposes a model of a two-phase medium flowing around a thin airfoil, taking into account the effect of particle reflection from the airfoil surface and, in addition, provides a solution to some problems in a linear formulation under various assumptions regarding the volume occupied by particles and friction between phases.

If there are a lot of solid particles in the flow, then it is necessary to take into account the mutual influence of the phases. In a general formulation, it is difficult to solve this problem without using numerical methods. Therefore, a solution to a special case is proposed, where the influence of the reflected flow on the flow of a two-phase medium is neglected. In this case, the dividing line is only a line of reflected current, that is, a third flow. In [5], based on [3], the equations of a two-phase medium are given in a simpler form; for this case they have the form:

$$\gamma_0\left[(M^2-1)\varphi_{1xx}-\varphi_{1yy}\right]-\frac{\rho_2}{\rho_{2i}}\left(\varphi_{2xx}+\varphi_{2yy}\right)=$$

$$=-\frac{K}{U_0}\cdot\frac{M^2}{\rho_0}\left(\varphi_{2x}+\varphi_{2y}\right) \qquad (2.1)$$

$$\frac{\rho_2}{\rho_{2i}}\rho_{10}\varphi_{1x}-\gamma_0\rho_2\varphi_{2x}=-\frac{K}{U_0}(\varphi_1-\varphi_2) \qquad (2.2)$$

Here $\varphi_0=\frac{\rho_{10}}{\rho_0}$, the remaining notations are identical to §1.

It is obvious that equations (2.1) and (2.2) are valid in regions I and II (see figure). The equation of motion of the third flow after linearization and transformations, as in [9], will be:

$$\varphi_{3x} + \alpha\varphi_3 = \alpha\varphi_1(x, y) \qquad (2.3)$$

When writing (2.3), the direct action of solid particles in the oncoming flow and the action of gas through the pressure gradient [6] not reflected flow were not taken into account. Let us consider the flow of a two-phase flow around bodies in the reverse formulation, that is, we will assume that the dividing line with a constant angle of inclination is given $\beta$and we will determine the surface of the streamlined profile. To solve this problem, we write the boundary conditions:

$$\varphi_{1y} = U_0\beta_1(x) \ \text{при} \ \ y = 0, \qquad (2.4)$$

$$\varphi_{3y} = U_0\beta \ \ \text{при} \ \ y = \beta \cdot x, \qquad (2.5)$$

$$2U_0\beta_1(x) = \varphi_{2y} + \varphi_{2y} \ \ \text{при} \ \ y = 0. \qquad (2.6)$$

besides,

$$\varphi_1 = \varphi_2 = 0 \ \ \text{при} \ \ x - \mu y = 0, \ \ \varphi_{3x} = 0 \ \ \text{при} \ \ x = y = 0 \qquad (2.7)$$

here is $\beta_1(x)$ – the angle of inclination of the thin profile. Applying the Laplace transform [7] with respect to the variable to systems (2.1) and (2.2) x and taking into account condition (2.4), formulas for the velocity potentials were obtained $\varphi_1$and $\varphi_2$are not given here. From the formula for $\varphi_2$we have at $y = 0$

$$\varphi_{2y} = U_0\left[\frac{\rho_0}{\rho_{2i}}\beta_1(x) + \alpha_1\left(1 - \frac{\rho_0}{\rho_{2i}}\right)\exp(-\alpha_1 x)\int_0^x \beta_1(\tau)\cdot\exp(\alpha_1\tau)\,d\tau\right] \quad (2.8)$$

where $\alpha_1 = \alpha/\gamma_0$;$\rho_0$ – true gas density. Equation (2.3) taking into account (2.5) and (2.7) gives the solution

$$\varphi_3(x, y) = -\frac{U_0\beta^2}{\alpha}\cdot\exp(-\alpha x) +$$

$$+\left\{\frac{U_0\beta^2}{\alpha}\cdot\exp\left(\frac{\alpha}{\beta} - y\right) - \alpha\int_0^y\left[\int_0^x \varphi_{1y}\cdot\exp(\alpha x)\,dx\right]_{x=\frac{y}{\beta}} dy\right\}\exp(-\alpha x) +$$

$$+\alpha\cdot\exp(-\alpha x)\cdot\int_0^x \varphi_1(x, y)\cdot\exp(2x)\,dx \qquad (2.9)$$

Hence, differentiating with respect to y, we have at$y = 0$

$$\varphi_{3y} = U_0\left[\beta + \alpha\int_0^x \beta_1(\varepsilon)\cdot\exp(\alpha\varepsilon)\,d\tau\right]\exp(-\alpha x) \ \ (2.10)$$

Let's put (2.8) and (2.10) into (2.6), let's add some

$$\left(2 - \frac{\rho_0}{\rho_{2i}}\right)\beta_1(x) = \beta\cdot\exp(-\alpha x) + \alpha\cdot\exp(\alpha x)\int_0^x \beta_1(\tau)\cdot\exp(\alpha\tau)\,d\tau +$$

$$+\alpha_1\left(1-\frac{\rho_0}{\rho_{2i}}\right)\cdot\exp(-\alpha_1 x)\cdot\int_0^x \beta_1(\tau)\cdot\exp(\alpha_1\tau)\,d\tau. \qquad (2.11)$$

Next, applying the Laplace transform [7] and passing to the original, from (2.11) we obtain that

$$\beta_1(x)=\frac{\beta}{1+\gamma_0\left(1-\frac{\rho_0}{\rho_{2i}}\right)}\cdot$$

$$\cdot\left[1-\frac{(1-\gamma_0)\left(1-\frac{\rho_0}{\rho_{2i}}\right)}{2-\frac{\rho_0}{\rho_{2i}}}exp\left(-\frac{\alpha_1+\alpha\left(1-\frac{\rho_0}{\rho_{2i}}\right)}{2-\frac{\rho_0}{\rho_{2i}}}\right)\right]. \qquad (2.12)$$

If $\frac{\rho_0}{\rho_{2i}} \ll 1$, then from (2.12) we have

$$\beta_1(x)=\frac{\beta}{1+\gamma_0}\left[1-\frac{1-\gamma_0}{2}\exp\left(-\frac{\alpha_1+\alpha}{2}x\right)\right]; \qquad (2.13)$$

It's obvious that $\frac{dy}{dx}=\beta_1(x)$. Therefore, introducing dimensionless variables $\frac{\alpha_1+\alpha}{2}x=x_1$, $\frac{\alpha_1+\alpha}{2}y=y_1$ and integrating (2.13), we find the profile surface equation in the form

$$y_1=\frac{\beta}{1+\gamma_0}\left[x_1-\frac{1-\gamma_0}{2}(1-\exp(-x_1))\right]. \qquad (2.14)$$

Now, using (2.13) and (2.14), we can obtain the calculated formulas for the velocity field and pressure in quadratures.

Thus, the surface of a profile flown over a two-phase medium with a significant concentration of solid particles, taking into account their specular reflection, is, in contrast to the results of [9], a curve slightly concave to the flow, and the three-velocity region II with increasing x_1 slowly narrows.

Using the described method, calculations were made for the initial parameters $\beta=\frac{\pi}{18}$, $\mathrm{M}=2, \gamma_0=0{,}9$ and the results are shown graphically (see figure).

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