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TWO-PHASE TURBULENT FLOWS. METHODS FOR DESCRIPTION AND NUMERICAL MODELING

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ABSTRACT

The article is about modern methods for a mathematical description and a numerical modeling of two-phase turbulent flows, which are worked out of the collective through the last 10-15 years. It is given results from a numerical experiment for a kind of jet non-isothermal two-phase flows.

Two-phase turbulent flows are basically used in the energetics, the chemistry, the dry technologies and in the food technologies. Their studying is at a great interest from scientific and practical point of view. Therefore, the current article is about one of these methods for numerical investigation of flows of such kind.

MATHEMATICAL MODEL

It is known two ways for mathematical interpretation of the two-phase (of course and poly-phase) flows. The statistic method is based on the Boltzman's theory of gas mixtures. Because of the complex mathematical description its use is very difficult. That makes the second method – phenomenal, more convenient and more accessible than the first one, the second method uses Newton's equations, which are well known from engineers.

I won't describe here the method of passive mixtures, because it is physically ungrounded and because it isn't fit with the real picture of the flow [1], [2].

Two-fluid (or poly-fluid) method examines each of the phases as separate fluid with its own velocity, density and temperature. The mixture phase doesn't have its own tensor of inner pressures P, i.e. its own viscosity and pressure. That means the state equation can't be used for them. On the other hand they have their own turbulence, and their own tensor of turbulent pressures. That is explained with the fact the turbulence is not quality of the fluid, but it is a characteristic of the flow.

It is accepted that the losses of the quantity of movement and the energy are consequence from the between-phase interaction, the hits between particles and so on, and these losses are compensated from the quantity of movement and the energy of the carrier phase. The forces of between-phase interaction in the equations of movement for the gas phase are with mark "–", and with mark "+" for the mixture phase. The basic forces are determined when the physical picture of the flow is done.

The mixture phase is regarded as "rare multitude of particles", i.e. the time between two hits between particles is much more than the time for relaxation after its own hit.

The Reynolds's equation for the two phase of the two-dimensional flow are:

$$1. \frac{\partial}{\partial x} [y^j U_g \rho_g] + \frac{\partial}{\partial y} [y^j V_g \rho_g] = 0$$

$$2. \frac{\partial}{\partial x} [y^j U_p \rho_p] + \frac{\partial}{\partial y} [y^j V_p \rho_p] = 0$$

$$3. [y^j U_p] \frac{\partial \rho_p}{\partial x} + [y^j V_p] \frac{\partial \rho_p}{\partial y} = - \frac{\partial}{\partial y} [y^j \rho_p V'] - \overline{\rho_p V_p}$$

$$4. [y^j \rho_g U_g] \frac{\partial U_g}{\partial x} + [y^j \rho_g V_g] \frac{\partial U_g}{\partial y} = - \frac{\partial}{\partial y} [y^j \rho_p \overline{U_g V_g}] - F_x y^j$$

$$5. [y^j \rho_p U_p] \frac{\partial U_p}{\partial x} + [y^j (\rho_p V_p + \overline{\rho_p V_p})] \frac{\partial U_p}{\partial y} = - \frac{\partial}{\partial y} [y^j \rho_p \overline{U_p V_p}] + F_x y^j$$

$$6. [y^j \rho_g U_g] \frac{\partial h_g}{\partial x} + [y^j \rho_g V_g] \frac{\partial h_g}{\partial y} = - \frac{\partial}{\partial y} [y^j \rho_g \overline{h_g V_g}] - [y^j \rho_g \overline{h_g V_g}] \frac{\partial U_g}{\partial y} -$$

$$- Q y^j + F_x y^j (U_g - U_p) + F_y y^j (V_g - V_p) - \sum_{i=1}^3 F_i \overline{V_{pi}} +$$

$$+ 2 \cdot R_j \delta \bar{n}_g (\overline{T_g} - \overline{T_p}) \overline{V_g} - 2 \cdot R_j \delta \bar{n}_g \frac{\overline{I_{tg}}}{Pr_t} \cdot \frac{\partial \overline{T_g}}{\partial y}$$

$$7. [y^j \rho_p U_p] \frac{\partial h_p}{\partial x} + [y^j (\rho_p V_p + \overline{\rho_p V_p})] \frac{\partial h_p}{\partial y} = - \frac{\partial}{\partial y} [y^j \rho_p \overline{h_p V_p}] + Q y^j +$$

$$+ 2 \cdot R_j \pi \bar{n}_p (\overline{T_p} - \overline{T_g}) \overline{V_p} - 2 \cdot R_j \delta \bar{n}_p \frac{\overline{I_{tp}}}{Pr_t} \cdot \frac{\partial \overline{T_p}}{\partial y}$$

$$8. P = \rho_g \cdot R \cdot T_g$$

where: subscripts *g* and *p* are for the carrier phase and for the mixtures; *j* = 0 is for the plane flows; *j* = 1 is for the axes-symmetric flows; *F_x* - the forces of between-phase interaction.

METHODS FOR SOLUTION. MODELING OF TURBULENT PRESSURES

The integral methods. The integral methods are used for researching of turbulent jets and this method brings the system of private differential equation to the system of integral conditions, which are ordinary differential equations. These equations can be solved by using the alikeness of the velocity and temperature of the jet flows. The method is convenient and exact for engineering problems [3], [4], [5].

The numerical methods. The equations for movement and model equations for the turbulence are exchanged with differential schemes in the numerical methods, with using the method of final differences. The most used scheme in our solutions is open, and it is Duffert-Frankel's type [6].

The turbulent pressures are modeled with models from 1st row, which is $k - \varepsilon$ model with its own modification for the two phases of the flow. The modification used from us [6], [7], which is $k_g - k_p - \varepsilon$, makes use of three model equations about turbulent energy of the gas phase and of the mixtures and one equation about the dissipation of the energy of the mixtures. The turbulent alongside pressures are, according to the Kolmogorov's theory:

$$9. \overline{v_{lg}} = C_\mu \cdot \frac{\overline{K_g^2}}{\varepsilon}; \overline{v_p} = C_\mu \cdot \frac{\overline{K_p^2}}{\varepsilon}$$

$$10. \overline{\varepsilon} = C_D \cdot \frac{\overline{K_g^{1.5}}}{L}$$

where: $C_\mu = 0.09$ is empirical coefficient.

The methods, which are given above, are one modern direction for solving the equations of movement [8], [9], but they required very powerful computers and much time.

THE RESULTS FROM NUMERICAL EXPERIMENT

For illustration of described possibilities of the numerical methods for investigating of the two-phase flows are given results received by $k_g - k_p - \varepsilon$ model. The numerical experiment is hold with the next initial conditions for the two-phase turbulent jet:

mixtures' concentration – $\chi = 1.00$

mixtures' diameter – $D_p = 0.000145m$

velocity of the gas phase – $u_{g0} = 35m/s$

velocity of the mixtures – $u_{p0} = 35m/s$

temperature of the gas phase – $T_{g0} = 300K$

temperature of the mixtures – $T_{p0} = 400K$

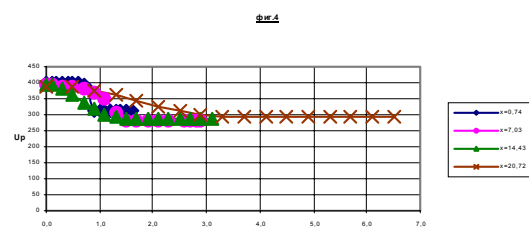
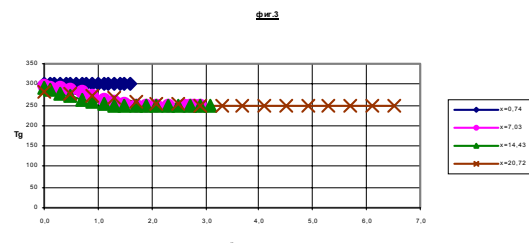
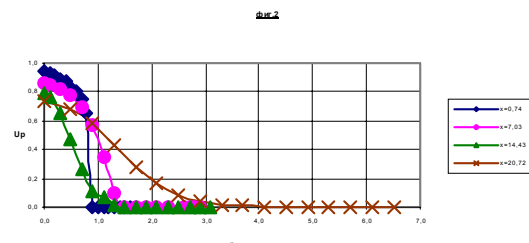
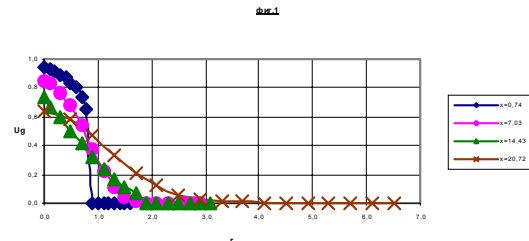
density of the gas phase – $\rho_{g0} = 1.04kg/m^3$

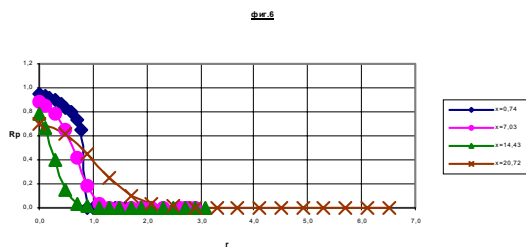
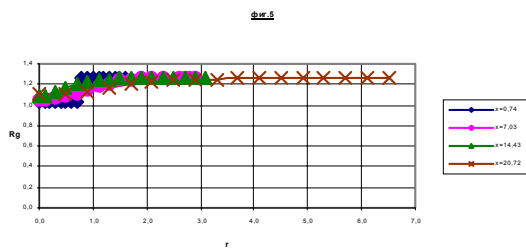
density of the mixtures – $\rho_{p0} = 800kg/m^3$

temperature of the environment – $T_2 = 200K$

On fig. 1÷6 are shown the transverse distribution of velocities, temperatures and densities correspond to the gas phase and admixtures for cut $x=20,72$ (the last one). The results show the workability of the chosen method and its numerical realization for the two-phase turbulent jets.

The lack of enough space in the current article is the cause that the other numerical results are not shown





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