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TWO-PHASE WITH NON-STANDARD EFFECTS STABILITY EQUATIONS OF FLOWS

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Introduction

The paper takes into account the unstable effects of the interaction forces of the phases in deriving the stability equations of two-phase currents. In a straight-line nonstationary motion of a disperse mixture, the forces acting on the particle can be given in the form of the sum of the adhesive friction force, the Archimedean force, the added mass force Basse forces. For a heterogeneous environment [1] the conservation equations proposed in the literature are as follows:

$$(1-\alpha)\rho_1\left(\frac{\partial \hat{v}}{\partial \hat{t}}+\hat{v}\hat{\nabla}\hat{v}\right)=-(1-\alpha)\hat{\nabla}\hat{p}+\alpha\frac{9}{2}\frac{\mu}{a^2}(\hat{u}-\hat{v})+$$
$$+\mu\hat{\nabla}\hat{\nabla}\hat{u}-\frac{4}{3}\pi a^3\rho_1\frac{\partial \hat{v}}{\partial \hat{t}}+\frac{2}{3}\pi a^3\rho_1\frac{\partial}{\partial \hat{t}}(\hat{u}-\hat{v})+$$
$$+6a^2\sqrt{\pi\rho_1\mu}\int_{-\infty}^{\hat{t}}\frac{\partial}{\partial\tau}(\hat{u}-\hat{v})\frac{\partial\tau}{\sqrt{\hat{t}-\tau}}\ , \qquad (1)$$
$$\frac{\partial(1-\alpha)}{\partial \hat{t}}+\hat{\nabla}(1-\alpha)\hat{v}=0, \qquad (2)$$
$$\alpha\rho_2\left(\frac{\partial \hat{u}}{\partial \hat{t}}+\hat{u}\cdot\hat{\nabla}\hat{u}\right)=-\alpha\hat{\nabla}\hat{p}+\alpha\frac{9}{2}\frac{\mu}{a^2}(\hat{v}-\hat{u})+\frac{4}{3}\pi a^3\rho_1\frac{\partial \hat{v}}{\partial \hat{t}}+\frac{2}{3}\pi a^3\rho_1\frac{\partial}{\partial \hat{t}}(\hat{v}-\hat{u})+$$
$$+6a^2\sqrt{\pi\rho_1\mu}\int_{-\infty}^{\hat{t}}\frac{\partial}{\partial\tau}(\hat{v}-\hat{u})\frac{d\tau}{\sqrt{\hat{t}-\tau}}\ , \qquad (3)$$
$$\frac{\partial\alpha}{\partial \hat{t}}+\hat{\nabla}\cdot\alpha\hat{u}=0 \quad . \qquad (4)$$

To write these equations in dimensionless form, we introduce the following definitions:

$\hat{v}=Vv,\ \hat{u}=Uu,\ \hat{t}=\frac{t}{\omega},\ \hat{x}=Lx,\ \hat{y}=Ly.$

(1) –(4) – we accept these assumptions to solve the equations [1,2,3,4,5,6,7]:

1) particles are spherical and their motion obeys Stokes' law;

2) since the volumetric concentration of particles $a \ll 1$ is considered small, the interaction between individual particles is not taken into account;

3) The einstein correction of the viscosity, which is proportional to the volumetric concentration of the particle, is ignored.

When such assumptions are taken into account, written in dimensionless form, equations (1) - (4) have the following form [1].

$$(1-\alpha)\left(\frac{\partial \mathrm{v}}{\partial t}+(\mathrm{v}\cdot\nabla)\mathrm{v}\right)=-(1-\alpha)\nabla p+\alpha\frac{S_1}{\tau}(\mathrm{u}-\mathrm{v})+\frac{1}{2}\alpha\frac{\partial}{\partial t}(\mathrm{u}-\mathrm{v})-\alpha\frac{\partial \mathrm{v}}{\partial t}+$$

$$+\sqrt{\frac{9}{2\pi}}\,\alpha\sqrt{\frac{S_1}{\tau}}\int_{-\infty}^{t}\frac{\partial}{\partial \tau}(\mathrm{u}-\mathrm{v})\frac{d\tau}{\sqrt{t-\tau}}+\frac{1}{Re}\nabla^2\mathrm{v}\,, \tag{5}$$

$$\frac{\partial(1-\alpha)}{\partial t}+\nabla\cdot(1-\alpha)\mathrm{v}=0\,, \tag{6}$$

$$\alpha\left(\frac{\partial \mathrm{u}}{\partial t}+(\mathrm{u}\cdot\nabla)\mathrm{u}\right)=-\frac{\alpha}{S_1}\nabla\rho+\frac{\alpha}{\tau}(\mathrm{v}-\mathrm{u})+\frac{1}{2}\frac{\alpha}{S_1}\frac{\partial}{\partial t}(\mathrm{v}-\mathrm{u})+\frac{\alpha}{S_1}\frac{\partial \mathrm{v}}{\partial t}+\sqrt{\frac{9}{2\pi}}\frac{\alpha}{\sqrt{\tau S_1}}\int_{-\infty}^{t}\frac{\partial}{\partial t}(\mathrm{v}-\mathrm{u})\frac{d\tau}{\sqrt{t-\tau}}, \tag{7}$$

$$\frac{\partial\alpha}{\partial t}+\nabla\cdot\alpha\mathrm{u}=0, \tag{8}$$

here $\mathrm{v}=(\mathrm{v}_1,\mathrm{v}_2), \mathrm{u}=(\mathrm{u}_1,\ \mathrm{u}_2)$ velocity vectors for pure gas and particles, respectively $p-$ pressure, $S_1=\frac{\rho_2}{\rho_1}$ density ratio, ρ_1- density of pure gas, ρ_2- particle material density, $\tau=SRe-$ dimensionless size - the relaxation time of the particles, $Re=\frac{\rho_1 U_0 L}{\mu}$ – Reynolds number, $S=\frac{2}{9}\left(\frac{a}{L}\right)^2\frac{\rho_2}{\rho_1}$ size here a- particle radius, L – half the width of the channel, U_0- characteristic velocity of flow, μ- viscosity coefficient, $\nabla=\frac{\partial}{\partial x}i+\frac{\partial}{\partial y}j$, $\nabla^2=\frac{\partial^2}{\partial x^2}+\frac{\partial^2}{\partial y^2}$ – Laplace operators.

To check for stagnation (5) – (8) system solutions are, usually, $U(y)$, $V(y)$ in the form of a superposition of the main laminar flow and small motions:

$$V=V(y)i+\mathrm{v}'(x,y,t),$$
$$U=V(y)i+\mathrm{u}'(x,y,t),$$

$$P=P_0(x,y)+p'(x,y,t),$$
$$\alpha(x,y,t)=\alpha_0+\alpha_0'(x,y,t),$$

here $i-x$ unit vector in the direction. Leaving only the first-order minor terms in the equations, we get:

$$(1-\alpha_0)\left(\frac{\partial V'}{\partial t}+V\frac{\partial V'}{\partial t}+V_2'\frac{\partial V}{\partial t}i\right)=-(1-\alpha_0)\nabla p'+\alpha_0{}'\nabla p_0++\alpha_0\frac{S_1}{\tau}(\mathrm{u}'-\mathrm{v}')+\frac{1}{2}\alpha_0\frac{\partial}{\partial t}(\mathrm{u}'-\mathrm{v}')-$$

$$-\alpha_0\frac{\partial V'}{\partial t}+\alpha_0\sqrt{\frac{g}{2\pi}}\sqrt{\frac{S_1}{\tau}}\int_{-\infty}^{t}\frac{\partial}{\partial t}(\mathrm{u}'-\mathrm{v}')\frac{d\tau}{\sqrt{t-\tau}}+\frac{1}{R_e}\nabla^2\mathrm{V}' \tag{9}$$

$$-\frac{\partial\alpha_0{}'}{\partial \mathrm{t}}+(1-\alpha_0)\nabla\cdot\mathrm{V}'+\mathrm{V}\frac{\partial\alpha_0{}'}{\partial x}=0, \tag{10}$$

$$\frac{\partial \mathrm{u}'}{\partial \mathrm{t}}+\mathrm{V}\frac{\partial \mathrm{u}'}{\partial x}+\mathrm{u}_2'\frac{\partial \mathrm{V}}{\partial y}\mathrm{i}=\frac{1}{\mathrm{S}_1}\nabla\mathrm{p}'+\frac{1}{\tau}(\mathrm{V}'-\mathrm{u}')+\frac{1}{2\mathrm{S}_1}\frac{\partial}{\partial \mathrm{t}}(\mathrm{V}'-\mathrm{u}')+\frac{1}{\mathrm{S}_1}\frac{\partial\mathrm{V}'}{\partial \mathrm{t}}+\sqrt{\frac{\mathrm{g}}{2\pi\tau\mathrm{S}_1}}\int_{-\infty}^{\mathrm{t}}\frac{\partial}{\partial \mathrm{t}}(\mathrm{V}'-\mathrm{u}')\frac{\mathrm{d}\tau}{\sqrt{\mathrm{t}-\tau}}\,, \tag{11}$$

$$\frac{\partial\alpha_0{}'}{\partial \mathrm{t}}+\alpha_0\nabla\cdot\mathrm{u}'+\nabla\frac{\partial\alpha_0{}'}{\partial x}=0. \tag{12}$$

(9)-(12) – we look for the solutions of the equations in the following form:

$$\begin{bmatrix}\mathrm{v}'\\ \mathrm{u}'\\ p'\\ \alpha'\end{bmatrix}=\begin{bmatrix}\mathrm{v}_0'(y)\\ \mathrm{u}_0'(y)\\ p_0'(y)\\ \alpha_0'(y)\end{bmatrix}e^{i(kx-\omega t)} \tag{13}$$

(13) – equation (9) - (12) after we lose the pressure, we get:

$$-i\omega\left(ikV_{20}'-\frac{\partial V_{10}{}'}{\partial y}\right)+ikV\left(ikV_{20}'-\frac{\partial V_{20}{}'}{\partial y}\right)-ikV_{10}'\frac{\partial V}{\partial y}-V_{20}'\frac{\partial^2 V}{\partial y^2}-\frac{\partial V_{20}'}{\partial y}\frac{\partial V}{\partial y}=$$

$$=\frac{\alpha_0}{1-\alpha_0}\frac{g_1}{\tau}\left[\left(ik\mathrm{u}_{20}'-\frac{\partial \mathrm{u}_{10}'}{\partial y}\right)-\left(ikV_{20}'-\frac{\partial V_{10}'}{\partial y}\right)\right]-\frac{1}{2}\frac{\alpha_0}{1-\alpha_0}i\omega\left[\left(ik\mathrm{u}_{20}'-\frac{\partial \mathrm{u}_{10}'}{\partial y}\right)-\left(ikV_{20}'-\frac{\partial V_{10}'}{\partial y}\right)\right]+$$

$$\frac{\alpha_0}{1-\alpha_0}i\omega\left(ikV_{20}'--\frac{\partial V_{10}'}{\partial y}\right)+\frac{3\alpha_0}{2(1-\alpha_0)}\sqrt{\frac{S_1}{\tau}}\sqrt{\omega}\,(1-i)\left[\left(ik\mathrm{u}_{20}'-\frac{\partial \mathrm{u}_{10}'}{\partial y}\right)-\left(ik\mathrm{v}_{20}'-\frac{\partial \mathrm{v}_{10}'}{\partial y}\right)\right]+$$

$$+\frac{1}{1-\alpha_0}\frac{1}{Re}\left[\left(\frac{\partial^2}{\partial y^2}-k^2\right)\left(ik\mathrm{v}_{20}'-\frac{\partial \mathrm{v}_{10}'}{\partial y}\right)\right], \tag{14}$$

$$i\omega\alpha_0'+(1-\alpha)\left(ik\mathrm{v}_{10}'+\frac{\partial \mathrm{v}_{20}}{\partial y}\right)+\mathrm{v}\cdot ik\alpha_0'=0, \tag{15}$$

$$u'_{20}\frac{\partial^2 V}{\partial y^2}-\frac{\partial u'_{20}}{\partial y}\frac{\partial V}{\partial y}=\frac{1}{\tau}\left[\left(ikv'_{20}-\frac{\partial v'_{10}}{\partial y}\right)-\left(iku'_{20}-\frac{\partial u'_{10}}{\partial y}\right]-\frac{1}{2S_1}i\omega\left[\left(ikv'_{20}--\frac{\partial v'_{10}}{\partial y}\right)-\left(iku'_{20}-\frac{\partial u'_{10}}{\partial y}\right)\right]-$$
$$-\frac{1}{S_1}i\omega\left(ikV'_{20}-\frac{\partial v'_{10}}{\partial y}\right)+\frac{3}{2}\frac{1}{\sqrt{\tau S_1}}\sqrt{\omega}\,(1--i)\left[\left(ikv'_{20}-\frac{\partial v_{10}}{\partial y}\right)-\left(iku'_{20}-\frac{\partial u'_{10}}{\partial y}\right)\right], \qquad (16)$$

$$-i\omega\alpha'_0+\alpha_0\left(iku'_{10}+\frac{\partial u'_{20}}{\partial y}\right)+v\cdot ik\alpha'_0=0. \qquad (17)$$

(17) - as can be seen from the equation, if the excitation u'_0 specific amplitude of velocity $\delta \ll 1$ If the size, then α'_0 $0(\alpha_0\delta)$ the order size will be here $\alpha_0 \ll 1$. Therefore, as in the [2,3,4,5,6,7] literature, we are at the first approach (14) - (17) in systems α'_0 participating participants $\alpha'_0 = 0$ assuming that we cannot ignore it. In this case, it is convenient to introduce two current functions to integrate the continuity equations (15) and (17).

$$-v'_{10}=\frac{\partial\psi}{\partial y}, \qquad v'_{20}=ik\psi,$$
$$-u'_{10}=\frac{\partial\varphi}{\partial y}, \qquad u'_{20}=ik\varphi.$$

In this case, equations (14) - (17) take the following form:

$$D^2\psi-ik\,Re\left(V-\lambda-\frac{if}{k\tau}\right)D\psi+ik\,Re\frac{d^2V}{dy^2}\psi+\frac{f}{S}D\varphi-i\lambda k\frac{f}{2S_1}(D\varphi-D\psi)+$$
$$+i\lambda k\frac{f}{S_1}D\psi-\frac{3}{2}Re\,f\sqrt{\frac{k}{S_1\tau}}\,(i--1)\sqrt{\lambda}\,(D\psi-D\varphi)=0\ , \qquad (18)$$

$$D\psi-ik\tau\left(U-\lambda-\frac{i}{k\tau}\right)D\varphi+ik\tau\frac{d^2U}{dy^2}\varphi-i\lambda\frac{k}{2S_1}(\partial\psi-\partial\varphi)-i\lambda\frac{k}{S_1}D\varphi-$$
$$-\frac{3}{2}\sqrt{\frac{k\tau}{S_1}}\,(i-1)\sqrt{\lambda}\,(D\varphi--D\psi)=0\ , \qquad (19)$$

here $D=\frac{\partial^2}{\partial y^2}-k^2$, $\lambda=\frac{\omega}{k}$, k –number of waves, $\lambda=\lambda_r+i\lambda_i$ - unknown constant to be determined, λ_r - phase speed, λ_i - growth rate, $f=\alpha_0 S_1$ - the mass-specific concentration of particles, if $\lambda_i>0$ the current will not be constant, otherwise $\lambda_i<0$ is stable when. $\lambda_i=0$ if so, the vibration will be neutral constant.

(18) and (19) in the equations $V(y)$ and $U(y)$ the stationary flow rates of pure gas and particles are determined accordingly.

The boundary conditions for the movements in the Poiseuille stream are as follows:

$$\psi(\pm1)=\frac{d\psi}{dy}(\pm1)=0, \qquad (20)$$
$$\varphi(\pm1)=0. \qquad (21)$$

For pure gas, equation (20) represents the normal condition of impermeability and viscosity, while for solid particles, equivalence condition (21) represents equality.

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