Instability of accelerating aerosol surface

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Keywords: aerosol dynamics; interpenetrating fluids; mixing in aerosol transport
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The problem sometimes arises in motions of dispersed mixtures, which is connected with a character of their interaction with an outer homogeneous medium when the conditions exist for development of hydrodynamic instability at the surface of separation. This mechanism is intensively in work in the process of powder dispersing by the energy of explosion and it can influence the dust motion in high atmosphere leading up to the dynamic coagulation of aerosol. Such problems in practice call forth the necessity to investigate the general properties of governing equations of two-phase media motion. The stability of solutions of such equations has been investigated recently with regard to jam-motions in pipelines, two-phase flows in mixing layers, filtration ousting of one liquid by another. In order to determine the heterogeneity influence on the flow it is insufficient to use the models of homogeneous fluid mechanics and two-phase models are required.

The present investigation shows that, in contrast with homogeneous medium, two-velocity equations of the interpenetrating continua possess three types of disturbances: an entropy-vorticity one along with two acoustic ones. Analysis shows that the acoustic branch of solution is responsible for the mechanism of instability. The latter consists in cumulative convergence of disturbed flow in that part of a disturbance, which is plunging into the outer homogeneous medium. Vice versa, the entropy-vorticity branch of solution determines damping mechanism, which consists in quite opposite, diverging shape of a disturbance and counteracts to the unstable mechanism. It may be a reason of changing spikes and bubbles their places, so that it may really affect the phase convection inside a mixing layer. Namely the extra branch of a solution is responsible for the entropy and vorticity production in a suspension. The present statement includes two cases: the system is under action of gravity force, otherwise it has an acceleration directed perpendicular to the interface.

The linear stability analysis of plane accelerating boundary, which separates monodisperse suspension of solid particles and homogeneous incompressible fluid, reveals two roots of the aperiodic instability. One of them coincides with the classic RT root in the particle absence limit; another root is able to only compete with at huge accelerations. The found instability is governed by the modified Shields and Atwood numbers. In general, heterogeneity somewhat destabilizes a suspension at small volume concentrations, while at a greater content the particles have essentially damping influence on RTI. Fine-particle suspensions have a stronger damping effect than the coarse-particle ones. Thus, heterogeneous influence on RTI can not be ignored even at small particle volume concentrations.

The found type of instability is caused by the action of inertial mass force since it disappears when the acceleration vanishes. The action of the interphase friction is the natural stabilizing mechanism since when the carrying phase viscosity increases, this root disappears too.

For the unstable mechanism, the increment of amplitude growth increases unlimitedly as wavelength tends to zero. Naturally, the disturbance wavelength must be limited from below by such values, at which it becomes comparable with the particle size a, when the equations of two-phase fluid motion become invalid. Thus, such values of wavenumber h may be adopted, for which $ha<0.1$. If we assume that $a=10^{-5}m$ for aerosol particles and $g=9.8\ m/\sec^2$ for the two-phase system acceleration, we obtain value of the characteristic time of e-fold amplitude growth for the fastest disturbance: $\tau_e \approx 10^{-2}\sec$, which is sufficient for the instability proceeding.

Three aerosol systems were considered as examples: atmospheric dust, mist of secondary droplets in a wake of atomizing drop and explosive powder dispersion, which particle density values ρ_{d0} differ drastically. They showed that the main factor of heterogeneity influence is particle fineness, another one – viscosity of a carrying phase. The instability performance is feasible, since characteristic values of the instability induction time are realistic in the considered processes; besides, the obtained theoretically unstable wave lengths agree well with the experimental disturbance sizes.