STABILITY OF A LAYER OF FLUID WITH HEAVY SOLID IMPURITY

O. N. Dementev

Chelyabinsk State University, Chelyabinsk, Russia

A viscous incompressible liquid containing an admixture of heavy solid particles is considered. The liquid and the impurity are assumed to be interpenetrating and interacting with each other continuous media, the interaction between particles is neglected. The interaction between the phases during their relative motion obeys the Stokes law. The volume fraction of particles is so small that the Einstein correction to the fluid viscosity can be neglected. The particles are assumed to be spherical, non-deformable, of the same mass and radius; the density of the particle material is much greater than the density of the liquid.

The fluid fills a horizontal infinite layer bounded by solid parallel planes. Particles with a uniform concentration enter the layer through the upper boundary, and the lower boundary is heated. The particles settle, therefore, in the unperturbed state, there is a transverse motion of the impurity in the layer with a uniform vertical velocity. Particles enter the layer at the temperature of its upper boundary.

In the limiting case of suspended particles, the temperature distribution turns out to be linear along the vertical. With an increase in the settling rate of particles, as well as with an increase in their mass concentration and relative heat capacity, the distortion of the linear distribution of the liquid temperature increases. With a further increase in the above parameters, a boundary layer is formed at the lower boundary, inside which the main change in the temperature of the carrier medium is concentrated.

We will consider the stability of the layer with respect to normal perturbations that are periodic along the horizontal. The resulting boundary value problem determines the spectrum of perturbation decrements and the stability limits for the equilibrium of a liquid (gas) layer containing impurity particles. Decrement of the damping of perturbations depends on the independent parameters of the problem: the Grashof, Prandtl and Galileo numbers (or particle settling velocity), impurity mass concentration, wave number, and relaxation times. To solve the boundary value problem, the Runge–Kutta–Merson step-by-step integration method was used with the Gram–Schmidt orthogonalization of the resulting solution vectors at each integration step; orthonormalization was carried out to the maximum modulo (at this step) solution vector.

With an increase in the mass concentration of an impurity, a temperature boundary layer begins to form at the lower boundary of the layer (there is a “blowing” of the gas temperature distribution). With an increase in the particle velocity, an increase in the distorting effect of the impurity on the temperature distribution of the carrier medium is also observed. The stabilizing effect of the action of particles on the stability of the equilibrium increases in this case. In a layer of air 2 cm thick, the movement of wood particles at a speed of 10 cm/s increases the stability by almost 4 times. However, at high values of the settling rate, its further increase leads to a slight distortion of the established temperature distribution of the carrier medium and, hence, to a small increase in the stabilizing effect.