VIBRODISPERSION-EQUIPMENT DESIGN

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Theoretical dependences are given relating the critical values of the amplitude, frequency, and nozzle diameter to the physical properties of the liquid or gas in the course of drop or bubble formation at a cylindrical nozzle vibrating longitudinally at the frequency of sound.

Recently, in gas–liquid dispersion technology, there has been wide use of vibrodispersion equipment, which serves to intensify heat and mass transfer, chemical reaction, the production of granulated material from a melt, and the preparation of mixtures and conclusions.

The construction of most vibrodispersion equipment is based on the use of outlet and nozzle attachments excited by longitudinal harmonic oscillations at frequencies of up to 1 kHz. The equipment may operate through jet or drop (bubble) emission of the medium being dispersed. The size of the resulting particles is regulated in the range from 100 μm to 2 mm with a high degree of homogeneity (70–90%).

For the successful design of vibrodispersion equipment, it is necessary to have calculation dependences between the particle, diameter, the vibrational intensity, the attachment geometry, and the physical properties of the medium.

The design of jet vibrodispersion, as a rule, is based on Rayleigh–Weber concepts regarding the instability and decay of moving particles. The following expression is often used to determine the jet-excitation frequency f in particle formation [2]

$$f = 0.627\left(\frac{\sigma}{\rho_1 d_j^3}\right)^{\frac{1}{2}}.$$

The excitation wavelength λ and the nozzle diameter D corresponding to this expression must be held within the limits [3]

$$3.5d_j < \lambda < 7d_j,\quad 0.5\ \text{mm} < D < 1.5\ \text{mm}.$$

Investigations have shown [4, 5] that vibrodispersion with drop (bubble) emission ($\mathrm{Re} \le 13 \cdot 10^2$) may be of three main types:

1) the formation of stable particles of diameter

$$d_s = \left[\frac{6D\sigma}{g\Delta\rho + \left(\rho_1 + \frac{1}{2}\rho_2\right)A\omega^2}\right]^{\frac{1}{3}}; \qquad (1)$$

2) nonsteady decay of unstable particles;

3) steady decay of unstable particles to others of smaller diameter, given by the formula

$$d_p = \left[\frac{2\sigma}{g\Delta\rho + \left(\rho_1 + \frac{1}{2}\rho_2\right)A\omega^2}\right]^{\frac{1}{2}}. \qquad (2)$$

The first and third types yield particles of homogeneous size. The second case corresponds to transitional conditions of vibrodispersion, when homogeneity of the particles is low.

The parameters of the transitional stage will now be determined.

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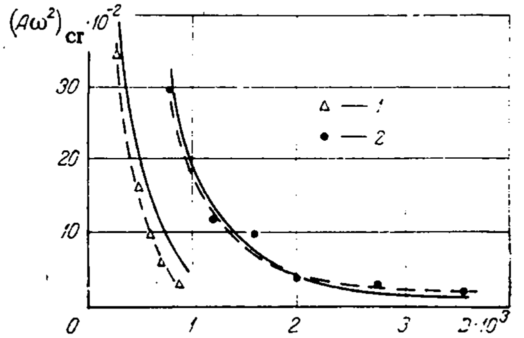

Fig. 1. Comparison of calculated (continuous curves) and experimental (dashed curves) data for the dependence of the vibrational intensity corresponding to transitional conditions of vibrodispersion on the nozzle diameter: 1) molten paraffin (t = 60°C) in air (t = 20°C); 2) air (t = 20°C) in distilled water (t = 18°C). $A\omega^2$, m/sec²: D, m.

As already found [6], the critical diameter of the stable particles forming at a cylindrical nozzle vibrating longitudinally at the frequency of sound is

$$(d_s)_{cr} = \left[\frac{8\sigma}{g\Delta\rho + \left(\rho_1 + \frac{1}{2}\rho_2\right)A\omega^2}\right]^{\frac{1}{2}}. \qquad (3)$$

Comparison of Eqs. (1) and (3) allows the vibration intensity $(A\omega^2)_{cr}$ corresponding to the transition from the formation of stable particles to the decay of unstable particles to be determined

$$(A\omega^2)_{cr} = \frac{1}{\rho_1 + \frac{1}{2}\rho_2}\left(\frac{128\sigma}{9D^2} - \Delta\rho g\right). \qquad (4)$$

If the vibrator has fixed values of A and ω, transitional conditions may be eliminated by appropriate choice of the outlet diameter, which should not exceed the value

$$D_{cr} = \left[\frac{128\sigma}{9g\Delta\rho + \left(\rho_1 + \frac{1}{2}\rho_2\right)A\omega^2}\right]^{\frac{1}{2}}. \qquad (5)$$

Thus, if particles of homogeneous size are to be obtained, the following condition must be satisfied

$$(A\omega^2)_{cr} > A\omega^2 > (A\omega^2)_{cr}$$

or

$$D_{cr} > D > D_{cr}.$$

To obtain particles in a broadly regulated size range, the critical values of A and ω^2 must correspond to the middle of the vibrator operating range.

The usefulness of the proposed recommendations for the design of vibrodispersion equipment operating with drop (bubble) emission was confirmed experimentally for the example of the dispersion of molten paraffin in air (ρ_1 = 0.78 g/cm³, $\rho_2 = 1.2\cdot 10^{-3}$ g/cm³, σ = 27.63 dyn/cm) and for the dispersion of air in distilled water ($\rho_1 = 1.2\cdot 10^{-3}$ g/cm³, ρ_2 = 1.02 g/m³, σ = 72.75 dyn/cm). The diameters of the cylindrical nozzles employed were: 0.3, 0.5, 0.6, 0.7, 0.8, 0.9, 1.2, 1.6, 2.0, 2.8, and 3.6 mm.

The calculated and experimental data are compared in Fig. 1.

NOTATION

σ, interphase surface tension; ρ_1, density of medium being dispersed; ρ_2, density of surrounding medium; Δρ, absolute value of density difference; d_j, jet diameter; A, vibrational amplitude; ω, vibrational angular frequency; g, acceleration due to gravity.

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FEATURES OF A CRYOGENIC FLUID FILLING VAPOR CAVITIES BEING FORMED IN FRONT OF A CUT-OFF ARMATURE

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The fundamental parameters of the unsteady processes of filling a vapor cavity in a short pipeline with water and cryogenic fluids are compared. The influence of flow interaction with the channel walls on the regularities of acceleration and deceleration is established.

An analysis of statistical data on the utilization of industrial cryogenic systems shows [1, 2] that the reason for accidental breakdowns in the equipment is most often the hydraulic shocks associated with the appearance and subsequent filling of the vapor cavities being formed in the mainlines because of the inevitable heat influxes to a cryogenic fluid. These processes possess a number of features, among which should be noted:

The vapor cavities are formed on sections with a temporary stop in the circulation (before a closed armature and in dead-end branches), a driving pulse appears because of the resumption of circulation or an abrupt rise in pressure in the system;

The governing influence on the regularities of the phenomenon is exerted by specific properties of the working fluids (nearness to the saturation curve, low heats of vapor formation and condensation);

The phenomenon is characterized by a kinematic and thermal nonstationarity as well as short duration;

The mutual influence of the hydrodynamic flow parameters and the heat and mass-transfer processes during interaction between the cryogenic fluid and the walls of the mainline and the vapor volume plays an essential role which complicates the development of a computational model considerably.

The main attention in this paper is spent on clarifying the qualitative regularities. The mechanism of the phenomenon was investigated by comparing the stream parameters with heat transfer present and absent. This was achieved because of a step-by-step execution of the experiments: initially with a high-boiling fluid (water), which afforded the possibility of the total elimination of heat transfer from the consideration and the investigation of the dependence of the nature of the process on the initial and boundary conditions (size of the gas cavity, pressurization, capacity of the terminal resistance) and also of giving a physical interpretation of the effects detected. Tests with cryogenic fluids (nitrogen and oxygen) under the same conditions permitted clarification of the influence of the thermal interaction between the stream and the channel walls on the regularities obtained earlier.

The experimental set-ups were analogous to the diagram (Fig. 1) and consisted of a 100-liter capacity pressure vessel, a working pipeline of diameter $d_y = 50$ mm and length $l = 4$ m, a fast-response valve, a set of terminal resistances, a pressurization system, and a measuring complex. The KIP system permitted writing the following quantities: the pressurization in the supply tank; the pressure in the vapor cavity in front of the diaphragm; the velocity of fluid motion; the behavior of the valve disk; and the temperature of the vapor,

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