MAXIMUM SHEAR STRESS OF EMULSION WITH A MAGNETIC PHASE

V. F. Medvedev, M. S. Krakov, and V. I. Bakalenko

UDC 532.135:541.18.051.3:537.84

The article determines the effect of a homogeneous magnetic field on the maximum shear stress of a dense emulsion with a magnetic phase.

Obtaining magnetic liquids with specified properties [1] makes it possible to use them as disperse phase of emulsions serving as working medium in various mass-exchange processes. For the hydraulic calculation of mass-exchange apparatus we have to know the rheological properties of emulsions. One of the factors determining these properties is the shape of the drops of the disperse phase [2]. Under the effect of magnetic forces the spherical drops of a magnetic liquid are elongated along the magnetic field lines [3].

Medvedev [4] suggested the model of a dense unstable emulsion. According to this model the maximum shear stress is proportional to the work expended on changing the surface area of a drop in consequence of shear strain:

$$\tau_0 = \frac{6\beta\sigma\triangle f}{\pi d^3 \operatorname{ctg}\Theta}. \tag{1}$$

When drops of the disperse phase are elongated under the effect of a magnetic field, their surface area changes. In view of this (1) assumes the form

$$\tau_0 = \frac{6\beta\sigma(\Delta f - \Delta f_m)}{\pi d^3 \operatorname{ctg}\Theta} = \frac{6\beta\sigma\Delta f}{\pi d^3 \operatorname{ctg}\Theta} - \frac{6\beta\sigma\Delta f_m}{\pi d^3 \operatorname{ctg}\Theta}. \tag{2}$$

We determine the effect of the magnetic field on the surface area of the drops of the disperse phase. When the elongations are small, the drops assume the shape of ellipsoids. The semiaxes of the ellipsoid are correlated with the initial diameter of the sphere by the relations

$$a = \frac{hd}{2};\quad b = \frac{d}{2\sqrt{h}};\quad h = 1 + \varepsilon. \tag{3}$$

The dependence of the relative elongation h on the magnetic field intensity is determined by the expression [5]

$$\frac{\mu_0 H_0^2 \chi^2 d}{4\sigma(1 + n_x\chi)^2} = 2h^2 - \frac{1}{h^2\sqrt{h}} - h, \tag{4}$$

where $n_x = \frac{1 - e^2}{2e^3}\left(\ln\frac{1 + e}{1 - e} - 2e\right)$. When we substitute (3) into (4), we obtain for small ε

$$\varepsilon = \frac{\mu_0 H_0^2 \chi^2 d}{22(1 + 1/3\chi)^2\sigma}. \tag{5}$$

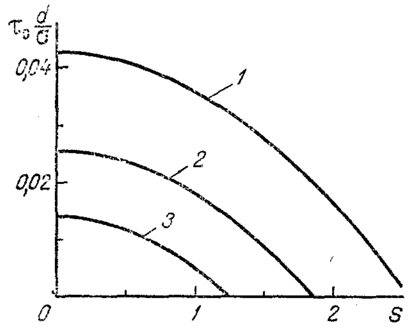
We write the change of area of the ellipsoid under the effect of the magnetic field for small elongations

$$\Delta f_m = \pi d^2 \frac{2}{5}\varepsilon^2. \tag{6}$$

With a view to (5) and (6) expression (2) assumes the form

S. M. Kirov Belorussian Technological Institute, Minsk. Translated from Inzhenerno-Fizicheskii Zhurnal, Vol. 51, No. 1, pp. 52-55, July, 1986. Original article submitted May 14, 1985.

 0022-0841/86/5101-0790$12.50



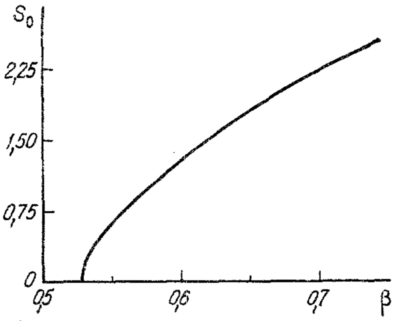


Fig. 1 Fig. 2

Fig. 1. Dependence of $\tau_0\, d/\sigma$ on the parameter S: $\beta = 0.741$ (1); 0.655 (2); 0.596 (3).

Fig. 2. Dependence of S_0 on the volume fraction of the disperse phase β.

$$\tau_0 = \frac{6\beta\sigma\Delta t}{\pi d^3 \operatorname{ctg}\Theta} - \frac{3\beta S^2\sigma}{605 \operatorname{ctg}\Theta d}, \tag{7}$$

where

$$S = \frac{\mu_0 H_0^2 \chi^2 d}{\sigma(1+1/3\chi)^2}.$$

Following [4] we write

$$\frac{6\beta\sigma\Delta f}{\pi d^3 \operatorname{ctg}\Theta} = (0{,}195\beta - 0{,}102)\frac{\sigma}{d}. \tag{8}$$

We find the dependence of Θ on the volume fraction of the disperse phase β from the expression [4]

$$\beta = \frac{\pi}{6(1-\cos\Theta)\sqrt{1+2\cos\Theta}}. \tag{9}$$

With an error of 1.5% this dependence has the form

$$\Theta = 90 - 56{,}8(\beta - 0{,}524)^{0{,}43}. \tag{10}$$

Substituting (8) and (10) into (7) we obtain an expression for determining the effect of a homogeneous magnetic field on the maximum shear stress of a dense emulsion with magnetic phase

$$\tau_0 = \left\{0{,}195\beta - 0{,}102 - \frac{3\beta S^2}{605 \operatorname{ctg}[90 - 56{,}8(\beta - 0{,}524)^{0{,}43}]}\right\}\frac{\sigma}{d} = \{39{,}325\beta - 20{,}57 - \beta S^2 \operatorname{tg}[90 - 56{,}8(\beta - 0{,}524)^{0{,}43}]\}\frac{\sigma}{d}, \tag{11}$$

which is illustrated in Fig. 1.

With some value $S = S_0$ the maximum shear stress becomes equal to 0, and this enforces Newtonian behavior of the emulsion. Consequently, acting by a magnetic field on a dense emulsion with a magnetic phase, we can change the maximum shear stress, and with $S = S_0$ we can change the nature of the behavior of the liquid. The curve in Fig. 2 makes it possible to determine the field intensity necessary for overcoming the maximum shear stress with different contents of disperse phase. In the region above the curve the emulsion behaves similarly to a Newtonian liquid, in the region below the curve it behaves similarly to a non-Newtonian liquid.

NOTATION

τ_0, maximum shear stress; β, volume fraction of the disperse phase; σ, interfacial tension; d, initial drop diameter; Θ, acute angle of the rhombohedron side formed by the centers of the drops, deg; Δf, change of surface area in consequence of deformation of drops of disperse phase in shear; Δf_m, change of surface area of a drop under the effect of a magnetic field; a and b, major and minor semiaxis of the ellipsoid, respectively; h, relative elongation of the drop; $e = \sqrt{1-b^2/a^2}$, eccentricity of the ellipsoid; μ_0, magnetic permeability of vacuum; χ, magnetic susceptibility; H_0, intensity of the external magnetic field; n_x, demagnetizing factor; S, dimensionless complex.

LITERATURE CITED

1. S. E. Khalafalla, "Magnetic fluids," Chem. Technol., 5, No. 19, 540-546 (1975).
2. A. I. Guzhov, A. P. Grishin, L. P. Medvedeva, and V. F. Medvedev, "The mechanical behavior of unstable emulsions," Inzh.-Fiz., Zh., 30, No. 3, 467-472 (1976).
3. V. G. Bashtovoi, A. G. Reks, and E. M. Taits, "The effect of a homogeneous magnetic field on the shape of the drop of a magnetic liquid," in: Applied Mechanics and Rheophysics [in Russian], ITMO AN BSSR, Minsk (1983), pp. 40-45.
4. V. F. Medvedev, "Maximum shear stress of emulsions," Inzh.-Fiz. Zh., 24, No. 4, 715-718 (1973).
5. É. Ya. Blum, Yu. A. Mikhailov, and R. Ya. Ozols, Heat and Mass Exchange in a Magnetic Field [in Russian], Zinatne, Rige (1980).
6. L. D. Landau and E. M. Lifshits, Electrodynamics of Continuous Media, Pergamon (1960).

DIFFUSION-CONVECTION MODEL OF GRAVITATIONAL SEPARATION IN A POLYDISPERSE SUSPENSION

V. G. Deich

UDC 622.762

A model of the evolution of the volume concentration fields of the separate fractions of a polydisperse suspension is presented. For the case of two fractions a solution is obtained in the static regime illustrating the mechanism of separation with respect to particle size.

The majority of papers on the mathematical modeling of disperse flows in technological apparatus use a system of equations for a multivelocity continuum [1]. The hyperbolic nature of this system leads to solutions of the wave type with very sharp surfaces of discontinuity (see, for example, [2]). In practice, however, the concentration fields of the components of a disperse mixture are spread out, and this implies that the equations describing their evolution are parabolic. In [3] a parabolic equation was introduced (the Fokker–Planck equation) for the distribution functions of the velocities and positions of solid particles in a suspension, taking into account random forces of the white noise type which act on the particles. Such forces can result from the turbulence of the flow of the liquid phase [4], but, as indicated in [5], often laminar motion exists as well.

In the present paper we derive a system of equations of the parabolic type for the concentration fields of narrow fractions of a polydisperse suspension. It is assumed that the temporal viscous relaxation of the velocities of the solid particles can be neglected and that their steady-state values are determined with the help of well-known semiempirical formulas.

We write the equation of motion of a particle in the Stokes regime of sedimentation:

$$\frac{\rho_p \pi d^3}{6}\frac{du}{dt} = \frac{(\rho_p - \rho_f)\pi d^3 g}{6} + 3\pi\mu d\Phi(c)w + F'(t), \tag{1}$$

where the dimensionless function $\Phi(c)$ takes into account the effect of the other particles (hindrance) on the hydrodynamical drag. It is assumed that the most important contribution to the stochastic term $F'(t)$ comes from fluctuations in c:

$$F' = 3\pi\mu d\langle w\rangle \frac{d\Phi}{dc}\Delta c, \tag{2}$$

G. V. Plekhanov Leningrad State University. Translated from Inzhenerno-Fizicheskii Zhurnal, Vol. 51, No. 1, pp. 55-60, July, 1986. Original article submitted April 23, 1985.

 0022-0841/86/5101-0792$12.50