THE STABILITY OF KEROSENE BASED FERROFLUID: MAGNETIZATION MEASUREMENTS [1)]

УСТОЙЧИВОСТЬ ФЕРРОЖИДКОСТЕЙ, ОСНОВАННЫХ НА КЕРОСИНЕ: ИЗМЕРЕНИЯ МАГНЕТИЗАЦИИ

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Ferrofluids are a colloidal dispersion of single domain particles in a liquid carrier. They are attractive materials from the point of view of technical applications [1]. The stability of ferrofluids is crucial for the use of these materials in various devices. Therefore the single domain magnetic particles are made small to prevent a spontaneous gravitational sedimentation. To prevent particle agglomeration through the Van der Waals attractive forces and magnetostatic interparticle interactions the particles are generally coated with long-chain polar molecules. If this were not accomplished, these interactions would rapidly lead to particle agglomeration and large phase separation. The presence of a surface coating and the stability acquired are the principal questions of the technology of magnetic fluids. The room temperature magnetization curve of the ferrofluid indicates a superparamagnetic behaviour. For a ferrofluid containing particles of one size magnetization would be described by the Langevin function $L(ax)$. However, real ferrofluids contain particles of diferent sizes. Taking this into account one may express the magnetization as [2]:

$$I(H) = I_s \int_0^{\infty} L(ax) f(x)\, dx, \qquad (1)$$

where $L(y) = \operatorname{cotgh} y - \frac{1}{y}$ is the Langevin function, I_s' is the saturation magnetization of the bulk material, $a = \pi I_s' D_r^3 H / 6 k_B T$, $x = D/D_r$ is the reduced diameter, D_r is the median diameter of the particles, $f(x)$ is the particle size distribution function. There is evidence to suggest that the log-normal distribution function occurs in fine particle systems [3].

For a log-normal distribution of non interacting particles in a ferrofluid the median diameter D_r of the volume distribution and the standard deviation σ are given by [2]

$$D_r = \left[\frac{18 k_B T}{\pi I_s'}\left(\frac{\chi_i \mu_0}{3 I_s H_0}\right)^{1/2}\right]^{1/3} \qquad (2)$$

and

$$\sigma = \frac{1}{3}\left[\ln\left(\frac{3\chi_i \mu_0 H_0}{I_s}\right)\right]^{1/2}, \qquad (3)$$

where χ_i is the initial susceptibility, I_s is the saturation magnetization of the fluid, I_s' is that of the bulk material and H_0 is the field for which the initial slope of the I vs $1/H$ graph of the fluid intercepts the $1/H$ axis as defined by Chantrell et al. [2].

We have studied the stability of kerosene-based ferrofluid with Fe_3O_4 particles stabilized by the oleic acid, using magnetization measurements. The magnetization of a ferrofluid in an applied magnetic field was obtained using an induction magnetometer.

Fig. 1 shows the magnetization curves for an as-prepared ferrofluid and after 2, 9, 14 days of spontaneous gravitational sedimentation and aggregation effects.

After 14 days the ferrofluid was stabilized. This was confirmed by magnetization measurements after one and two months after preparation within the framework of experimental accuracy.

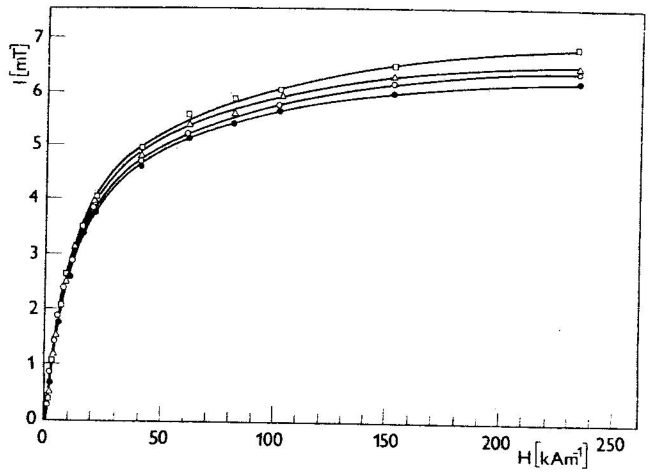

Fig. 1. The magnetization curves for a kerosene based ferrofluid for as prepared 0 and after 2, 9, 14 days of gravitational sedimentation. Full lines are theoretical curves based upon the superparamagnetism theory.

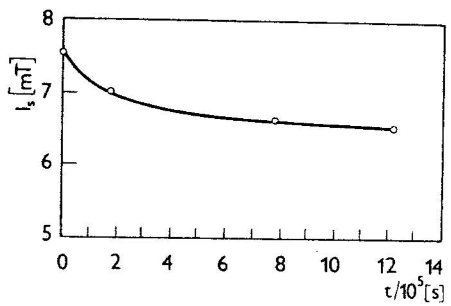

Fig. 2. The time evolution of the saturation magnetization of the ferrofluid.

Fig. 2 shows the time evolution of the saturation magnetization I_s. Using eqs. (2), (3) we have calculated the parameters σ, D_r of the log-normal particle size distribution illustrated in fig. 3. By means of these parameters we have calculated from (1) the theoretical lines of the magnetization curves (full lines in fig. 1).

Fig. 4 gives the time evolution of the log-normal particle size distribution function.

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From these measurements we can conclude that there exists a spontaneous gravitational sedimentation of magnetic particles (the change of saturation magnetization I_s) and an aggregation of magnetic particles (a decrease of the standard deviation σ and a small increase of the median diameter D_v). That means that small particles form via agglomeration the larger ones which can easily sediment.

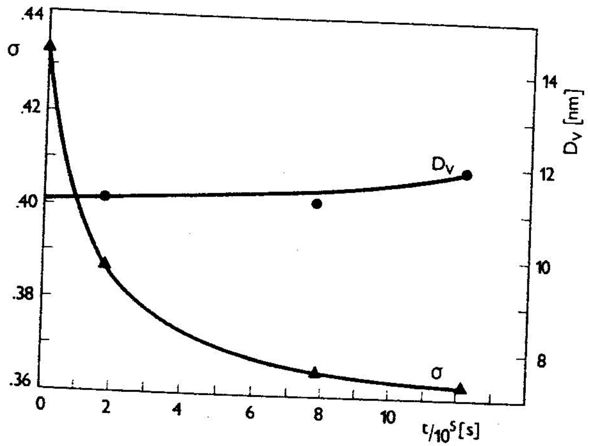

Fig. 3. The parameters of log-normal particle size distribution: D_v is the median diameter of magnetic particles, σ is standard deviation.

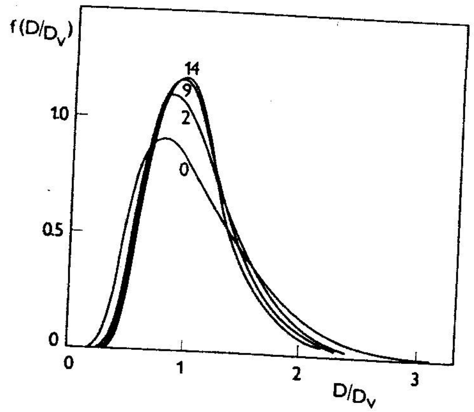

Fig. 4. The time evolution of the log-normal particle size distribution (0, 2, 9, 14 — days of spontaneous sedimentation).

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