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INVESTIGATION OF MICRO-STRUCTURAL PROPERTIES OF MAGNETIC FLUIDS BY MEANS OF THE DILUTION SERIES METHOD

Maria Poienar[1], C. N. Marin[2]

[1] *National Institute for Research and Development in Electrochemistry and Condensed Matter, Tîrnava 1, 300223 Timişoara, Romania*

[2] *West University of Timişoara, Faculty of Physics, Dept. of Electricity and Magnetism, Bd. V. Pârvan, no. 4, 300223, Timişoara, Romania*

Abstract

Series of dilutions of a kerosene-based magnetic fluid with magnetite particles stabilized with oleic acid is employed to study the colloidal stability of the magnetic fluid, using magnetization curve measurements. Analyzing the dependence of the mean magnetic diameter of particles on their volume fraction in the magnetic fluid, information regarding the colloidal stabilization of particles within magnetic fluid is obtained. The result of the analysis is supported by the magneto-optic investigations of the magnetic fluid.
Keywords: magnetic fluids, particle agglomeration.

1. Introduction

Magnetic fluids are stable colloidal systems consisting of single-domain magnetic particles, dispersed in a carrier liquid. In order to prevent the agglomeration of particles, these are coated with surfactant [1].

Neglecting the interparticle interactions, the magnetization of magnetic fluids follows the Langevin dependence [1]:

$$M = \int_0^\infty \frac{n\pi D^3 Ms}{6}\left[\coth\left(\frac{\mu_0 \pi D^3 MsH}{6kT}\right) - \frac{6kT}{\mu_0 \pi D^3 MsH}\right] f(D) dD \qquad (1)$$

where n is the particles concentration; D is the magnetic diameter of a particle; Ms is the spontaneous magnetization of the bulk material of the particles; $\mu_0 = 4\pi\cdot 10^{-7}$ He/m is the free space permeability; H is the intensity of the magnetic field; k is the Boltzmann's constant; T is the temperature of the system and $f(D)$ is the particle size distribution.

Depending on the type and on the size of particles, on the thickness and on the type of surfactant, on temperature or on the presence of an external magnetic field, inside the magnetic fluids particle agglomerations may occur.

The aim of this paper is to present an investigation method of the colloidal stability of magnetic particles in magnetic fluids.

2. Experimental results and discussions

The investigated sample was a commercial kerosene-based magnetic fluid with magnetite particles stabilized with oleic acid. Starting from an initial sample, other four samples were prepared by successive dilution with kerosene. For each sample, the magnetization curve was drawn, by means of the ballistic method and the results are presented in Fig. 1.

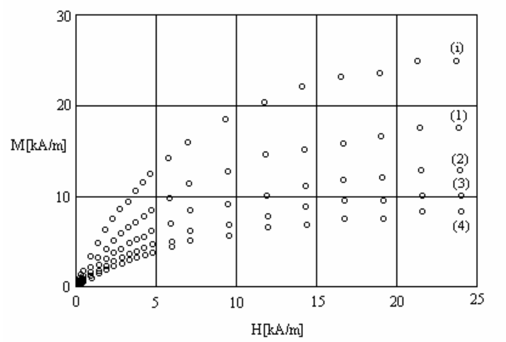


Fig.1. Static magnetization curves of the magnetic fluid at different dilutions ((i) – initial sample, (1) – the first dilution, (2) – the 2nd dilution, (3) – the third dilution and (4) – the fourth dilution)

Fitting the theoretical dependence (1) to the experimental curves and assuming a log-normal particle size distribution (given by the Eq. (2)) the parameters $\mu = \frac{1}{2}\ln\left[\frac{D_{med}^2}{1+\left(\frac{\Delta}{D_{med}}\right)^2}\right]$ and $\sigma = \sqrt{\ln\left[1+\left(\frac{\Delta}{D_{med}}\right)^2\right]}$ were determined. Here, D_{med} is the average magnetic diameter of particles and Δ is the standard deviation of the particle size distribution.

$$f(D) = \frac{1}{\sqrt{2\pi}\sigma D}\exp\left[-\frac{1}{2}\left(\frac{\ln(D)-\mu}{\sigma}\right)^2\right] \quad (2)$$

Using the parameters μ and σ (as determined from the fit), the average magnetic diameter D_{med} of the particles was computed with the relation: $D_{med} = \exp\left(\mu + 0.5\sigma^2\right)$

(3)

The error in the determination of the mean magnetic diameter was computed with the relation:

$$\Delta D_{med} = (\Delta\mu + \sigma\Delta\sigma)D_{med} \tag{4}$$

where $\Delta\mu$ and $\Delta\sigma$ are the standard errors of the parameters μ and σ, as determined from the fit.

Fig. 3 presents the dependence of the mean magnetic diameter of particles on their volume fraction, Φ in magnetic fluid. One can observe that D_{med} decreases with the dilution of the magnetic fluid.

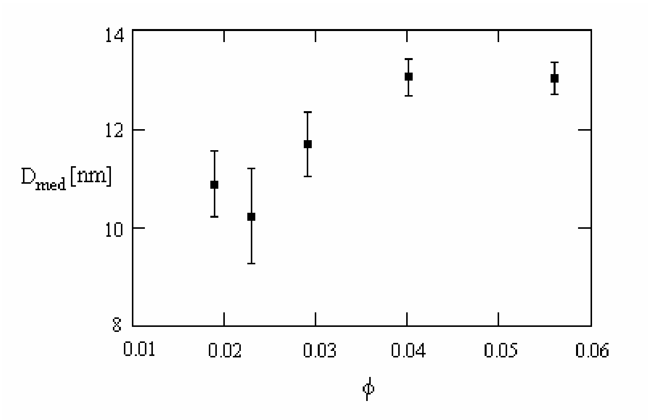
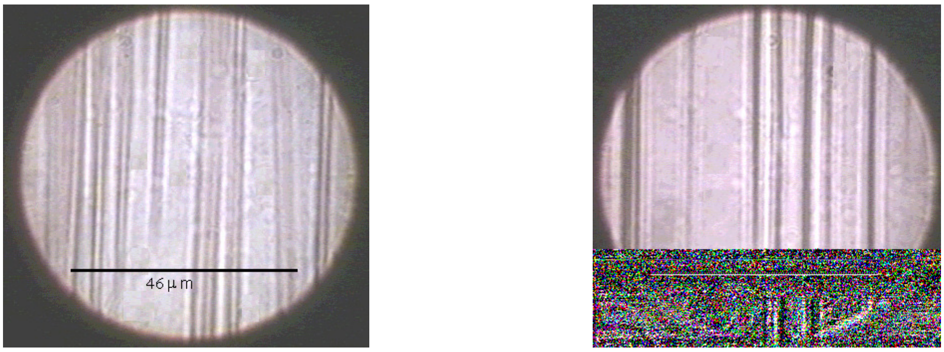


Fig.2. The experimental dependence of the mean magnetic diameter of particles, D_{med} , on the magnetic fraction of particles, ϕ

The fact that the mean magnetic diameter of particles depends on their volume fraction is a deviation from the Langevin behaviour. This deviation can be theoretically explained in terms of interparticle interactions and particles agglomeration [2], [3]. To uphold the assertion that the change of D_{med} with ϕ is due to the particle agglomeration, we analysed the samples under the optic microscope. The experimental arrangement is similar to that one from Ref. [4]. The optic microscope analysis demonstrated that in each sample subjected to a static magnetic field, large particle agglomerations occur. In Fig. 3, microscope images are presented for the initial sample and for the most diluted sample and the particle agglomerations appear as black stripes. Based on the microscope analysis, we can assert that the dependence of mean magnetic diameter of the particles on their volume fraction is due to the magnetic dipole-dipole interactions between the particles and to the formation of particles agglomeration.



a) *b)*

Fig.3. Microscope images of the initial sample (a) and of the most diluted sample (b) in H=11.2kA/m.

3. Conclusions

Based on the Langevin approximation, the magneto-granulometry of a dilution series of a magnetic fluid was performed. The experimental results demonstrated that the mean magnetic diameter of the particles changes with dilution, thus the Langevin approximation is not valid for this magnetic fluid.

As resulted from the magneto-optic analysis, within the samples subjected to a magnetic field, large particle agglomerations occur. Therefore, the deviation from the Langevin behaviour is due to the interactions between the particles and to the formation of particles agglomeration into the magnetic fluid.

As a final conclusion, we can assert that the magneto-granulometry of a dilution series of magnetic fluid may be utilised for the analysis of the colloidal stability of magnetic fluids. Thus, if the mean magnetic diameter of particles changes with dilution of the magnetic fluid sample, then the sample is colloidal unstable with dilution, or particle agglomerations occur in the presence of a static magnetic fluid.

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