Journal of Magnetism and Magnetic Materials 201 (1999) 38–40

Journal of magnetism and magnetic materials

www.elsevier.com/locate/jmmm

Magnetic fluids of low viscosity

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Received 10 June 1998; received in revised form 18 November 1998

Abstract

A high gradient magnetic separation method is proposed to obtain, lower viscosity magnetic fluid samples starting from an initial one. Experimental results, obtained for different magnetic field intensities applied to the separation cell and different magnetic fluid flow rates, have shown that the method allows to obtain magnetic fluids 2–3 times less viscous than the initial ones, at the same samples' saturation magnetization. © 1999 Elsevier Science B.V. All rights reserved.

Keywords: Viscosity; Magnetic fluids; High gradient magnetic separation

1. Introduction

A brief analysis of magnetic fluid (MF) applications shows that in most of the cases MFS with higher saturation magnetization and lower viscosity are required. However, many theoretical and experimental studies have shown that the increase of the MF saturation magnetization brings about a significant increase of the MF viscosity caused by particle interactions and polydispersivity [1].

The aim of our study was to find a practical method to obtain, starting from usual MF, final MF with the lowest possible viscosity, by decreasing the particle interactions and polydispersivity.

Some theoretical and experimental studies have shown the presence in many samples of MF of an important solid phase with low magnetic properties (very small or non-monodomenic particles) which gives a low contribution to the MF magnetizaion but a high contribution to the MF viscosity. The removal of this phase from the MF can determine an important reduction of its viscosity.

It was also shown that important increase of MF viscosity is determined by small clusters formation even in good quality MFs. The clusters formation mechanism is mainly an accretion one, in which small particles are attracted by the large ones. Therefore, a narrow distribution function of the particles by their dimensions will allow to obtain lower viscosity MFS.

In the classical methods of centrifugation and high gradient magnetic separation (HGMS) of the MF, particles migration in the separated samples occur and the final obtained samples always contain the same class of particles with more or less different distribution function of their dimensions. Our main idea was to retain a narrow class of good magnetic particles and to eliminate all the other classes.

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PII: S0304-8853(99)00115-8

2. Experimental method and results

The experimental method consists of a HGMS of the MF, using the technique described in paper [2]. A schematic diagram of the separation cell is presented in Fig. 1. Between the polar pieces 1 of an electromagnet, is set a vertical glass tube 2 filled up with the randomized ferromagnetic lattice 3 made of stainless steel wire having 0.1 mm diameter. The packing fraction of the lattice was 10%. The feeding device 4 together with the valve 5 allows to control the movement of the different substances in the cell.

The experimental procedure is as follows:

In the first step, the separation cell is filled with an initial sample of 10 ml of MF (denoted as type 'E'), in the presence of a magnetic field. A particle migration to the ferromagnetic wires occurs and a concentration of the magnetic particles around the wires is obtained. Initially, for a short period (experimentally determined by us to be about 10 min and maintained in all experiments) very small and non-magnetic particles were not concentrated around the wires.

In the second step, 10 ml of pure liquid, that is the basic liquid of the MF was injected into the separation cell through the feeding device 4, the feeding rate (liquid velocity in the cell) being controlled by the valve 5. In this way, the liquid matrix of the MF containing very small and non-magnetic particles not retained around the wires is pushed out of the separation cell and replaced by the pure liquid. We have also shown [2] that, depending on the intensity of the magnetic field applied to the cell and liquid flow rate through the cell, the hydrodynamic forces can exceed the magnetic forces acting on very large particles that will be carried out together with the mentioned liquid matrix. During this step, a final sample of MF, denoted as type 'A' is collected through the valve 5.

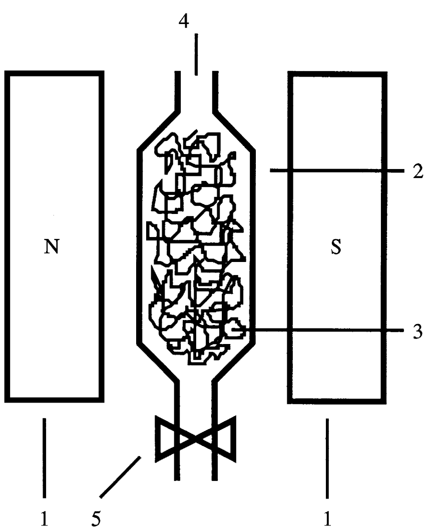

Fig. 1. Schematic diagram of the separation cell.

In the third step, the magnetic field applied to the separation cell is cut and another final sample of MF, retained in the cell during separation in magnetic field and denoted type 'B', is collected. Obviously, this sample contains a narrow class of particles dispersed in the pure liquid. By choosing an adequate magnetic field intensity and liquid flow rate inside the cell, during the first and second presented steps, we have obtained quasi-monodomenic MF.

Experimental results were obtained for MF based on magnetic particles coated with oleic acid and dispersed in kerosene. The magnetic field intensity during the separation processes was between 100 and 400 kA/m and the liquid velocity in the cell was between 0.1 and 1 mm/s.

The viscosity measurements were achieved using a capillary viscometer with suspended level (capillary tube having 15 cm length and 1 mm diameter), at constant temperature (17°C).

For a better comparison, the final samples of type A and B were concentrated near the initial samples saturation magnetization, by forced evaporation.

In Fig. 2, the experimental results obtained for the effective viscosity coefficient versus magnetic field intensity, are presented in the case of an initial sample (1) and the final samples of type A (2) and B (3). The intensity of the magnetic field applied to the separation cell was 250 kA/m and the MF velocity in the cell was 0.2 mm/s. All the samples had a saturation magnetization of 150 Gs.

The magnetization curves were obtained for magnetic field intensities up to 500 kA/m using the method Gouy 5 [3]. The distribution functions of the particles by their magnetic radius, determined

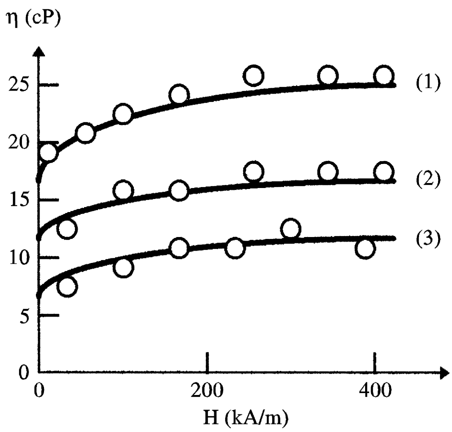

Fig. 2. Dynamic viscosity coefficient versus external magnetic field intensity for samples E (1), A (2) and B (3).

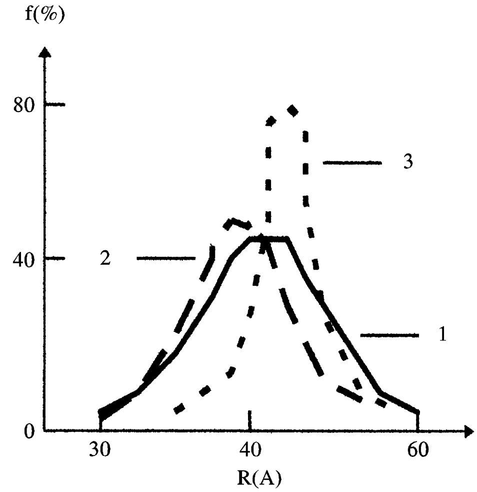

Fig. 3. The distribution functions of the particles by their magnetic radius for samples E (1), A (2) and B (3).

from the magnetization curves with an absolute error of 5 Å, are presented in Fig. 3 for the same samples E(1), A(2) and B(3).

Fig. 2 shows some interesting results. Curve 1, obtained for the initial sample, is a typical one, obtained for almost MF. Saturation of the effective viscosity coefficient is not obtained at high magnetic field. The cluster formation caused by the strong particle interactions and MF polydispersivity determine a slow increase of the viscosity with the field.

Curve 2 shows a lower viscosity of the sample of type A, caused by a lower polydispersivity of the MF. The cluster formation is much lower in this case and a saturation of the effective viscosity coefficient occurs.

Curve 3, obtained for the sample of type B, shows a remarkable result: the effective viscosity coefficient is about two times lower with respect to the initial sample. This effect is due to the narrow distribution of the particles by their dimension and to the removal of the particles with low magnetic properties.

Similar results obtained for several samples of MF, in different conditions of MF treatment in the separation cell. Further investigation in order to obtain a maximum effect (a minimum viscosity) is necessary.

3. Conclusion

The exchange of the liquid matrix of the MF, using the HGMS method proposed, allows to obtain from given samples of MF, other MF samples with lower viscosity and higher stability.

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