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Stability of Magnetic Fluids in Magnetic Fields

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Stability of magnetic fluids in magnetic fields is one of the major factors determining the possibility of their practical use and resource of their exploitation. This paper examines the stability of magnetic fluids based on kerosene in constant and variable magnetic fields. It is shown that the synthesized magnetic fluids are stable during long-term exposure to magnetic fields and can be used as the working fluid in a number of magnetic fluid devices.

Keywords: Magnetic fluid, Colloidal stability, Magnetic field.

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1. INTRODUCTION

Magnetic fluids (MF) is a colloidal system of single-domain magnetic particles (disperse phase) dispersed in a carrier liquid (dispersion medium) [1]. The combination of the properties of the magnetic material and the liquid, which does not exist in known natural materials, has opened up ample opportunities for development of technical devices with magnetic fluid as the working fluid.

The effectiveness of engineering applications of magnetic fluids is determined by a combination of the required performance parameters (saturation magnetization, viscosity, temperature range, vacuum properties, etc.). However, the main criterion for the quality and efficiency of magnetic fluids is their colloidal stability in static mode as well as under external influence. Methods for colloidal stability determination in static mode and thermal stability of magnetic fluids were considered in one of the previous papers [2]. This paper deals with the stability of magnetic fluids in magnetic fields.

2. EXPERIMENTAL DETAILS

In most magnetic fluid devices magnetic fluids are under the constant influence of the magnetic field. That is why the stability of magnetic fluids in constant and variable magnetic fields becomes one of the most important factors determining the possibility of their practical use and resource exploitation.

As a sample, the synthesized magnetic fluid based on kerosene (MKK 001-60) was used. The magnetic fluid on kerosene basis is the least viscous among all magnetic fluids, hence if the MF is inherently unstable the carrier fluid outflow followed by MF stratification in the magnetic field will be most evident. The experiment was also conducted with the magnetic fluids obtained by dilution of the initial magnetic fluid. Magnetic fluid MKK 001-60 specifications are given in Table 1.

Magnetic fluid density was measured according to GOST (national standard) 18995.1-73 at 20 °C. MF plastic viscosity was measured according to GOST 26581-85 at 20 °C using a rotary viscometer RHEOTEST RN4.1. To measure magnetic fluid saturation magnetization the ballistic method was employed.

The study of magnetic fluids stability in magnetic fields was carried out in two stages.

During the experiment (the first stage), the magnetic fluid MKK 001-60 (MF volume is 10 ml), was poured into a tube made of non-magnetic material mounted in the gap between the tapering poles of an electromagnet FL-1 (Fig. 1). The magnetic field set in the gap was inhomogeneous. The maximum induction in the minimum gap at point C was $Bmax = 2.4$ Tesla and the minimum value at point D close to the bottom exterior surface MF – $Bmin = 0,6$ Tesla. The average value of gradient induction modulus is 25.7 T/m. Continuous exposure to high gradient magnetic field on the magnetic fluid was two hours.

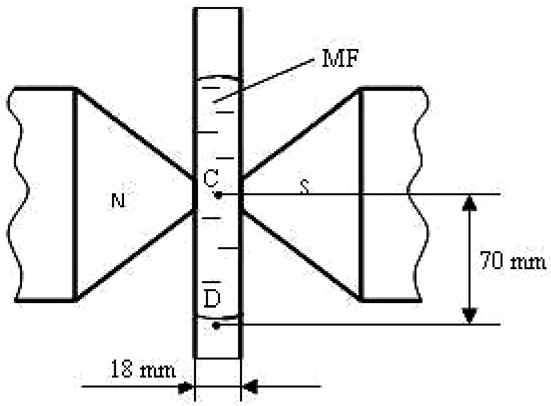

Fig. 1 – The experimental setup

In this experiment, the visual outflow of carrier fluid in a magnetic field was not observed for either initial magnetic fluid or magnetic fluids obtained by dilution.

On the second stage sealed glass cups of 50 mm in diameter containing magnetic fluids MKK 001-60 and MKK 001-60 (10) (MF volume is 100 ml) were kept for two months in constant magnetic field, the induction was 0.8 Tesla. Five days following the magnet removal the top layer of magnetic fluid was taken without stirring to determine the density, plastic viscosity and saturation magnetization. The remaining magnetic fluid was centrifuged after which its density, plastic

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Table 1 – Magnetic fluids specifications

Magnetic fluid type	Volumetric content of magnetite, %	Saturation magnetization, kA/m	Density, g/cm^3	Plastic viscosity, P·s
МКК 001-60	15,8	59,9	1,469	0,286
МКК 001-60 (1)	14,5	55,2	1,415	0,135
МКК 001-60 (2)	13,3	50,4	1,360	0,0702
МКК 001-60 (3)	11,9	45,3	1,301	0,0379
МКК 001-60 (4)	10,6	40,3	1,243	0,0231
МКК 001-60 (5)	9,3	35,3	1,186	0,0172
МКК 001-60 (6)	7,9	30,0	1,125	0,013
МКК 001-60 (7)	6,3	23,9	1,055	0,0102
МКК 001-60 (8)	5,3	20,1	1,011	0,00814
МКК 001-60 (9)	4,1	15,6	0,959	0,00698
МКК 001-60 (10)	2,6	10,0	0,895	0,00603

Table 2 – Specifications of magnetic fluids after two-month constant magnetic field exposure

Magnetic fluid type	Saturation magnetization, kA/m	Density, g/cm^3	Plastic viscosity, P·s
МКК 001-60 (top layer)	60,6	1,471	0,288
МКК 001-60 (after centrifugation)	60,6	1,471	0,287
МКК 001-60 (10) (top layer)	10,5	0,902	0,00611
МКК 001-60 (10) (after centrifugation)	10,5	0,902	0,00613

viscosity and saturation magnetization was also measured. Table 2 shows the specifications of magnetic fluids MKK 001-60 and MKK 001-60 (10), determined after two-month constant magnetic field exposure.

Tables 1 and 2 show that saturation magnetization, density and viscosity of magnetic fluids MKK 001-60 and MKK 001-60 (10), measured after two-month constant magnetic field exposure, practically coincide with specifications of similar initial MFs. A slight increase (less than 1 %) of some parameters is within instrumental error.

3. RESULTS AND DISCUSSION

The stability of magnetic fluids including their resistance to magnetic fields is influenced by various factors. The foremost are the amount of energy of the adsorption interaction between surfactant molecules and active sites on particle surface in the dispersed phase; affinity of the nonpolar part of the surfactant molecules with the carrier fluid; the presence or absence of unprotected areas on dispersed-phase particle surface; mono- or polydispersity and particle size of the dispersed phase.

Obviously, a major role in the synthesis of magnetic fluids is played by adsorption process, i.e. spontaneous transition of the surfactant molecules in the surface layer. If the energy of adsorption interaction equals 100 kJ/mole or more and chain-like part of the surfactant molecules dissolves in the carrier liquid, the carrier liquid outflow does not occur even in a high-gradient magnetic field, which is proved by the conducted experiment. Intermolecular interactions between the surfactant molecules and the carrier fluid molecules, as well as the interaction between the surfactant molecules and the active sites on the surface of the dispersed phase are so strong that under magnetic field influence neither desorption of surfactant molecules on the surface nor stabilized magnetic phase (magnetite) precipitation occur.

Gaining further knowledge on the adsorption and solvation effects and on energy and structural changes taking place in magnetic fluids synthesis can undoubtedly help to quantify the effects of all the above and create the optimal conditions (including induction value of the magnetic field) for MF application in specific electromechanical and other devices.

CONCLUSIONS

We can draw three main conclusions.

Firstly, the low viscosity magnetic fluid МКК 001-60 is resistant to magnetic fields.

Secondly, the stability of the initial magnetic fluid is not affected by repeated dilution of the carrier liquid, and diluted magnetic fluids are also resistant to magnetic fields.

Thirdly, the synthesized magnetic fluids can be used as the working fluid in a number of magnetic fluid devices.

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