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Dielectric Criteria of Colloidal Stability of Nanodispersed Ferrofluid Lubricating Oils

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Abstract

One of the most promising modern lubricants is nanostructured ferrofluid, which can be used in tribounits for various purposes due to its unique physical and triboengineering properties. However, the existing ferrofluids are less effective than traditional lubricants mostly because of the friction-caused colloidal structure destruction. The article considers the possibility of increasing aggregate and sedimentation stability of the ferrofluid lubricating oil colloidal system using a selection of surfactant stabilizer by its dielectric permittivity value.

The experimental results provided the colloidal stability data of ferrofluids that have different chemistry. The paper proposes the dielectric criteria, which can help select surfactant stabilizers when creating new stable magnetic liquids. It is shown that magnetic liquids stability dependence on dielectric permittivity of structural components might be explained by its influence on the sorption processes during the formation of protecting solvation shells for magnetic particles.

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Keywords: magnetic lubricant; magnetic liquid; colloidal stability; dielectric permittivity.

1. Introduction

The experience in creating emerging technology and re-engineering outdated technology shows that increasing reliability and service life of machinery, tools and technological equipment may be successfully achieved by modernization of tribocouplings in their construction. Therefore, the problem of developing new types of tribounits and applying innovative lubricants is important [1-4]. Nowadays, one of the most prospect modern lubricants is nanostructured ferrofluid oil [5-7]. Due to its unique physical and triboengineering properties ferrofluid oil might be

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used in tribounits in various types of bearings and sealings [8-11]. The main advantage of magnetic liquids comparing to known nonferrofluid oils is that they are transferred to a frictional contact area affected by constant inhomogeneous magnetic fields [12]. Oil recovery between friction surfaces is automated and does not require artificial changing of a tribounit construction and including into it mechanical devices for fluid movement. However, familiar ferrofluid oils are weaker than traditional lubricants mostly due to colloidal structure destruction during friction [13]. Thus, it is necessary to create new ferrofluid oils with higher colloidal stability.

Generally, ferrofluid oil is a three-component colloidal system. Two components (dispersed phase and carrier fluid) might be picked out theoretically considering control experiments. The third component of a magnetic liquid is surfactant stabilizer which determines aggregate and sedimentation stability of a colloidal system. Scientific literature shows some general requirements to a surfactant stabilizer about the size and configuration of molecules, their preferred orientation on the surface in the adsorbed state, dissolution and relative concentration. However, it does not reduce the search area of new stabilizers significantly due to the lack of scientifically based physical and chemical characteristics of molecules in a surfactant stabilizer. The purpose of the paper is to determine the possibility of using the values of dielectric permittivity of a stabilizer and a dispersed phase in order to form a criterion of ferrofluid oil colloidal stability.

2. Experimental research and results

The authors investigated colloidal stability of ferrofluid oil based on carrier fluids which are different in chemical, electric, rheologic and other properties. The ferrofluid oil under consideration should have had only a low-polarity base, non-ionogenic surfactant stabilizer and hydroximag nanoparticles. Some physical and chemical data on the researched liquids for a dispersed phase are shown in Table 1. Ferrofluid oils were obtained according to a general magnetic liquid technology, which is described, for example, in [14]. A surfactant stabilizer for all colloids was only an oligoester OE-3 with dielectric permittivity ε_p=4,95. The original colloidal magnetization was about 30 kA/m.

Table 1. Physical and chemical characteristics of dispersed phases affecting magnetic colloid stability.

Carrier fluid	Viscosity, 10^{-3} Pa.s	Dielectric permittivity, εr	Dipole moment μ, D	Relative magnetization reduction, %	E
Toluol	0,55	2,37	0,31	100	0,51
2- pecoline	8,1	4,28	1,17	30	0,13
Dioctyl-sebate	19-23	4,4	4,28	10	0,11
Dibutyl-sebate	7-11	4,46	3,96	21	0,10
Dioctyl-phthalate	80-85	5,1	3,06	19	0,03
Buthylacetate	0,67	5,1	1,84	35	0,03
Dibutyl-phthalate	19-20	6,1	2,87	55	0,23
Tricresilphosphate	70-90	6,7	2,84	100	0,35

The obtained magnetic colloids were tested for stability in a gravity field for surfactant stabilizing capacity rapid assessment. A fixed volume of ferrofluid oil (40 ml) was loaded into a test-tube centrifuga T-23 and held during 2 hours with centrifugal acceleration about 5600 g. After that we were controlling dispersed phase separation and registered magnetization reduction due to a magnetite transferring into a pellet. In order to determine magnetic properties of a colloidal system we applied a magnetometer, which was described in [15]. Considering the fact that colloid magnetization linearly depends on dispersed particles concentration, we estimated stability of the obtained colloids according to magnetization fractional change in a centrifugal force field.

Among a generous amount of possible complex parameters that simultaneously consider polarizability of separate components of binary solutions (a dispersed phase is a stabilizer) we chose a parameter, which shows a relative difference between their dielectric permittivities $E= |\varepsilon_p - \varepsilon_r|/ \varepsilon_p$, where ε_p is surfactant dielectric permittivity,