

FERROFLUIDS AND MAGNETORHEOLOGICAL FLUIDS USED IN ELECTROMECHANICAL DEVICES

DRAGOI D. D., BESLEAGA Cr

University of Bacău, SC IMF SA Bucharest

Abstract : The ferrofluids or the magnetic liquids are biphasic mediums obtained by physicochemical procedure to confer properties to some liquids and which integrate into their structure ultra fine, ferro and ferromagnetic subclass magnetic particles stabilized with certain substances. The extremely reduced dimensions of the particles within 0.30 – 20 nm (in the region of 10 nm, in a typical way) give a special role to their movement of thermal agitation in maintaining stability

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1. Introduction

The ferrofluids or the magnetic liquids are biphasic mediums obtained by physicochemical procedure to confer properties to some liquids and which integrate into their structure ultra fine, ferro and ferromagnetic subclass magnetic particles stabilized with certain substances. The extremely reduced dimensions of the particles within 0.30 – 20 nm (in the region of 10 nm, in a typical way) give a special role to their movement of thermal agitation in maintaining stability [1]. Aving to the concentration of circa 10^{17} - 10^{18} magnetic particles per cubic centimeter, the magnetic colloids be have like a quasi – homogeneous medium and spectacularly includes the properties of a highly magnetizable medium [2].

The basic liquids most frequently used are: hydrocarbons (oil, toluene, inorganic solid substances used in making ultra fine magnetic particles are insoluble in the base liquids, the coupling of the magnetic particles with the liquid phase is achieved by adding a chemical substance whose structure allows, on the hand, to be absorbed on the surface of the particles (fig.1.a) and, on the other hand, to dissolve in the basic liquid (fig. 1.b).

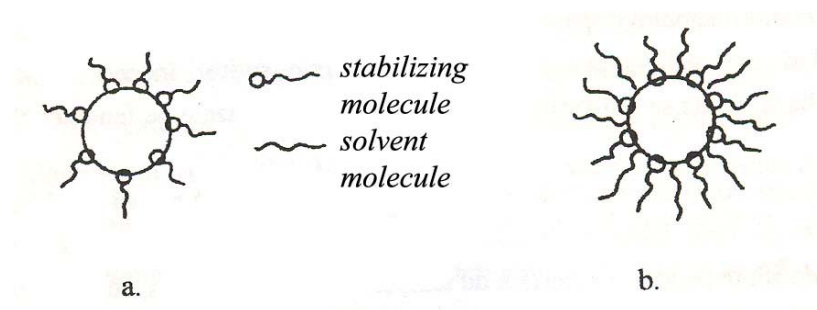


Fig. 1. The coupling of the magnetic particles with liquid phase: a) the coupling solid magnetic particle – stabilizer; b) the coupling of solid magnetic particle – stabilizer – basic liquid.

The chemical substances that allow this coupling are called surface – active agents (surfactants) or stabilizers. A typical example of such a substance is oleic acid, $C_{17}H_{33} - COOH$. Its molecules contain the polar group – COOH that is absorbed on the surface of the particle and part of the hydrocarbon, which from a chemical viewpoint is similar to the dispersion medium and so it dissolves in this. The effective thickness of the layer, δ , can vary between 0.3 nm and 1 nm, depending on the structure and the molecular mass of the stabilizing agent and on the solvent. To prevent the agglomeration of the magnetic particles and so the separation of the solid phase, it is necessary distance 2δ between their surface, the energy of the thermal agitation be bigger than the energy associated to London forces and the magnetic forces of interaction between particles. Besides this stabilizing role, the active surface agents have also the role of preventing the oxidation of the colloidal particle.

2. THE MAGNETIC BEHAVIOR OF A FERROFLUID

The magnetic behavior of a ferrofluid is due to the coupling of the individual magnetic particles with the substantial volume of surrounding liquid: Thus, when a magnetic field is applied, each particle is subjected to a force oriented in the direction of the applied field, this force being transmitted to the volume of the surrounding liquid giving birth to a volume force.

From a magnetic viewpoint, the ferrofluids are nonmagnetic in the absence of an exterior magnetization in the field, but not presenting a hysteresis. By modifying in the field, manifesting a magnetization in the field, but not presenting a hysteresis. By modifying the concentration of the magnetic particles in the suspension, the saturation magnetization and the magnetic suspension, the saturation magnetization and the magnetic permeability can varied in large limits.

In the absence of the exterior magnetic field, the viscosity of the fluids presents an ideal newtonian behavior, without depending on the speed gradient. In a uniform magnetic field owing to the applied magnetic field, the viscosity grows at last four times in comparison to the one in the absence of the field, an this appears only in intense magnetic fields.

3. SPECIFIC PHENOMENA

The studies of ferrofluids brought to light a series of specific phenomena by means of which these materials make possible the solving of new or old problems in science and technology.

A ferrofluid volume can be positioned from a distance by the action of a magnet, and a ferrofluid volume can be suspended having as a free surface the interior surface.

The horizontal free surface of a magnetic liquid is instable in a field or gradient of vertical magnetic field, presenting a regular configuration of a hexagonal from, isolated tops, etc.

The propagation of the waves on the surface of a ferrofluid is affected by the presence of a magnetic field, and so the deadening of the waves.

A magnet brought near a vessel partially filled with ferrofluid attracts the fluid against the gravitational forces, positioning it on the walls of the vessel.

A permanent magnet submerged into a ferrofluid suspends itself without being in contact with the walls of the vessel the liquid is in, being stably levitated by the pressure of the liquid generated by its own magnetic field. The levitation of a nonmagnetic body in a point inside a magnetic liquid can be achieved using an external source magnetic field.

A magnetic field subjected to a rotating magnetic field starts to rotate, and on this behavior there can be achieved mechanical gyroscopes based on the rotating phenomenon of the ferrofluids. The specific convective in caused by the spatial variation of the magnetization due to its dependence on the temperature; likewise, it manifests itself when there is a transversal gradient of temperature on the liquid layer.

Ferrofluids are described as soft magnetic materials. This means that $B(H)$, the characteristic of induction-magnetic field, has an extremely reduces hysteresis, and a more applied magnetic field can produce magnetic saturation. Ferrofluids can also be characterized as isotropes, showing a supermagnetic behavior. The isotropic materials have magnetic properties independent of the direction of the applied magnetic field. In the absence of the external magnetic field, ferrofluids are nonmagnetic showing a magnetization in field. The size of the magnetization, M , defines an important characteristic in applications that need the ferrofluid should maintain a pressure or action of the device. The magnetization of saturation, M_s , defines particularly the maximum pressure that can be produced in a fluid with applied magnetic field a higher value of M_s causes the increase of the pressure exerted by the ferrofluid in a magnetic field. An increased saturation magnetization is obtained by increasing the concentration of the solid magnetic material in suspension when the ferrofluid is produced.

Table 1 shows the principal physical properties for three oil based ferrofluids produced by Ferrotec, Ferrofluidics Division. The curves of the corresponding magnetization are presented in figure 1.

Physical properties of some ferrofluids .- Table 1

Properties	EMG901	EMG905	EMG909
Density, ρ (Kg/m ³) la 27°C	1350	925	834
Viscosity, η (Newton-sec/m ²) la 27°C	$14,3 \cdot 10^{-3}$	$6,6 \cdot 10^{-3}$	$3,1 \cdot 10^{-3}$
Magnetic saturation, M_s , (Gauss)	600	400	200
Concentration of particles in volume (%)	10,8	7,2	3,6
Dimension of particles (nanometers= 10^{-9} m)	10	10	10

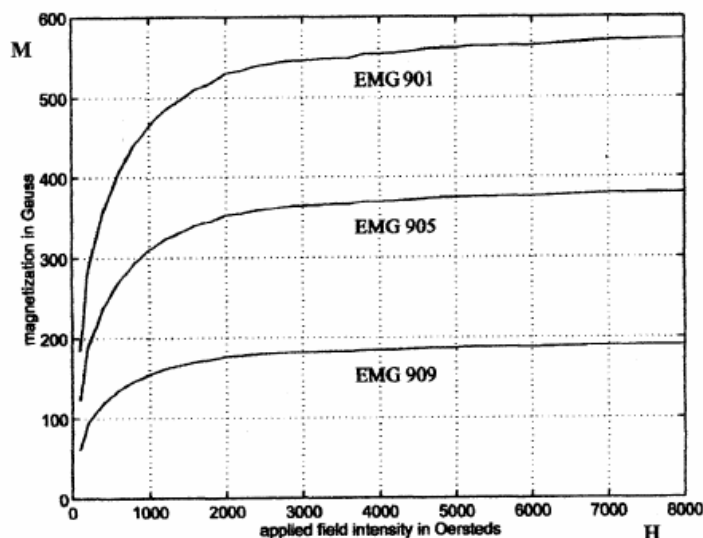


Fig. 1.1 Magnetization curbs for the ferrofluids EMG901, 905, 909 ($10^4 G_s = 1T$; $1 Oe \approx 80 A/m$).

4. CONCLUSIONS

A great diversity of applications in many fields of activity results from the existence of the properties and specific phenomena of the ferrofluids alone mentioned.

The engineering applications of the ferrofluids are connected to their basic properties such as: the positioning of a ferrofluid volume in a magnetic field, the sustention (levitation) of a magnetic body in a ferrofluid by applying a magnetic field, the self – sustention (self – levitation) of a permanent magnet, the rotation movement of the

magnetic liquid by a rotating magnetic field. The main directions of potential applications are: escapeless mobile seals, waste separators, sensors and transducers, bearing with a very limited wearing, vibration dampers, magnetic lubricants, nonconventional technologies of processing materials, ultrarapid printing, and nondestructive control procedures. From among these, some have been promoted as technologies or industrial products in various countries with an advanced economy, such as rotating and exclusion seals, inertial dampers, sensor and transducers. The procedures and the devices based on the ferrofluid are characterized by efficiency and high performances, constructive simplicity, and a high functioning period.

There are two categories of important properties of the ferrofluids that should be well understood for the study and the designing of the mechanical and electromechanical devices which use ferrofluids: magnetic properties and rheological properties.

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