CURRENT STATE OF RESEARCH AND FERROFLUID APPLICATIONS

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REZUMAT. Lucrarea îşi propune să facă o trecere în revistă a soluțiilor şi procedeelor folosite în studiul comportării ferofluidelor începând cu primele experimente în tehnica spațială, utilizarea apoi la scară largă, procedee de obținere şi aplicații ale acestora în tehnica actuală.

Cuvinte cheie: ferofluid, câmp magnetic

ABSTRACT. The paper aims to do an overview of solutions and procedures used in the study of ferrofluid starting with first experiments in space technology, the use on a large scale, production methods and their applications in current technology.

Keywords: ferrofluid, magnetic field

1. INTRODUCTION

Magnetic fluids are obtained by immersing the ultra fine magnetic particles in a base liquid. Each particle behaves like a permanent magnet, so it will interact with external magnetic fields. Density of ferromagnetic powder on ferrofluid is very high and can reach to 10^{23} particles per cubic meter. Due to the very small particle size (approximately 10 nm), sedimentation tendency is canceled by molecular thermal agitation, so the powder does not sinks to the bottom of the container.

In terms of physical, magnetic fluids behave like a normal liquid, but also has strong magnetic properties. Ferrofluids are perfectly soft magnetic materials, showing saturation magnetization in the presence of intense magnetic fields, but have no magnetic hysteresis.

Fig. 1. Action of the external magnetic field on the ferrofluid - reproduced from [6].

As regards the electrical properties of ferrofluids, it retains the basic characteristics of the fluid being electrically non-conductive fluid if is composed of hydrocarbons, fluorocarbons, esters, diesters, water and conductive for fluid based on mercury, gallium alloys, and other metals.

2. BRIEF HISTORY

Since 1960 NASA began research on magnetic fluids and was experimenting on their behavior in weightless environment, so that first tests has been conducted in order to find solutions to the fuel control in the absence of gravity of the spacecraft. In 1968 is founded Ferrofluidics Corporation led by Ronald Rosensweig, first private company that develops research on ferrofluids and produce on an industrial scale magnetic liquids. Rosensweig is the one who adds the term "ferrofluid", concept adopted later in the scientific literature.

In Romania, ferrofluids begin to interest since 1972 when the Center for Technical Physics and Polytechnic Institute of Iasi direct their research towards this area. Later, in 1975, Polytechnic Institute of Timisoara followed by mining and energy companies are concerned about the possible use of the ferrofluids.

3. METHODS OF OBTAINING FERROFLUIDS

While researching the possibilities of obtaining ferrofluids, scientists have faced a number of problems, first of them, due to the deposition phenomenon, represented by the need to use sub-domains of ferromagnetic material particles. Therefore have been experimented mechanical processes of obtaining colloidal powder by grinding, then continuing with thermal decomposition processes, electrolysis, electrocondensation and chemical precipitation.

Another problem to be overcome was to prevent agglomeration of particles. The solution was to design a stabilizing that covers each ferromagnetic particle with a molecular layer that acts as a dispersing agent, causing a elastic rejection and opposing to forces of attraction that occur between particles.

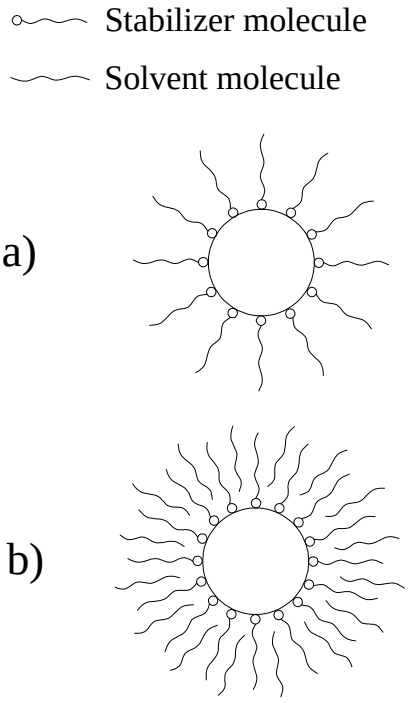

Fig. 2. a) The coupling magnetic solid particle-stabilizer
b) The coupling magnetic solid particle-stabilizer-base liquid
reproduced from [1]

The third component of the ferrofluid is the base fluid in which are floating the particles covered by the stabilizer. Initially, the base liquid was composed only of hydrocarbons and then the range of solutions expand to water-based products, silicones, fluorocarbons, esters, diesters, etc.

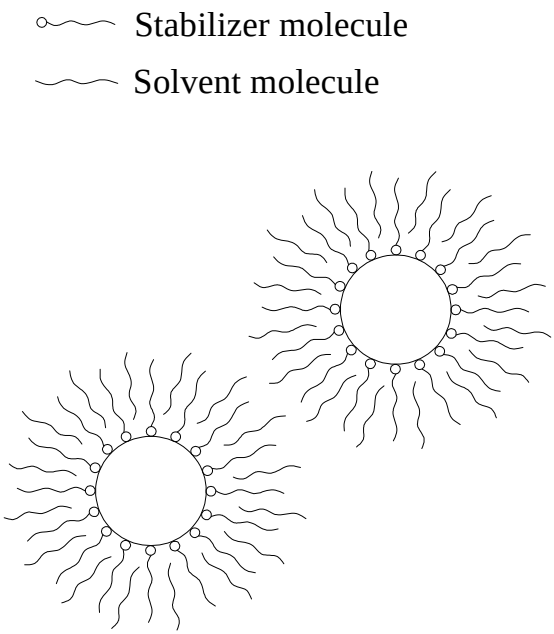

Fig. 3. Stabilizer layer limit particles approximation at least "2δ" preventing their agglomeration - reproduced from [1].

4. PRACTICAL APPLICATIONS OF FERROFLUIDS

After NASA experiments concerning the use of ferrofluids in spatial technology, research in this area continues and is performed first industrial applications, some of them described below.

a) One of the problems solved by ferrofluids was the ***sealing of moving parts***. Thus, for sealing a shaft passage moving by rotation, translation or rototranslation attempted replacement of semering gasket with a layer of ferrofluid, positioned, with a magnetic field, between the two parts. Because the fluid film accede perfectly to both moving parts and the stationary ones, the resulting seal is more effective and no longer requires a perfect polishing of contact surfaces.

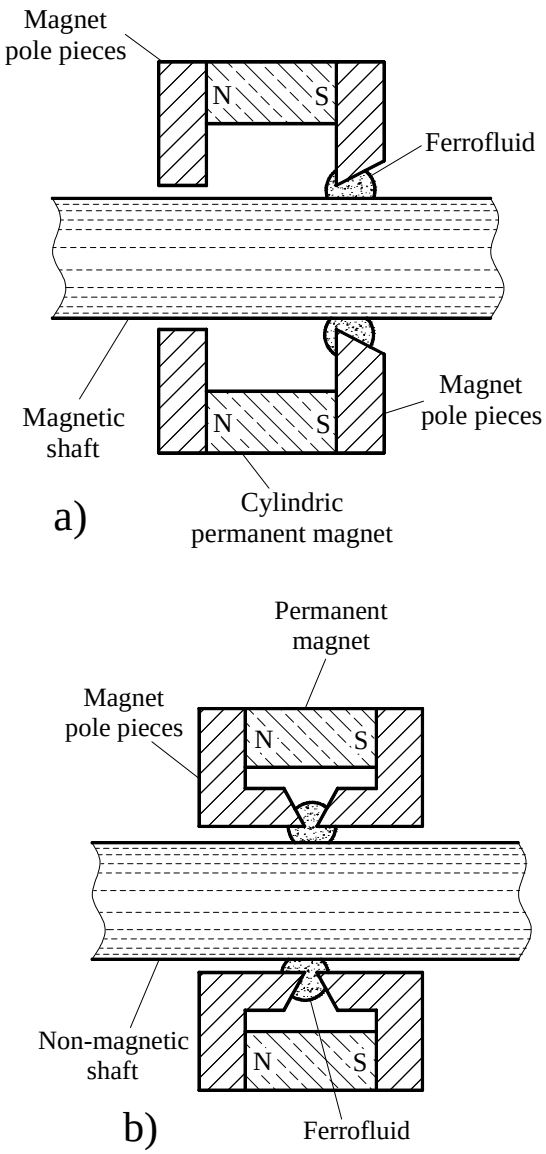

Fig. 4. a), b) Examples of ferrofluid sealing - reproduced from [1].

Ferrofluids also can be used as alternative solutions to centrifugal sealant, which are efficient only at high speeds of rotation. The use of external magnetic fields to position the seal film has the advantage of the possibility of creating a proper seal at very low rotational speeds or even zero.

b) Another practical application is the ***bearings and lubrication with ferrofluid***. Similar to ferrofluid sealing solutions, ferrofluid bearings involves using a magnetic field to position the ferrofluid, this provides both function of sealing and lubrication. Depending on the requirements of use, bearings can be made for various operating modes such as low or high working speeds, different loads or different sealing requirements. The most simple and eloquent examples of ferrofluid bearings is shown in Figure 5 below:

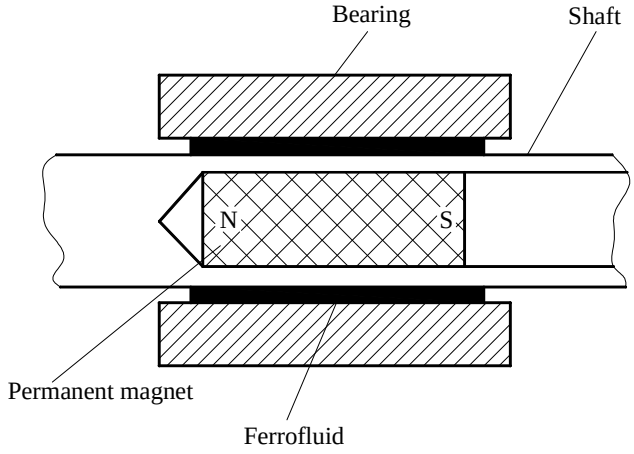

Fig. 5. Simple ferrofluid bearing - reproduced from [1].

As shown in the figure above, ferrofluid liquid is retained between the non-magnetic axis and non-magnetic bearing case by a permanent magnet inserted into the shaft.

The ferrofluid lubrication property is due to its ability to maintain basic physical properties of the liquid, so using a good lubricant oil leads to the achievement of a ferrofluid with the same qualities. Improved efficiency of ferrofluid bearings and wear prevention characteristics given by ultramicroscopic particle size of ferromagnetic material and the possibility of keeping the lubricant in the contact points with magnetic fields.

c) ***Damping using ferrofluid*** system is a solution applied in a wide range of areas such as sensitive components of the measuring equipment vibration damping, audio speakers damping and car shock absorber. One of the constructive variants of the damper involves the use of a piston with a permanent magnet embedded, ensemble that slides along a cylinder of non-magnetic material. The use of ferrofluid in the construction of the damper, besides the damping effect have a second advantage, the permanent centering of the piston in the cylinder.

Regarding the use of the ferrofluids in sound equipment, an example of ferrofluid speaker is shown below.

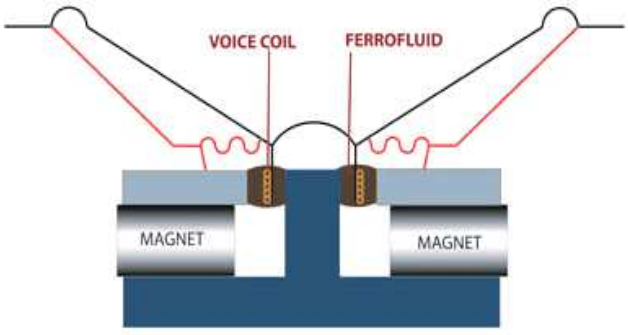

Fig. 6. Ferrofluid speaker - reproduced from [5].

Besides the technical solutions above described, ferofluidele shows its practical utility in very interesting and ingenious applications such as electrical switches, pistons, valves, accelerometers, densitometers, separation facilities, writing and display systems and more.

5. CONCLUSIONS

Ferrofluids are liquids with magnetic properties, composed of ferromagnetic ultrafine particles, covered by a layer of stabilizer (to prevent conglomeration), and submerged in a base liquid. Every single particle acts as a permanent magnet and interact with external magnetic fields. Due to the molecular agitation and stabilizer that prevents sedimentation and conglomeration, ferromagnetic material and base liquid have a uniform and homogeneous behavior, so interaction with magnetic fields is for the entire fluid.

Due to the unique mix of ferromagnetic and fluid properties, ferrofluids are are materials of interest to a wide range of fields such as space technology, electromechanical, medicine, biology, acoustics, etc.

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