Ferrofluids and Their Uses in Industry

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***Abstract* - This article entitled "Ferrofluids and their uses in industry", presents several lines of research on the applicability of the industry ferrofluids.**

***Index Terms* - applications, ferrofluids, magnet, magnetic, microparticle, engine, suspension.**

I. INTRODUCTION

Ferrofluids (magnetic liquids) can be obtained using a variety of liquids which include water, glycerin, hydrocarbons, silicones and fluorocarbons. They have a wide range value of the viscosity, humidity, density, miscibility, surface tension and other physical and chemical properties. The concentration of magnetic particles in magnetic liquids gives the magnetic properties. A magnetic fluid is nonmagnetic in the absence of a magnetic field, but exhibit strong magnetic properties in the presence of a magnetic field, but no histeresys.

On the magnetic properties of magnetic liquids can be both diamagnetic and paramagnetic as their magnetic susceptivity is negative or positive. Because dual behavior of liquid material and magnetic material colloidal matter of fine magnetic particles have the magnetic fluid. On the magnetic properties of ferrohidrodynamic liquids a system bifase with magnetic properties similar solid materials, when available in a magnetic field, behavior also a homogeneous liquid, both in the presence of a magnetic field, and his absence.

In magnetic fluid interaction with the magnetic field were observed a number of sensational events, such as:
- a quantity of magnetic liquid can be suspended in space by the action of a magnetic field;
- a permanent magnet can be stable levitation (the autosuspend) in a magnetic fluid;
- body-weight gains an apparent variable depending on the intensity of the magnetic field and magnetic liquid;
- movement-generating fluid through thermal and magnetic parts with no mechanical mobile;
- ability to run and to drive magnetic flux;
- formation of spontaneous drop of liquid with high stability in the presence of a magnetic field perpendicular to the surface of the liquid;
- rotation of a magnetic fluid by a rotating magnetic field.

In principle, any liquid (conductor or nonconductor) may constitute the basis of a magnetic fluid. Most often used hydrocarbons, silicon oils, water, diesters, fluorocarbons, esters etc., and mercury, depending on the pursued. The stability of a magnetic fluid is ensured by the very small size (≤ 100 Å) of magnetic particles (Fe_3O_4, Fe, Co), dispersed in the liquid core, because Brownian movement effectively opposes the tendency of agglomeration and sedimentation of particles.

II. USES OF FERROFLUIDS IN INDUSTRY

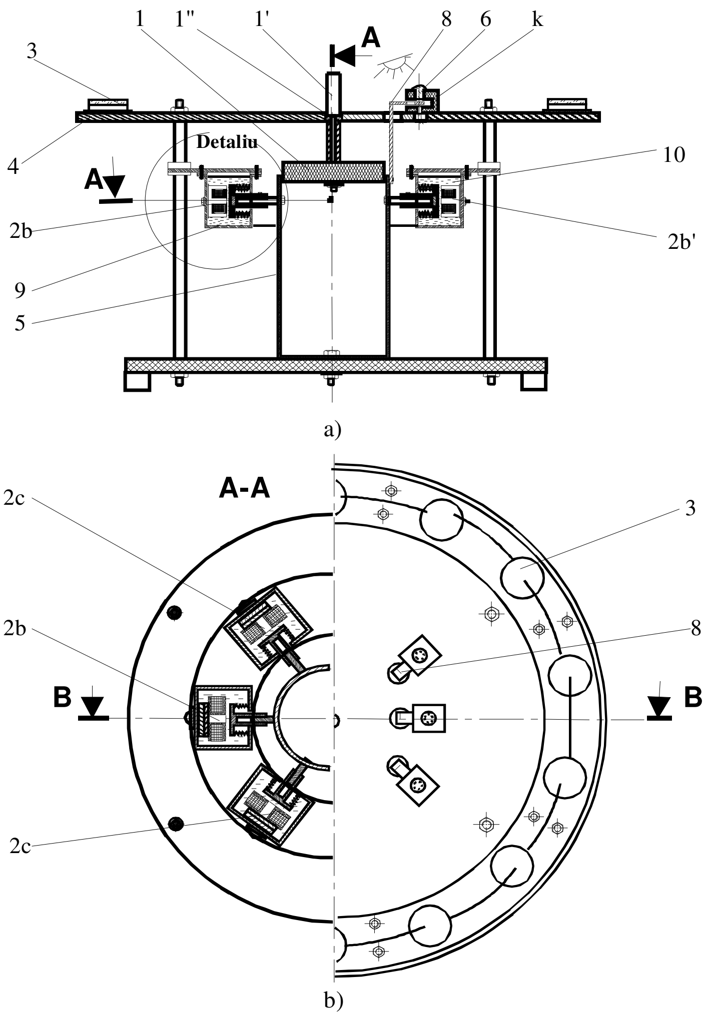
2.1 Electric motor with low speed solar MES- VR

A variation of the solar engine ferrofluid is shown in figure 1 and which is, in fact, a MES-VR done on the engine rotor solar electric roller-shaped disk. Each of the six electromagnets is immersion in a weathertight housing 9 that is a ferrofluid with satisfaction μr value 10 and is fed from a source of photovoltaic cells directly exposed to solar radiation. Pairs of electromagnets are activated in succession, leading to the emergence air gap engine, a magnetic field equivalent rotating with 2p = 2, which rotate at a speed of rotation that depends on the speed of the sequence pairs of electromagnets connected to the source. Rotating magnetic field created by the state, acting on the rotor through a deformable element 11, Fig. 2, type bellow located inside a sealed cavity 9 and submit the electromagnetic attraction of a ferromagnetic plate, constituting reinforcement furniture electromagnetic. This is flexibly connected to the cylinder 5 by means of adjustable rods fixed coaxial, 13 and 14. The action, which is actually stator MES-VR, is fixed or electrical panel on which photovoltaic cells are arranged, or the columns supporting the top of the engine. (see figure 1).

By using ferrofluid in the module driving the flexible cylinder, a very good tightness of the tank, thus, decreasing the risk of wetting the insulation but achieving it at the same time, increased safety in operation. Because of friction, radial forces created by the electromagnets on the cylinder, are converted to forces tangential rotor which prints an identical sense of rotation with the field.

Benefits from this variation are not negligible:
- increased torque whose value is dependent on the type of used ferrofluid;
- increased safety in operation;
- reduction in relation to the photovoltaic source;

Expanding the use ferrofluids MES-VR with stock rotor is illustrated in figure 3. Stator and rotor engine are placed in a vat 9, closed with a lid 10, and which is placed the ferrofluid 13 in sufficient quantity for the two elements imerses said. Chances of success in using ferrofluids the solar engine is of course related to the purpose which it fulfills all the ferrofluid engines with:
1. reluctance reduction in magnetic circuits for magnetic stator;
2. achieve noise reduction by a concomitant sealing noise;
3. reduce the risk of degradation of the insulation under the action of moisture, dust and pollutants.



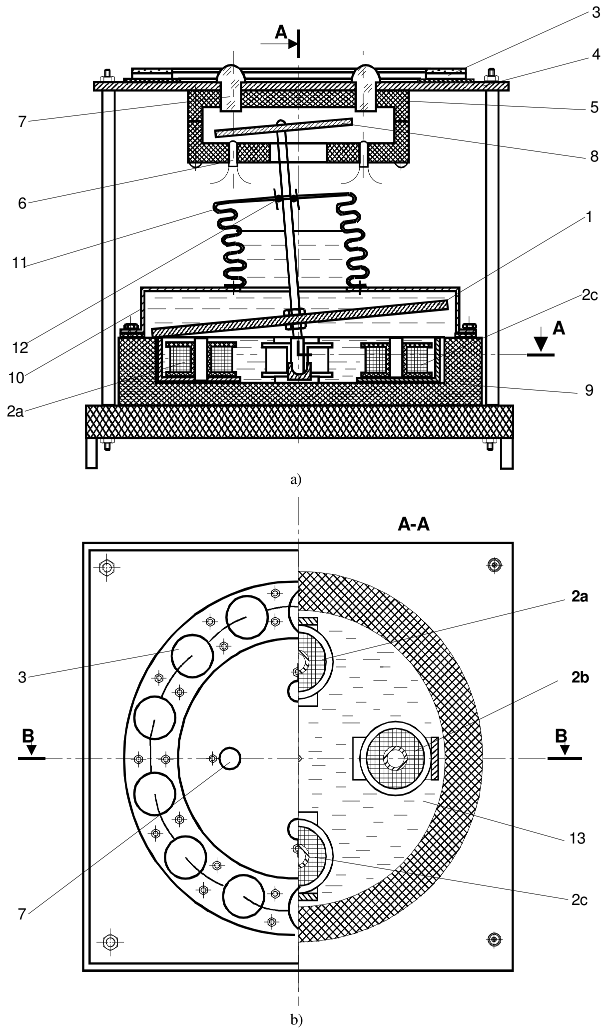


Fig. 1 Expanding the use ferrofluids MES-VR with flexible rotor; reproduced from [7, 8, 9]:
a) longitudinal section, b) section in steps:
1 – rotor; 1 '- tree; 1''- Ball bearing; 2nd-2a', 2b-2b ', 2c-2c' – electromagnets; 3 - photovoltaic cells;
4 - like electrical; 5-cylinder ferromagnetic thin; 6 - optical tube short; 7 - photoelectric element; 8-obturation rod; 9 - vat weathertight; 10 – ferrofluid; k - interstice;

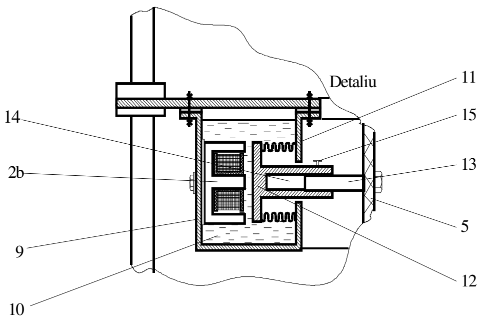
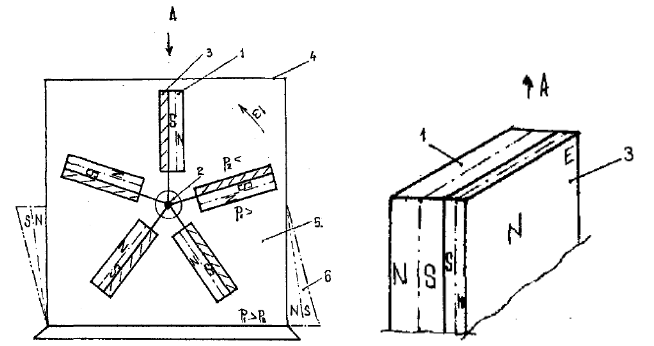


Fig. 2 Detail on the construction of the stator and the mode of action of the flexible cylinder, reproduced from [7, 8, 9, 10]: 9 - weathertight housing; 10 - ferrofluid 11-silfon; 12 - surface metal 13 - rod drive; 14 - camp; 15 - screw fixation;

Fig. 3 Expanding the use ferrofluids MES-VR with stock rotor, reproduced from [5, 7, 8, 9]
a) longitudinal section; b) section in steps
1 - stock rotor disk-shaped; 2 - 2a, 2b, 2c, 2d – electromagnets; 3 - photovoltaic cells;
4 - electrical panel; 5 - support plate; 6 - photoelectron switching device; 7 - optic tube; 8 - obturator disc; 9 – vat; 10 – cap; 11 – silfon; 12 - hutment airtight;
13 – ferrofluid.

2.2 Magnetic motor with magnetic liquid

Magnetic engine magnetic liquid, ensure emerge in energy magnetic convert mechanical rotation of a rotor with magnets, with the rotors consist of four or five permanent magnets 1, rectangulars, the polarized sides mount radially symmetric around a rotation axis 2, of stainless steel or bronze, symmetrical shielded on one side N or S, with a magnetic screen 3, metal nonmagnetic thickness at most equal to the thickness of rectangular magnets or magnet glued laminated polarized opposite to the permanent magnets 1, as can see figure 4a.



a) b)

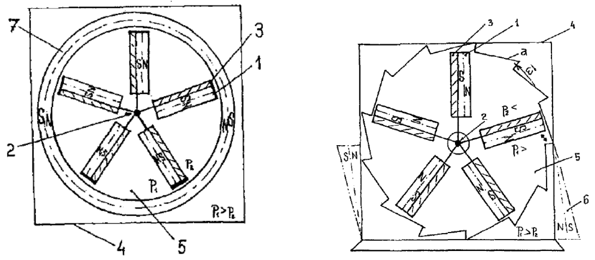
Fig. 4 a) cross section through a magnetic motor with magnetic fluid, reproduced from [8];
1-permanent magnet, 2-spindle central magnetic 3-screen, 4-frame, 5-magnetic fluid,
6-magnets shaped wedge;
b) partial detail view of a rectangular magnet of magnetic engine building

Permanent magnets 1 are able to rotate around the axis of rotation 2, as the rotors and some elements are introduced into a housing 4, the square-shaped section, preferably made of transparent plexiglass, which is filled with magnetic fluid 5. Casing 4 is closed tightly. As a result of hydrostatic pressure on the higher permanent magnets 1, than before their screen, the difference in pressure produced by attracting by the permanent magnets 1 magnetic powder of a magnetic fluid, with increasing local density, it leads the reaction force from the side wall, a moment of rotation of the rotor magnet 1, which will rotate. Thickness of magnetic screen 3 will be chosen so that the magnetic field at the surface of the screen should be as close to zero, as in Fig. 4b.

Another possibility of achieving magnetic engine magnetic liquid is that of Fig. 4a, in which case 4 is provided with some magnets shaped wedge 6, with length equal to a permanent magnet 1, the polarized place on side sideways at the bottom of the case 4, top wedges oriented in the direction of rotation of the engine and the repulsive interaction with the permanent magnets. Magnets shaped wedge 6, generates an additional pressure gradient of the magnetic fluid by magnetic attraction of the suspension, causing additional force acting on the sense of rotation of the engine.

In another variant of realization according to Fig. 5a, the magnetic engine magnetic fluid is made in basic solution, especially that the housing 4, 1 ... 2 mm at the permanent magnets 1, is equipped with a magnetic stator 7, the torroidal shape with a NS direction poles, oriented radial and the repulsive interaction with the permanent magnets rectangular rotors so that the tangential magnetic force is produced both by magnetic repulsion, the asymmetry between the element magnetic stator magnets 7 and Permanent 1 and hydrostatically by increased pressure within the magnetic fluid of the magnetic stator 7 and the permanent magnet.

The magnetic stator 7 can be positioned inside the casing 4 with the magnetic liquid 5 or carcass dispensable.



a) b)

Fig. 5 a) cross section through a magnetic motor magnetic liquid in a variant of realization torroidal magnetic stator, reproduced from [8]; 1-permanent magnet, 2-spindle central magnetic 3-screen, 4-frame, 5 -- magnetic fluid, 7-toroidal magnet stator; b) cross section through a magnetic fluid magnetic engine, interior profile of the carcass in a saw tooth, 1-magnets permanent, 2-spindle central magnetic 3-screen, 4-frame, 5-magnetic fluid, 6-magnets shaped wedge, a saw-tooth;

In an improved variant, the interior contours of the carcass 4, can be achieved in the teeth of circular saw, so that high pressure magnetic liquid, a cavity between the tooth profile of the inner casing 4 and the permanent magnets 1, generates a reaction force from the wall, generating the rotation rotor with permanent magnets 1, as seen in Fig. 5b.

2.3. Depreciation with ferrofluids

Ferrofluids are used, inter alia, the construction of measurement devices, to prevent oscillations of mobile elements. In Fig. 6 are some possibilities to configure the ferrofluidics dampers used for this purpose. A small quantity of ferrofluid is inserted in the space between the furniture piece and stationary parts, being retained by strong magnetic forces. The shearing stresses acting on the moving part can reduce oscillations and the extension of their generation.

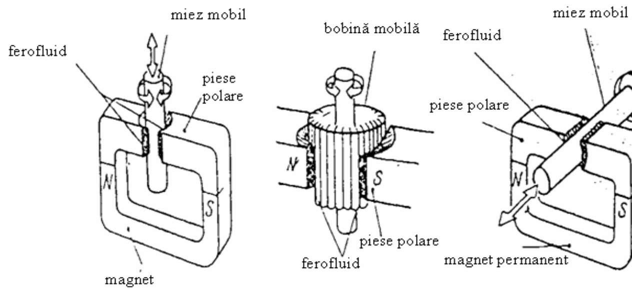


Fig. 6 Depreciation of ferrofluidics parts of the mobile devices measure; reproduced from [7]

2.4. Seal with ferrofluids

Ferrofluids enables the replacement of centrifugal forces sealed magnetic centrifugal force, carrying out seals ferrofluidics. Magnetic forces are independent of the speed of rotation, seals ferrofluidics provides a perfect sealed from zero speed at almost any speed. In a tight ferrofluidic magnetic field the ferrofluid positioned in the gap between the areas of mobile elements and stationary elements. Completely filling the gap, like a ring or strip sealed liquid the ferrofluid form a watertight barrier systems under high differential pressure or vacuum.

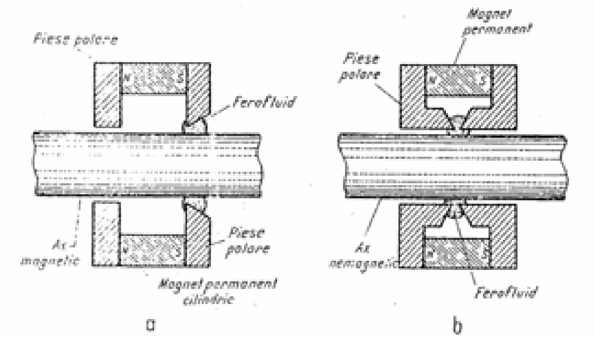


Fig. 7 Two basic configurations seals ferrofluidics, reproduced from [3]

In Fig. 7, a and b are given two basic configurations seal ferrofluidic. Ferrofluid fill the air gap a magnetic circuit which includes a permanent magnet and a system of polar components. In Fig. 7a, the axle is a part of magnetic circuit, while in Fig. 3b, the magnetic circuit does not include the axle.

2.5. Ferrofluidic camps

As with sealed ferrofluidics construction camps and equipment lubrication can exploit positioning ferrofluids magnetic fields in the structure right.

The easiest way to retain a liquid between the magnetic axis and the carcass of a sliding bearing is installed in the magnet axis. Fig. 8 illustrates a shaft nonmagnetic with a permanent magnet insert in his camp housing also being nonmagnetic.

Pretty elementary camp that is set to work in conditions of low loads and high speeds. At low speeds and schemes starting and stop making lubrication is limited because of fluid flow by space radiation.

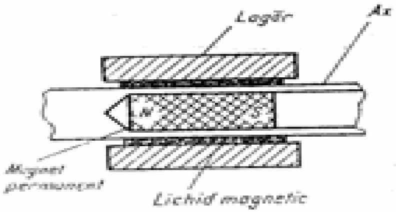


Fig. 8 Simple ferrofluidic camp, reproduced from [3]

3. CONCLUSION

Fluids with magnetic structure (magnetic liquids, magnetorheologic suspensions and composite magnetofluidics) systems are multicomponents and multiphase and therefore, stability and microstructure are strongly influenced by the gravitational field. These two features can be modified substantially improved even in the microgravity, when the separation of phases (which may occur in the presence of gravitational field) is significantly reduced and thus resulting a homogeneous structure.

Loom that research results will contribute to the development of new applications of magnetic fluids in complex ways to transfer and heat exchangers controllable magnetic, for microgravity conditions and land, to obtain new composite materials with applications in the aviation industry, for example sealing, semiactiv dampers, sensors, transducers. Research applications to ferrofluids have prospects by extending the application directions for biotechnology, biology, medicine and manufacture of sealing magnetofluidics, dampers, sensors.

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