ELSEVIER

Journal of Magnetism and Magnetic Materials 201 (1999) 410–412

Journal of magnetism and magnetic materials

www.elsevier.com/locate/jmmm

Magnetic fluid composites and tools for microgravity experiments

M.I. Piso[a], L. Vékás[b,*]

[a]Institute of Space Science-GRL, 220 Iuliu Maniu blvd., 77538 Bucharest, Romania
[b]Ctr. Fundemental & Adv. Techn. Res., Institute for Complex Fluids, 1Bd Mihai Viteazu blvd. #24, 1900 Timişoara, Romania

Received 2 June 1998; received in revised form 10 October 1998

Abstract

Microgravity conditions offer the natural environment for the research and applications of magnetic fluids, in particular for magnetic fluid composites. The nonmagnetic solid component of the composite needs no more magnetic stabilization, and the material becomes macroscopically homogeneous. Small external physical fields may produce relevant effects of ordering and act upon the internal organization and the properties of the fluid. Results are given for applications in inertial and gravitational sensors.

Keywords: Microgravity; Magnetic fluid composites; Inertial sensors

1. General

It was shown that the physical properties of magnetic fluids might be altered and the field of applications enlarged if deals with the magneto-fluidic composites. Briefly, they are mixtures of magnetic liquid (stable suspension of small ~ 10 nm solid magnetic particles in a carrier liquid) and larger nonmagnetic particles (~ 100–5000 nm) made of different types of materials. If the large particles are also electroconductive (metal or metal-coated), the resulting macroscopic medium manifests itself as a liquid with special attributes as optical, electromagnetic and mechanical–rheological properties [1].

Microgravity environment offers favourable conditions for magnetic fluid composites science and applications. To use composites in terrestrial conditions, magnetic fields with gradient are needed to create the opposite force to gravity. The nonmagnetic particles would settle to the bottom or to the top of the liquid in the vessel, except for the case when they have the same mass density as the magnetic liquid. In microgravity, the nonmagnetic solid component of the composite needs no more magnetic gradient stabilization, and the material becomes macroscopically homogeneous. In this case, small external physical fields may produce relevant effects of ordering on the internal structure and properties of the fluid. This property could be used both for scientific purposes and applications development.

The paper presents results, developed mainly by GRL Bucharest and ICF Timişoara, which suggest

* Corresponding author.
E-mail address: vekas@linuxl.mec.utt.ro (L. Vékás)

0304-8853/99/$ - see front matter
PII: S0304-8853(99)00150-X

possible applications of the magnetofluidic composites in microgravity fluid science and space technologies, in particular for applications in inertial and gravity gradient sensors.

2. Magnetic fluid composite accelerometer

For inertial sensors, the use of magnetic fluid composites is important not only for the possibility to modify the rheology. The magnetic fluid composite becomes a macroscopic fluid with a variable mass density, in the same time the particular electric properties allow the easier transducing of inertial fields in the electrical signal [2].

Several sensors for acceleration and slope using composites were developed during the last decade by the authors' research groups [3]. A brief description of the two-axis miniature accelerometer with magnetic fluid composites is given (Fig. 1).

The sensor was developed initially for low-frequency uses, as automotive applications: real speed measurement and braking control [4]. Due to the small dimensions of the demonstration unit (6 mm in diameter and 4 mm height), the field of application may extend to operational motion movement onboard a small orbital spacecraft.

The measurements performed in laboratory have proved a wide sensitivity range, between 10^{-3} and $10\ m/s^2$, with a deviation from linearity of 1–1.5% in the 0–10 m/s^2 range [5].

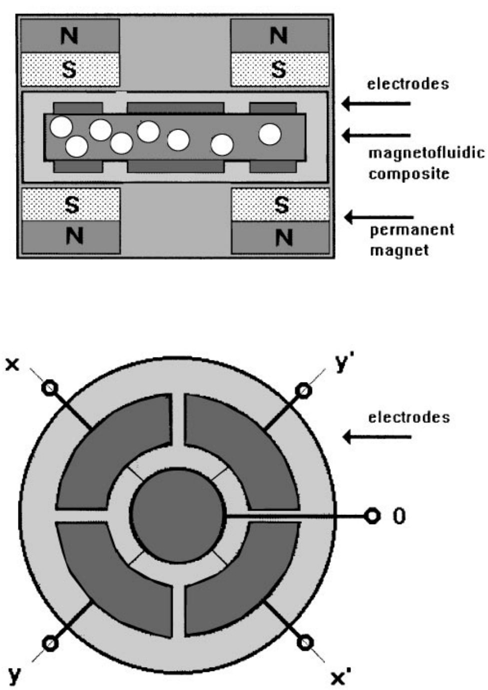

Fig. 1. Two-axis accelerometer.

3. Angular speed measurement

An interesting effect is that of internal rotation of the nonmagnetic component. Tungsten quasi-spherical particles of diameters between 5 and 20 μm were levitated by means of the two permanent magnets in a container filled with a dielectric kerosene based magnetic liquid, as shown in Fig. 2. The system has been excited by means of a rotating magnetic field generated by three coils with ferromagnetic cores disposed at 120° to each other. Applying a variable frequency rotating field and measuring the electromagnetic quality factor of the exciting electromagnets, a minimum has been observed at frequencies of 25–45 Hz.

The internal rotation stresses in the magnetic fluid create a couple on the surface of the nonmagnetic particles and so lead to their spin rotation, according to the mechanism described in Refs. [6] and [7]. The shear flow around the rotating particles produces the opposite couple of the ordinary viscous forces.

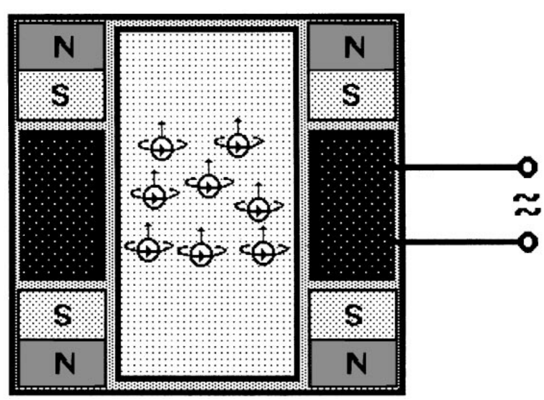

Fig. 2. Composite rotation experiment.

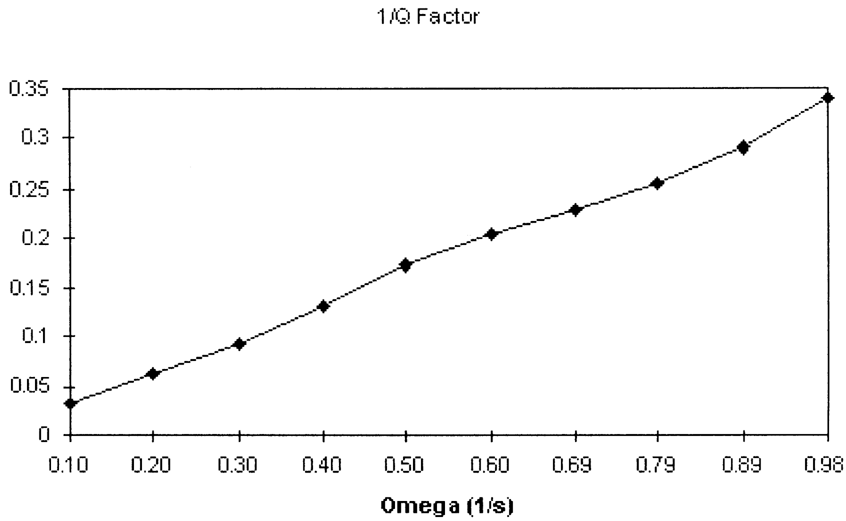

Fig. 3. Quality factor dependence on angular speed.

To indirectly evidence the mechanical rotation of the inner system of nonmagnetic inclusions, the inductances which generate the rotating field were connected as components of a parametric circuit.

Due to the internal viscous losses of the composite fluid, effective power consumption appeared. Performing a slight rotation of the container around an axis normal to the rotating field axis, a transient variation of the circuit quality factor appeared [8]. The dependence of this variation on the magnitude of the angular rotation speed of the container has been determined gravitationally, by suspending the system as a pendulum. The correlation between the angular rotation speed, as calculated by time integration of the angular acceleration, and the measured quality factor of the system, is given in Fig. 3.

An explanation has been given, as follows: due to the conservation of the angular momentum, a transient nonparallelism between the particles momenta and the symmetry axis of the rotating magnetic field occurs, and this nonparallelism directs to a variation of the impedance of the sensor. To confirm it, we performed a gravitational calibration of the system, by suspending it as a pendulum, the correlation between the axial angular acceleration and the Q factor has been measured.

This effect is due to individual stable rotations of the inclusions which occur in a manner such that the liquid seems to acquire a global angular momentum. Such property could be developed for gyration sensors, or for gyrostabilization of attitude for small spacecraft.

Acknowledgements

This work has been partially supported by the Research fund No. 23/1996 by the Romanian Space Agency.

References

[1] J. Popplewell, R.E. Rosensweig, J.K. Siller, J. Magn. Magn. Mater. 149 (1995) 53.
[2] M.I. Piso, M.A. Sârbu, J. Phys. C 2 (15) (1990) 903.
[3] M.I. Piso, Rom. Rep. Phys. 47 (3-5) (1995) 437.
[4] M.I. Piso, Biaxial Acceleration Transducer, Patent RO 99036, 1992.
[5] M.I. Piso, L. Vekas, Adv. Space Res. (1998) in press.
[6] G. Helgesen, A.T. Skjeltrop, J. Magn. Magn. Mater. 97 (1991) 25.
[7] B.E. Kashevsky, Phys. Fluids 9 (6) (1997) 1811.
[8] M.I. Piso, Adv. Space Res. (1998) in press.