Study of Magneto Viscous Effect in Paraffin based Ferro Fluid – Nano Material

Mrs. KOPPULA VANDANA DEVI

Lecturer in Physics, Vivek Vardhini College of Arts, Commerce & Science,

Jambagh, Hyderabad - 500 095

Mr. AMBALA SUDARSHAN

Lecturer in Physics, Government City College, Nayapul, Hyderabad - 500 002

Abstract

A Ferro fluid is a colloidal substance containing ferromagnetic particles that fall in size range of about 1nm to 100 nm, which obeys the official definition of a Ferro fluid adopted by the European commission. Hence a Ferro fluid may be classified as a nanomaterial. It consists of Nano ferromagnetic particles suspended in a carrier fluid with a surfactant such as oleic acid to prevent agglomeration of ferromagnetic particles.

Ferro fluids have had revolutionary applications in many fields ranging from Speakers to Space. They are constantly finding new applications in various fields due to their intrinsic properties. The parameters such as 1) The carrier fluid 2) The magnetic field intensity 3) The surfactant, which can be modified to change the properties of a Ferro fluid.

Considering their highly diverse applications, it is desirable to study the change in behaviour of a Ferro fluid upon modification of above said parameters.

Hence my study involves the change in viscosity of a Ferro fluid upon application of magnetic field of different intensities. The Ferro fluid considered in the following study uses paraffin wax as a carrier fluid instead of more conventional carrier fluids such as kerosene.

Introduction

The paper deals with study of magneto viscous effect using magnets of different strengths. I have considered paraffin wax as carrier fluid. Also mentioned various applications of Ferro Fluids along with recent advancements in the field.

Ferro Fluids

Ferro fluids are colloidal fluids which consist of ferromagnetic or ferrimagnetic particles of Nano scale suspended in a carrier fluid (usually oil) through Brownian motion. They are coated in a surfactant to inhibit cluttering between oil and the particles and to prevent accumulation and magnetic clumping of particles. If the fluid is exposed to a magnetic field, the fluid gets magnetized and forms a viscous solid.

Ferro fluids are composed of Nano scale particles (diameter usually or less than 10nm) of magnetite, hematite or some other compound containing iron and a liquid.

The composition of a typical Ferro fluid is about

85% - carrier, 10% - surfactant , 5% - magnetic solids

A ferro fluid usually does not retain magnetization in the absence of an externally applied field and thus is classified as a super paramagnet rather than a Ferro magnet.

Review of Literature

In 1963 a NASA scientist, Steve Papell, invented ferrofluid as a means to draw fluid into the combustion chamber of a rocket without the help of gravity, thoughj solid fuel technology replaced it rather quickly. It was considered again in as a means to control a spacecraft's temperature.

Scientists at Avco Space Sciences Division enhanced NASA's ferrofluid , developing a magnetic field that would draw

the Ferro fluid through a pipe ring around the spacecraft, stabilizing temperatures. Two scientists at Avco who were involved in the research, Ronald Moskowitz and Ronald Rosensweig, recognized the fluid's potential and licensed the technology. They formed Nashua, New Hampshire-based Ferro fluidics Corporation in 1969 and began applying it in various fields.

Applications

It is a multidisciplinary field consisting of Physical and Chemical sciences as well as in biology, medicine, engineering and so on.

In Electronic devices

Ferro fluid can be used as Liquid seals around the spinning drive shafts in hard disks. The rotating shaft is surrounded by magnets and little amount of ferro fluid , placed in the gap between the magnet and the shaft, will be held in place by its attraction to the magnet. The fluid of magnetic particles forms a barrier which stops debris from entering the interior of the hard drive.

In Mechanical engineering field

Ferro fluids have friction-reducing capabilities. If applied to the surface of a strong enough magnet, such as one made of neodymium, it can cause the magnet to glide across smooth surfaces with minimal frictional resistance.

Ferro fluid s can also be used in semi-active dampers in mechanical and aerospace applications. While passive dampers are generally bulkier and designed for a particular vibration source in mind, active dampers consume more power. Ferro fluid based dampers solve both of these issues and are becoming popular in the helicopter community, which has to deal with large inertial and aerodynamic vibrations.

In Spacecraft propulsion

Ferro fluid s can be made to self-assemble nanometer-scale needle-like sharp tips under the influence of a magnetic field. When they reach a critical thinness, the needles begin emitting jets that might be used in the future as a thruster mechanism to propel small satellites such as CubeSats.

In Medical applications

Almost all applications in medicine exploit the extreme relative size difference between magnetic nanoparticles and living cells. The applications presented in this section make use of ferro fluid s composed of iron oxide nanoparticles and are called SPION, short for super paramagnetic iron oxide nanoparticles.

Magnetic drug targeting : In this process the drugs would be enclosed by a layer of ferro fluid and the combination would be injected into an area of the patient's body that required the drug treatment. The drugs would then be held in the desired location by a magnetic field and allowed to act for a time period depending upon requirement. The field would then be turned off and the drugs would be allowed to disperse through the body. This process would drastically decrease the necessary dose for a treatment down to a level at which there would be no adverse side effects once the drug is released from the magnetic field. The motivation behind this type of treatment is for it to be used for drugs with adverse side effects, i.e. chemotherapy.

Cancer treatment called targeted magnetic hyperthermia : Using the ability of the nanoparticles to convert electromagnetic energy into thermal energy or heat. Here, ferro fluid is injected into a target tissue, which is usually a cancerous tumour. An oscillatory magnetic field is focused on the location, allowing the ferro fluid to vibrate. The vibration increases thermal energy at a frequency that does not allow the surrounding water to heat up. The fluid can reach a temperature that destroys the desired cells without damaging surrounding tissue.

Enhanced contrast agent in magnetic resonance imaging (MRI): MRI images depend on the difference in magnetic relaxation times of different tissues to provide contrast. If biocompatible ferro fluids can be selectively absorbed by some kind of tissue, then those tissues that would not normally have high resolution would. Also, developing a method for different tissues to uptake different amounts of ferro fluid would give the tissues drastically different relaxation times, and thus very sharp contrast and high resolution. One example of this method being utilized was with trials involving Dextran coated iron oxide particles. The coated particles are taken up by the reticuloendothelial system of many healthy cells, but not cancer cells. This would allow very good resolution of cancer cells.

Magnetic separation of cells: This technique calls for magnetic particles to be taken by a desired biological entity similar to the above method for MRI. Then once the particles are saturated inside a target tissue, a magnetic field gradient is used to pull said entity away from its native environment. One example of this procedure being of great use is separating bone marrow from cancerous portions of a sample in order to re-implant the marrow back into the person.

In Heat transfer

An external magnetic field imposed on a ferro fluid with varying susceptibility (e.g., because of a temperature gradient) results in a nonuniform magnetic body force, which leads to a form of heat transfer called thermomagnetic convection. This form of heat transfer can be useful when conventional convection heat transfer is inadequate; e.g., in miniature microscale devices or under reduced gravity conditions.

Ferro fluid s are commonly used in loudspeakers to remove heat from the voice coil, and to passively damp the movement of the cone. They reside in what would normally be the air gap around the voice coil, held in place by the speaker's magnet. Since ferro fluid s are paramagnetic, they obey Curie's law and thus become less magnetic at higher temperatures. A strong magnet placed near the voice coil (which produces heat) will attract cold ferro fluid more than hot ferro fluid thus forcing the heated ferro fluid away from the electric voice coil and toward a heat sink. This is an efficient cooling method which requires no additional energy input.

Ferro fluid s of suitable composition can exhibit extremely large enhancement in thermal conductivity (k; ~300% of the base fluid thermal conductivity). The large enhancement is due to the efficient transport of heat through percolating nanoparticle paths. Special magnetic nanofluids with tunable thermal conductivity to viscosity ratio can be used as multifunctional 'smart materials' that can remove heat and also arrest vibrations (damper). Such fluids may find applications in microfluidic devices and microelectromechanical systems .

Ferro fluid is held in contact with the voice coil(which produces heat) by the magnetic field will attract cold ferro fluid more than hot ferro fluid thus forcing the heated ferro fluid away from the electric voice coil and towards a heat sink. This is an efficient cooling method which requires no additional energy input.

Medicinal uses of Ferro fluids

Ferro fluid s had even revolutionalised medical science.

Chris suprok recently developed a device that uses ferro fluid to mimic the heart's ability to pump blood. They are working on a prototype that will combine several of these devices to make an artificial human heart that doesn't rely on motors or mechanical parts.

Ferro labs, manufacturer of ferro fluids, claims the ferro fluids can be used to seal ulcers, treat hyperthermia, magnetic resonance imaging (MRI) and preserve vision.

Ferro fluids are also used to treat retinal detachment, the leading cause of blindness. They are used to seal tiny retinal holes.

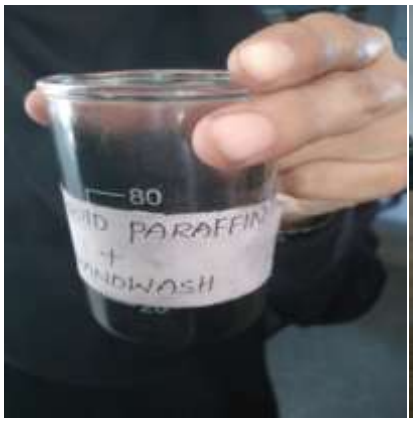
Chemotherapy delivers drugs designed to kill cancer cells through the blood stream. While this treatment can be effective, it can also kill healthy cells and cause immense physical strain on the body. Ferro fluid s may be used to direct these drugs to localized areas to treat cancerous cells and tumours, without subjecting the entire body to the strong chemicals used in chemotherapy.

Research Methodology

We have prepared a ferro fluid using Paraffin oil as carrier, Soap as surfactant and Toner as nano particles. We have calculated viscosity of the above fluid by ball dropping method.

$$\textbf{Viscosity } (\mu) = 2(\rho s - \rho l)(g)r^2/9V$$

We have calculated the time by dropping the balls in the Graduated cylinder containing fluid and by listening their striking sounds as it was not transparent. To calculate viscosity in magnetic field we used nonmagnetic material balls. With the help of Smartphone we have calculated milliseconds. We compared magnetic field strengths of magnets using deflection magnetometer by keeping the magnets at the same distance.




Picture1 **Picture2** **Picture3**

Calculated Viscosity of Paraffin oil using Ball dropping method 70mpa-s

Viscosity of Ferro Fluid made with Paraffin oil(By adding Toner and Surfactant) using Ball dropping method.

Mass of Aluminium ball = 10.5 gm, Radius =9.59 mm, Volume = 3.692 cm^3

- Density (ρ_b) = 2.81 gm/cm^3
- Mass of Ferro fluid = 70 gm
- Volume of Ferro fluid = 78 ml
- Height of Ferro fluid in Beaker = 4.5cm
- Avg. time taken by the Ball in milliseconds 30.66 ms
- Velocity of ball = 146 cm/s
- Viscosity (μ) = 0.26237Pa-sec (or) 262 mPa-sec

Comparing strength of magnets using deflection magnetometer by keeping magnet at a distance of 30cm (Here Θ in Degrees, B in Gauss)

Magnets	Θ_1	Θ_2	Θ_3	Θ_4	Θ_5	Θ_6	Θ_7	Θ_8	Average(Θ)	B=H tanΘ
Neodymium1	65	65	71	71	74	74	75	75	71.25	1.1194
Neodymium2	50	50	47	47	50	50	47	47	48.5	0.4295
Alnico magnet	18	18	15	15	20	20	15	15	17	0.1164

Table 1

Calculating Viscosity of Paraffin based Ferro Fluid with different Magnetic Field

Magnets	Avg.time taken by Ball milli s	Velocity cm/sec	Viscosity mpa-sec
Neodymium1	49	91	413
Neodymium2	45.5	98.9	380
Alnico magnet	32	140	272

Table 2

Conclusion

We have observed that ferro fluid made of food graded paraffin oil exhibits properties of ferro fluid and its viscosity increases with magnetic field strength.

References

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