

FERRO-LIQUID

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ABSTARCT

What are Ferro-fluids? Ferro fluids are a stable suspension of nanometer sized solid magnetic particles in a carrier fluid. The particles are coated with a surfactant; a chemical which prevents the particles from clumping together and forming a solid mass. The most common type of Ferro fluid, presented here, is an oil based fluid consisting of magnetite particles. Ferro-fluid responds to an external magnetic field exhibiting the captivating property of “spikes” along the magnetic field lines when placed in the proximity of a strong magnet. An example of a spike patterns on a Ferro fluid surface. This image is adopted from Minako Takeno's web site about the Appearance of Magnetism Drops of a ferro fluid floating in a non-magnetic liquid of the same density and spun by a rotating magnetic field are investigated experimentally and theoretically. The parameters for the experiment are chosen such that different *stationary* drop shapes including *non-axis-symmetric* configurations could be observed. Within an approximate theoretical analysis the character of the occurring shape bifurcations, the different stationary drop forms, as well as the slow rotational motion of the drop is investigated. The results are in qualitative, and often quantitative agreement, with the experimental findings. It is also shown that a small eccentricity of the rotating field may have a substantial impact on the rotational motion of the drop.

Aim - To prepare Ferro-Liquid

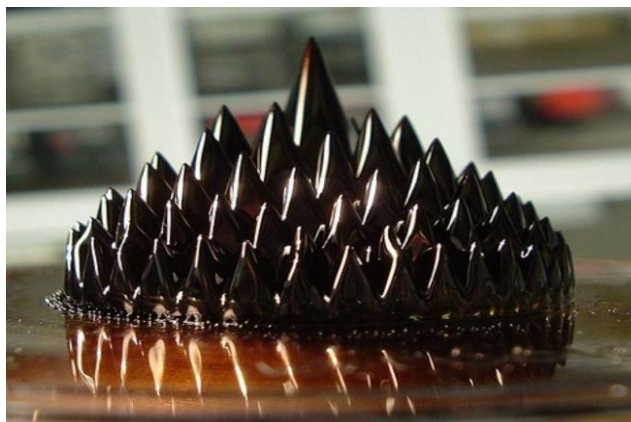
Apparatus-

- *Beaker*
- *Stirrer*
- *Vegetable Oil*
- *Laser Printer Toner Powder*
- *Neodymium Magnet*

I INTRODUCTION

What are Ferro-Fluids?

- Ferro fluids are made up of tiny magnetic fragments of iron suspended in oil (often kerosene) with a surfactant to prevent clumping (usually oleic acid). The fluid is relatively easy to make at home
- Ferro fluids are colloidal liquids made of nanoscale ferromagnetic, or ferromagnetic, particles suspended in a carrier fluid (usually an organic solvent or water). Each tiny particle is thoroughly coated with a surfactant to inhibit clumping. Large ferromagnetic particles can be ripped out of the homogeneous colloidal mixture, forming a separate clump of magnetic dust when exposed to strong magnetic fields. The magnetic attraction of nanoparticles is weak enough that the surfactant's Van der Waals force is sufficient to prevent magnetic clumping or agglomeration. Ferro fluids usually do not retain magnetization in the absence of an externally applied field and thus are often classified as "super paramagnets" rather than ferro magnets.



- Particles in ferro fluids are dispersed in a liquid, often using a surfactant, and thus ferro fluids are colloidal suspensions – materials with properties of more than one state of matter. In this case, the two states of matter are the solid metal and liquid it is in.[6] This ability to change phases with the application of a magnetic field allows them to be used as seals, lubricants, and may open up further applications in future nanoelectromechanical systems.
- However, ferro fluids lose their magnetic properties at sufficiently high temperatures, known as the Curie temperature

II PRINCIPLE

A ferro fluid is just a fluid with suspended particles of magnetic material (e.g. iron), coated with a surfactant so that the particles themselves cannot aggregate together. The fluid itself can be just ordinary water. Because the suspended particles can be magnetized in the presence of a local magnetic field, they will exert forces on the fluid they are suspended in. Thus, the fluid will essentially behave as though it were a magnetic liquid, which of course it isn't - it's a non-magnetic liquid carrying a suspension of solid magnetic particles. No, it's not a magnetic polymer.

III PROCEDURE

1. Measure 50mL of toner in the graduated cylinder and pour it into the beaker.



2. Next, measure 30mL of vegetable oil and pour it into the beaker.



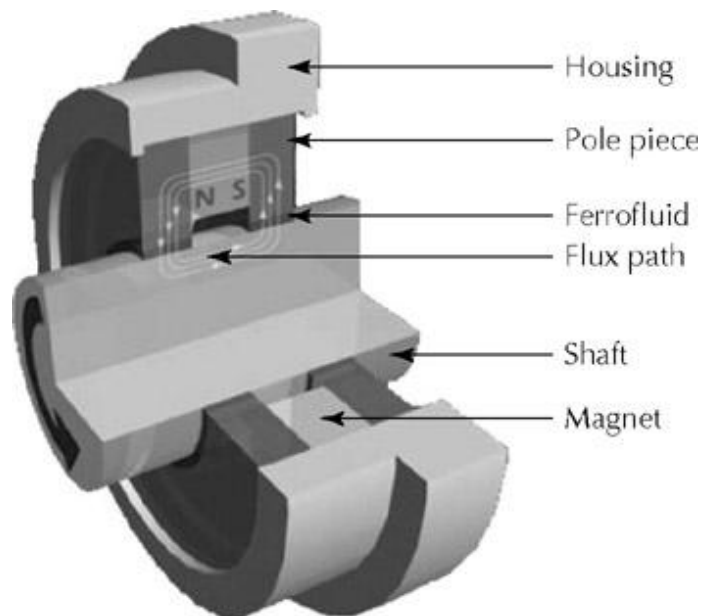
3. Use the stir to mix the toner and the vegetable oil. You want the solution to be as homogeneous as possible.
Safety Tip!! Always use caution with neodymium magnets. They are very powerful and will crush fingers, erase credit cards and damage computers.



4. Now its time to experiment with your ferro fluid. Place the neodymium magnet near the outside of the beaker. Observe what happens to the ferro fluid. You can try moving the magnet around and experimenting with applying it at different distances. If you have magnets of different strengths, you can experiment with the effects of those as well or using more than one magnet at once.

IV PRESENT APPLICATIONS

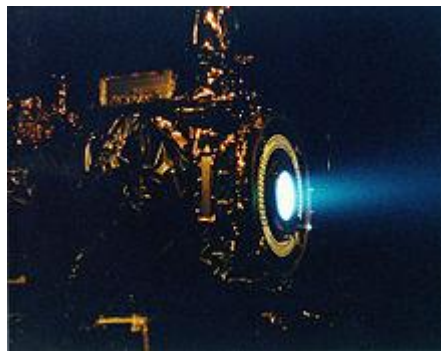
Ferro fluid is a really interesting material. As the name suggests it is a runny fluid....until it is subjected to a magnet. Ferro fluid reacts to magnetic fields, often changing into seemingly impossible shapes as it tries to maintain the shape of the magnetic field. The most common form of ferro fluid is ultra fine iron particles which have been Nano-coated and then suspended in another liquid. To the naked eye it just seems like a very dark brown/black liquid that responds to magnetism. Ferro fluid has been extensively used as a bearing/shaft seal, as it can maintain a relatively low friction, create a very good seal, allow high spin speeds and a simple magnetic can keep it exactly where it is needed. Ferro fluid is now commonly found as a seal on high-end hard disks. It has also found its way into exotic cars into the form of magneto rheological fluid in the suspension dampeners. An electrical current is passed through the dampener whenever a restriction of the dampener movement is required. This can be controlled tens of times a second as the car is driving over different road surfaces. Variations of ferro fluid have also been rumored to be used stealth aircraft technology in the form of Rader Absorbent Material (RAM).Ferro fluid is supplied in a container of 50ml.



V FUTURE SCOPE

- **Spacecraft Propulsion:**

Ferro fluids 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 Cube Sats.



- **Analytical instrumentation**

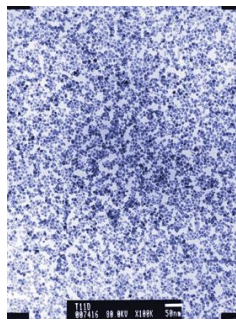
Ferro fluids have numerous optical applications because of their refractive properties; that is, each grain, a micro magnet, reflects light. These applications include measuring specific viscosity of a liquid placed between a polarizer and an analyzer, illuminated by a helium–neon laser.

Medical applications

Ferro fluids have been proposed for magnetic drug targeting. In this process the drugs would be attached to or enclosed within a ferro fluid and could be targeted and selectively released using magnetic fields.

It has also been proposed for targeted magnetic hyperthermia to convert electromagnetic energy into heat.

It has also been proposed in a form of Nano surgery to separate one tissue from another—for example a tumor from the tissue in which it has grown.



- **Heat transfer**

An external magnetic field imposed on a ferrofluid 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 fluids of suitable composition can exhibit extremely large enhancement in thermal conductivity (k ; ~300% of the base fluid thermal conductivity). The large enhancement in k is due to the efficient transport of heat through percolating nanoparticle paths. Special magnetic Nano fluids 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 (MEMS).

- **Optics**

Research is under way to create an adaptive optics shape-shifting magnetic mirror from ferro fluid for Earth-based astronomical telescopes.

Optical filters are used to select different wavelengths of light. The replacement of filters is cumbersome, especially when the wavelength is changed continuously with tunable-type lasers. Optical filters tunable for different wavelengths by varying the magnetic field can be built using ferro fluid emulsion.

- **Energy harvesting**

Ferro fluids enable an interesting opportunity to harvest vibration energy from the environment. Existing methods of harvesting low frequency (<100 Hz) vibrations require the use of solid resonant structures. With ferro fluids, energy harvester designs no longer need solid structure. One example of ferro fluid based energy harvesting is discussed in the journal article, *Electromagnetic ferro fluid-based energy harvester*.¹ First a ferro fluid is placed inside a container that is wrapped with a coil of wire. The ferro fluid is then externally magnetized using a permanent magnet. When external vibrations cause the ferro fluid to slosh around in the container, there is a change in magnetic flux fields with respect to the coil of wire. Through Faraday's law of electromagnetic induction, voltage is induced in the coil of wire due to change in magnetic flux

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