Ferrofluids

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Ferrofluids are one type of magnetic liquid, along with paramagnetic liquids. A magnetic liquid cannot be created by simply melting down a magnetic solid because magnetic materials lose their magnetic properties beyond a specific temperature, known as the Curie temperature, which is below the melting of magnetic materials. A ferrofluid consists of magnetic particles suspended homogenously in a solution (Coey 2010). Being commonly iron-based particles, this lends to the name of the substance from the Latin *ferrum* meaning iron, thus ferrofluid. A ferrofluid has all characteristics of a liquid, but when subjected to an external magnetic field, the magnetic particles cause the ferrofluid to align with the magnetic field that is present. Because magnetic fields are circular, the ferrofluid forms into a ball in order to align itself with the field lines. Ferrofluids are also known to be superparamagnetic. This property implies that the fluid aligns with any magnetic field just as a magnetic solid would, but the fluid demagnetizes much faster than any solid as demonstrated when a ferrofluid immediately loses its shape when a magnetic field is no longer present.

Any ferrofluid is compromised of multiple components, such as the ferromagnetic particles lending to the magnetic behavior of the fluid. The liquid lending to the majority of the ferrofluid itself is referred to as the carrier fluid. This carrier acts as a solvent for the particles and is generally a type of oil, such as common vegetable oil, or another, more complex chemical compound such as a hydrocarbon. Crucial to the magnetic properties of a ferrofluid is the prevention of molecular agglomeration, or grouping of the magnetic particles (Buschow 2001). Were the particles to agglomerate, they would settle out of the solution, and only these particles, rather than the entire fluid, would be attracted to any magnetic field. Helping to prevent this is the third component to any ferrofluid, the surfactant. The surfactant acts as a dispersing agent for the particles suspended in the fluid, keeping them from accumulating and grouping together and keeping the solution more uniform. Commonly known surfactants are soaps and detergents (Berger et al. 1999).

One of the most characteristic traits of a ferrofluid is the formation of outward spikes when exposed to a magnetic field. These spikes are formed because the magnetic force induced upon the fluid is great enough to overcome the surface tension of the liquid (Berger et al. 1999). The surfactant mixed in the solution helps to decrease the surface tension and thus lends to larger spikes. A greater magnetic field also results in larger spikes being formed. However, if the field that the fluid is subjected is too large, then the ferromagnetic particles may become separated from the fluid entirely.

Since its development, many applications of ferrofluids have been discovered to help solve numerous engineering problems. One of the most common present day applications for a ferrofluid is use as a rotating shaft seal in motors and generators (Ferrofluids 2008). Ferrofluids act perfectly as low-friction seals for shafts rotating inside of chambers of low or high pressure. When held in place by permanent magnets, the fluid forms an efficient and tight seal. This application of ferrofluid is found mostly in X-ray generators and computer disk drives. Another often seen application of ferrofluid is in everyday speakers. Speakers work by transmitting electricity to a coil located around a magnet. The magnetic field causes the coil to vibrate and thus produce sound. Ferrofluid is often coated over the coil. This serves the purpose to dampen any unwanted sound as well as to dissipate any unwanted energy from the coil as heat. More advanced applications are being researched specifically in the medical field. Scientists hope to be able to deliver medication to targeted areas within the human body through the use of a ferrofluid and a controlled magnetic field (Ferrofluids 2008).

Methods for mixing a ferrofluid can range from mixing complex compounds to simple household materials. The more complex methods produce better ferrofluids as would be expected. One such more complicated method involves chemicals such as hydrochloric acid, ammonia, $FeCl_2$, and $FeCl_3$ (Berger et al. 1999). These are corrosive and highly acidic chemicals which need be handled with care. A more simple method involves the common househeld items vegetable oil as the carrier, laser jet ink toner as the magnetic particle, and a surfactant such as soap, detergent, or even small amounts of distilled water. The ideal ferrofluid is approximately compromised of 5% magnetic solid, 10% surfactant, and 85% carrier fluid (Helmenstine 2008).

The process of synthesizing a ferrofluid was not difficult, but it did, however, require trial and error to discover a working ratio of the different ingredients. First, the toner was removed from the printer component. The toner used was in a powder form, although some comes as a liquid. This acted as the magnetic solute for the ferrofluid as it was an iron-based toner. Next, the powder was added in small increments to a small amount of vegetable oil and stirred until a nearly homogenous solution was achieved. Once a thin mixture was achieved, both oil and toner were added simply to increase the amount of solution. The solution was tested against a magnet and it was found that the fluid was, in fact, attracted to the magnet and outlined the shape of the magnetic field. However, no spikes formed on the surface of the fluid. The lack of spikes merely means that the surface tension of the fluid was too great for the strength of the magnet to overcome. The fluid does still demonstrate the shape of a magnetic field. The use of common materials, rather than chemicals found in a lab, also contributes to the performance of the ferrofluid.

Works Cited

Berger, Patricia, Nicholas B. Adelman, Katie J. Beckman, Dean J. Campbell, Arthur B. Ellis, and George C. Lisensky. "Preparation and Properties of an Aqueous Ferrofluid." *Journal of Chemical Education*. 76. no. 7 (1999): 943-48. http://voh.chem.ucla.edu/classes/Magnetic_fluids/pdf/ChemicalEducationArticle.pdf (accessed April 15, 2012).

Buschow, K.H.J., ed. *Encyclopedia of Materials*. Elsevier, 2001. s.v. "Ferrofluids: Applications." http://www.knovel.com/web/portal/browse/display?_EXT_KNOVEL_DISPLAY_bookid=1871&VerticalID=0 (accessed April 16, 2012).

Coey, J.M.D. *Magnetism and Magnetic Materials*. Cambridge University Press, 2010. http://www.knovel.com/web/portal/browse/display?_EXT_KNOVEL_DISPLAY_bookid=3242&VerticalID=0 (accessed April 15, 2012).

"Ferrofluids." *The University of Wisconsin-Madison Materials Research Science and Engineering Center*, Last modified 2008. http://mrsec.wisc.edu/Edetc/background/ferrofluid/index.html#apps. (accessed April 16, 2012).

Helmenstine, Anne M. "How to Make Liquid Magnets." *About.com*, http://chemistry.about.com/od/demonstrationsexperiments/ss/liquidmagnet_5.htm. (accessed April 15, 2012).