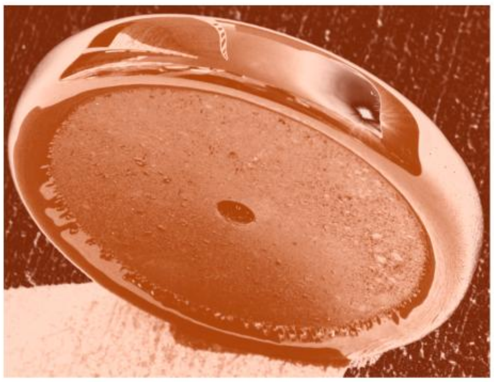
Ferrofluid Investigation

Group Project 2

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MCEN 4228: Flow Visualization

April 5th, 2010

Intent

The purpose of taking the photo of the ferrofluid was simply to show how a ferrofluid interacts with an extremely powerful magnet. Ferrofluid is not an intuitive liquid, and its behavior is unpredictable when surrounded by different shapes and sizes of magnets. Ferrofluid has a lot of practical applications, and I wanted to take a photo that revealed one of these real world applications.

Description of Apparatus

There were two things needed to create this visualization: a 3-1/2 inch diameter disc magnet, and a plentiful amount of ferrofluid. The ferrofluid was poured directly on the disc magnet, and immediately fled to the outside of the magnet. The set up is shown below in Figure 1.

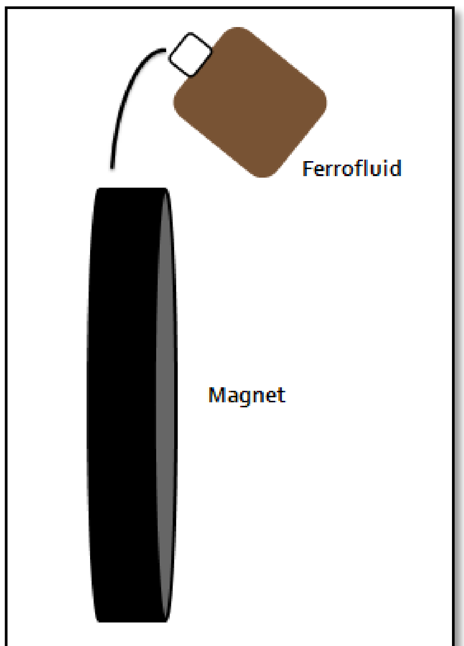

Figure 1 - Ferrofluid Set-Up

When the ferrofluid left the bottle, it was not influenced by the magnet. As the ferrofluid hit the magnet, it interacted with the local magnetic field. This was an instantaneous occurrence and required no time for the flow to interact with the field.

Ferrofluids are mixtures composed of three entities. They contain nanoscale ferromagnetic particles that are suspended in a carrier fluid (organic solvent or water). These particles are coated with a surfactant to prevent build ups. Common surfactants are oleic acid, tetramethylammonium hydroxide, citric acid and soy lecithin. This fluid does not retain its magnetization in the absence of an externally applied field. They are classified as "super paramagnetic" due to their large magnetic susceptibility [1]. The magnetic field surrounding a disc magnet is strongest on the edges. This is why the ferrofluid ran from the center of the disc to the outside edges of the magnet when poured. The fluid built up on the outside of the magnet, creating a ½" layer of ferrofluid. When force was applied to the fluid layer by a human hand, it was not enough to reach the magnet. When the magnet was set upward, the ferrofluid was displaced, and the magnet sat on the concrete. The magnet weighed 4.23lbs, which implied 136N of force was enough to reach the outer surface of the magnet, implying damping applications.

Engineering Applications of Ferrofluid

The three main applications of ferrofluid are sealing, damping and heat transfer. The main industries that most commonly use the fluid are computers, loudspeakers, motion control, semiconductors, sensors and petrochemicals [2].

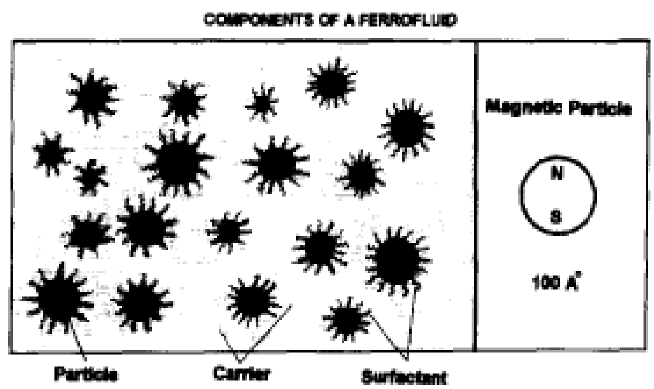

Figure 3 - Ferrofluid Components [2]

One interesting application of ferrofluid is damping of hybrid stepping motors. A stepper motor provides an interface between a computer and a mechanical device. These systems may have excess vibrations which affect the precision of operation as well as add unwanted noise. Ferrofluids are either directly incorporated into the stepper, or is attached via a ferro-fluid based viscous inertia damper to the shaft to reduce the vibrations and noise.

Ferrofluid is also applied within dynamic loudspeakers. They rely on the existence of a strong magnetic field in a small air gap, which generally includes ferrofluid and is critical to the speaker's performance. This allows for the loudspeaker to be critically damped, resulting in a smooth frequency response curve. The lubrication characteristics of a ferrofluid have also aided to the removal of any sound distortion resulting from the rubbing of the voice coil against the metal pieces within the speaker [3].

These are just two damping applications of ferrofluid. Literally millions of devices are built every year using these magnetic liquids.

Photographic Techniques

The only lighting for the video was the light from the Sun. Since the video was taken in the afternoon there is an evident shadow from the light source. The photo was taken using a Nikon D90 DSLR camera with a Nikon 18-200mm f/3.5-5.6 lens. Photoshop was used to crop the initial photo and to manipulate the colors into the black and white and the copper presented in the final image.

Photograph Date	March 18th, 3:15 PM
Distance from Lens to Object	2.5 in or 0.21 ft
Field of View	0.409 x 1.018 ft
Focal Length	200 mm or 0.66 ft
Image Size	1557 x 2034 pixels
Shutter Speed	1/80 sec
ISO Setting	200
Aperture	f/5.6

Horizontal field of view:

$$HFOV = d * \frac{i}{f} = 0.21 * \frac{1.8}{0.66} = 0.409\, ft$$
$$d = object\ distance$$
$$i = image\ dimension$$
$$f = film\ distance$$

Vertical field of view:

$$VFOV = d * \frac{i}{f} = 0.21 * \frac{3.2}{0.66} = 1.018\, ft$$
$$d = object\ distance$$
$$i = image\ dimension$$
$$f = film\ distance$$

Image Discussion

I am very pleased with my final image. I thought it was very beautiful, and revealed fluid phenomena that I was uninformed about previous to this project. I liked the reflection of the sun and also the building outside of the Durning lab on the fluid itself. The different colors gave the overall image a warm feel, and made it more interesting. If I could do anything different, I would pay more attention to the background of the image. The fluid physics are hard to interpret from the photo, but I think it's an interesting enough photo that people would be willing to read the report behind it to find out what is actually happening.

References

1. T. Albrecht, C. Bührer et al. (1997). "First observation of ferromagnetism and ferromagnetic domains in a liquid metal (abstract)". *Applied Physics a Materials Science & Processing* (AppliedPhysics A: Materials Science & Processing) **65**: 215. doi:10.1007/s003390050569
2. *Advances in Ferrofluid Technology* (1995): 174-80. *Journal of Magnetism and Magnetic Materials*. Web. 01 Apr. 2010
3. *Commercial Applications of Ferrofluids* 85 (1990): 233-45. *Journal of Magnetism and Magnetic Materials*. Web. 02 Apr. 2010.

Appendix

Image Assessment Form

Flow Visualization

Spring 2010

Name(s) Allison Hamrick

Assignment: Group Project 2 Date: April 5th, 2010

Scale: +, ! = excellent √ = meets expectations; good. ~ = Ok, could be better. X = needs work. NA = not applicable

Art	Your assessment	Comments
Intent was realized	+	
Effective	√	
Impact	√	
Interesting	+	
Beautiful	+	
Dramatic	√	
Feel/texture	+	
No distracting elements	+	
Framing/cropping enhances image	+	

Flow	Your assessment	Comments
Clearly illustrates phenomena	+	
Flow is understandable	√	
Physics revealed	√	It's hard to show application
Details visible	+	
Flow is reproducible	+	
Flow is controlled	+	
Creative flow or technique	+	
Publishable quality	√	

Photographic technique	Your assessment	Comments
Exposure: highlights detailed	√	
Exposure: shadows detailed	+	
Full contrast range	√	
Focus	+	
Depth of field	+	
Time resolved	+	
Spatially resolved	√	
Clean, no spots	+	

Report		Your assessment	Comments
Describes intent	Artistic	+	
	Scientific	+	
Describes fluid phenomena		+	
Estimates appropriate scales	Reynolds number etc.	~	
Calculation of time resolution etc.	How far did flow move during exposure?	+	
References:	Web level	+	
	Refereed journal level	~	
Clearly written		+	
Information is organized		+	
Good spelling and grammar		+	
Professional language (publishable)		+	
Provides information needed for reproducing flow	Fluid data, flow rates	N/A	
	geometry	N/A	
	timing	N/A	
Provides information needed for reproducing vis technique	Method	+	
	dilution	N/A	
	injection speed	N/A	
	settings	+	
lighting type	(strobe/tungsten, watts, number)	N/A	
	light position, distance	N/A	
Provides information for reproducing image	Camera type and model	+	
	Camera-subject distance	+	
	Field of view	+	
	Focal length	+	
	aperture	+	
	shutter speed	+	
	film type and speed or ISO setting	+	
	# pixels (width X ht)	+	
	Photoshop techniques	+	
	Print details	√	
	"before" Photoshop image	+	