University of Colorado

Ferrofluid Investigation

Group Project 2

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With Assistance from

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The purpose of taking a video of the ferrofluid was simply to show how a ferrofluid interacts when influenced by an extremely powerful magnet. Ferrofluid is not an intuitive liquid, and its behavior is unpredictable when surrounded by different shapes and sizes of magnets. I felt a video would best show this unpredictable and non-static behavior.

There were four things needed to create this visualization: a 3-1/2 inch diameter disc magnet, a 4 inch Petri dish, a 1-1/2 inch bolt and a plentiful amount of ferrofluid. The Petri dish was placed on top of the magnet, so that when the magnet was removed the ferrofluid could be collected instead of wasted. Then a 3-1/2 inch bolt was placed with the head side closest to the magnet. The ferrofluid was then poured onto the threaded side of the bolt. This set up is shown below.

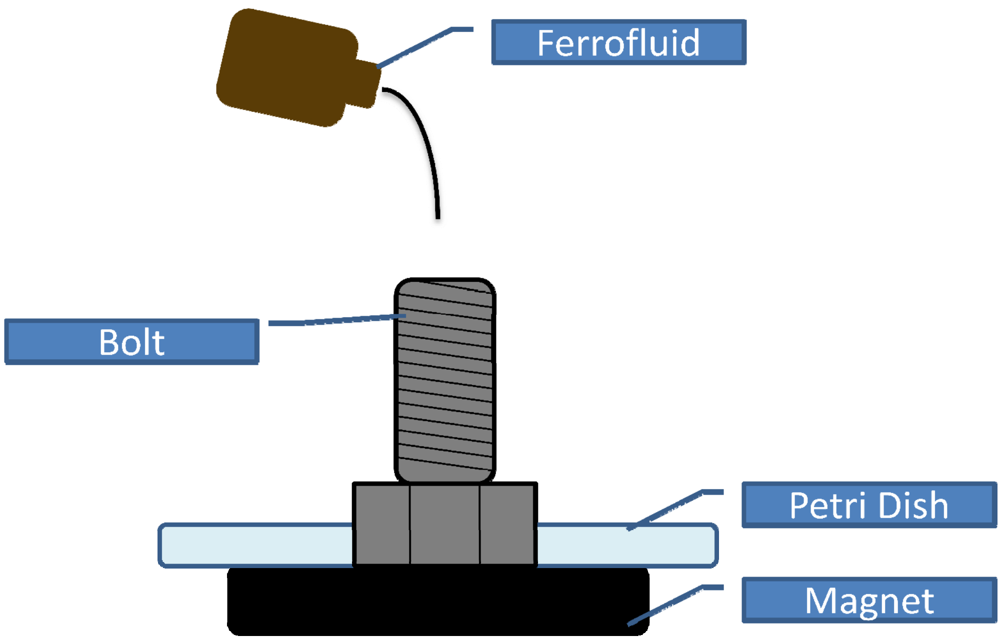

Figure 1: Ferrofluid Visualization

When the ferrofluid leaves the bottle, it is not influenced by the magnet. As the ferrofluid hits the bolt (magnetized) it interacts with the local magnetic field. This is an instantaneous occurrence and requires no time for the flow to interact with the field. When the fluid hit the top of the bolt, the normal-field instability was present there. As more fluid was added, the fluid started to gradually move down the channel of the threads of the bolt due to the increasing weight and influence of gravity. From the video, one can see from the 2 second mark to the 4 second mark the fluid moving down the threads. From this and estimating the density of the fluid as well as the dynamic viscosity, a Reynolds number for the fluid can be calculated by using Equation 1.

$$Re = \frac{\rho V L}{\mu}$$

Equation 1[1]

Using a ρ of 8 grams per cubic centimeter [2], a calculated V of 1.17 inches per second, a calculated L of 2.36 inches, and a dynamic viscosity of 1 mPa*sec [3] gives a Reynolds number 14.251. This is an extremely low Reynolds number, which is mainly due to the slow velocity of the fluid traveling down the threads of the bolt.

The project was conducted on the concrete pad outside of the Durning Lab on March 18th at 3:15 PM.. It is a visualization of the normal-field instability with a ferrofluid in the presence of a magnetic field. There was a slight breeze during the experiment and that is very evident towards the end of the video when the wind was gusting. 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 video has a field of view of 10 inches. When the video was filmed, the object was about 12 inches from the end of the lens. It was shot using a Nikon D90 DSLR camera with a Nikkor 18-200mm f/3.5-5.6 lens. The since the aperture of the lens cannot be changed manually while in the movie mode, the aperture was at its highest value for the given focal length. The focal length that the video was taken at was 135mm and the aperture was f/5.6. The video was compressed down to a 960x540 pixel MPEG-4 file using the H.264, AAC codec in iMovie '09. The video itself was not edited for exposure, time scale, or anything else. The sound was removed from the video as I deemed it was not necessary and was distracting.

This video shows the normal-field instability for a ferrofluid present in a magnetic field and how a ferrofluid is influenced by a strong enough magnetic field. It reveals how the fluid acts under the influence of gravity, wind, and other applied forces. I think that the fluid physics are shown as well as they could be. My intent was most definitely fulfilled in this project. In my opinion, capturing this instability on video shows a completely different perspective than a picture does because this flow was not static and moves due to the environment. I would have liked to have done this inside with a more uniform light source. The video was taken outside and a large shadow is present, which is distracting. Also, I wish I would have used a white background because even though the concrete in the background is out of focus it is still distracting.

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[1] Kundu, Pijush, and Ira Cohen. *Fluid mechanics*. Academic Pr, 2008. Print.

[2] Strebin, R. Jr. S., J. W. Johnson, and D. M. Robertson. "Application of Ferrofluid Density Separation to Particles in the Micrometer-size Range." (1976): 1. Web. 04 Apr. 2010. <http://adsabs.harvard.edu/abs/1976STIN...7717432S>.

[3] Odenbach, S, and H Stork. "Shear dependence of field-induced contributions to the viscosity of magnetic fluids at low shear rates." *Journal of Magnetism and Magnetic Materials*. 183 (1998): 188-194. Print.