Team First 2016

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Flow Visualization

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2016

Introduction

The purpose of this assignment was to explore a fluid flow from an artistic perspective. The project chosen for the "Team First" assignment was an exploration of ferrofluid and its interactions with strong magnetic fields. Ferrofluid is a fluid with ferrous nanoparticles suspended in an oil solution, that has strong reactions when interacting with magnetic fields. In this particular experiment, multiple magnetic forces were used to interface with the fluid.

The Apparatus

The apparatus for this flow visualization was quite simple. The ferrofluid used was FerroTec EFH1 which consists of a magnetic particle concentration of 7.9% by volume suspended in a light mineral oil. While the suspended particles have a nominal particle diameter of 10nm. Due to the small particle size and a force called Brownian Motion, the particles never settle on the bottom of the fluid. The setup, shown below in Figure 1, consists of two acrylic sheets separated by a distance of approximately 2" with the bottom tray containing the ferrofluid. A large stack of Neodymium magnets was placed below the bottom sheet while there were only 2 neodymium magnets above the top plate.

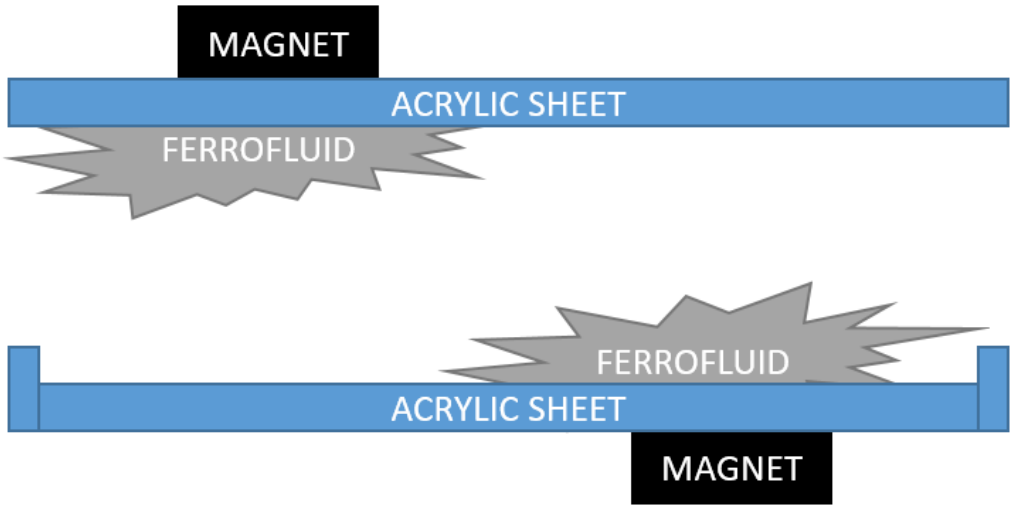

Figure 1: Apparatus setup showing the relative placement of the magnets and ferrofluid.

On the bottom plate was a four-star ferrous knob placed threaded side down as shown in Figure 2. The magnets on the top started at a large distance away from the stationary bottom magnets, and were slowly moved towards the bottom magnet and ferrofluid. As the top magnets approached the bottom magnets, the ferrofluid would have larger magnitude spikes in the direction of the top magnets and eventually jump to the top sheet of acrylic and magnets. This occurs when the magnetic force of the top magnet overpowers the magnetic force of the bottom magnet on a set of particles.

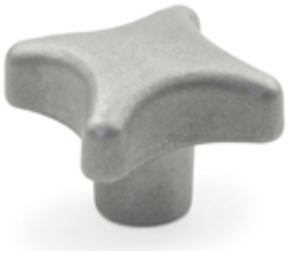

Figure 2: Four-star knob in the same orientation as in the experimental setup. (http://www.jwwinco.com/products/section8/din6335-ni/index.html)

When the magnetic force between the two magnets creates an aesthetically pleasing structure, both sets of magnets were held statically in that position. This results in a fluid velocity of zero (v=0), and a subsequent Reynolds number of zero. The spiking phenomena is best explained using van der Waal forces between the particles causing the fluid to create localized peaks, while each localized peak follows the magnetic field lines of the introduced magnets.

Visualization Technique

The image was taken using the setup described above in Figure 1. Photographically, there was a diffused desk lamp at 90 degrees to the right of the camera, facing down on the ferrofluid at a 45 degree from the horizon. The built-in camera flash was used to illuminate the fluid from the direction of the camera. Ambient light was illuminating the ferrofluid from the fluorescent lighting directly above the setup, and from an open window directly behind the setup delivering indirect sunlight.

Photographic Technique

This photograph was taken on a Nikon D5000 DSLR camera using a Nikon VR 18-200mm f/3.5-5.6G lens, on loan from Johanna Heilman. Since there was not a tripod available at the time, the image was taken holding the camera by hand looking at the fluid from a horizontal reference point. Focus was set to automatic to compensate for the lack of a steady tripod. The object was about 24” away from the lens with a zoomed focal length of 200 mm. Image resolution was large at 4288 x 2848 shooting in a 12-bit compressed RAW format. A desk lamp was shining onto the ferrofluid from the right side relative to the flow, along with the use of the camera’s built-in flash resulting in an ISO of 450 as there was enough external lighting to properly illuminate the flow. A shutter speed of 1/40s was used in order to try to better capture the contrast between the dark fluid layering on top of itself. The fluid flow was essentially frozen in time over the exposure period, but there may have been slight motion blur from the minute movements of the ferrofluid.

Table 1: Camera settings

Camera	Nikon D5000 (DSLR)
Lens	VR 18-200mm f/3.5-5.6G
Original Image Size	4288 x 2848
Final Image Size	1821 x 1624
Field of View	~ 2” x 3”

Focal Length	200 mm
Aperture	f/5.6
Shutter Speed	1/40s
ISO	Auto (ISO 450)
Flash	Built-in Flash

The image was edited slightly from the raw shot using GIMP. In order to maintain the scientific validity of the photo, it was cropped to a resolution of 1821 x 1624 which eliminated part of the fluid flow that was not resolved in the right side of the photo. The image's contrast curves were altered to try to achieve a greater contrast between the different layers and peaks. The decision to make the photo black and white was made to eliminate the background distractions and resulted in a sharper looking effect than the unedited version shown in Figure 3.

Figure 3: Unedited image

Image Intentions

The intention of this image was to capture the bizarre yet intriguing patterns formed by ferrofluid in a magnetic field. I believe the final image does a good job of capturing these intentions in an artistic manner. The image also succeeds in creating a mysterious and outer worldly tone. If I were to build upon this photoshoot, I would choose to use a tripod to get a more controlled setup, and possibly use water based dyes poured over the spikes to contrast and add color to the image.

Acknowledgements

Special thank you to Johanna Heilman for lending her DSLR camera for the photoshoot. Thank you to Jeremy Parsons and Max Scrimgeour for their assistance in setup and execution of the photoshoot. Thank you to Joseph Straccia for helping brainstorm ideas for an effective setup. Thank you to Professor Jean Hertzberg for very generously loaning ferrofluid to the team for the photoshoot.

Works Cited

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http://www.jwwinco.com/products/section8/din6335-ni/index.html

https://ferrofluid.today/pages/what-is-ferrofluid#scrollup

http://www.flowvis.org/media/course/FerrofluidTechData.pdf