Photographing Magnetic Waves using Ferrofluid

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Assignment: Team Third

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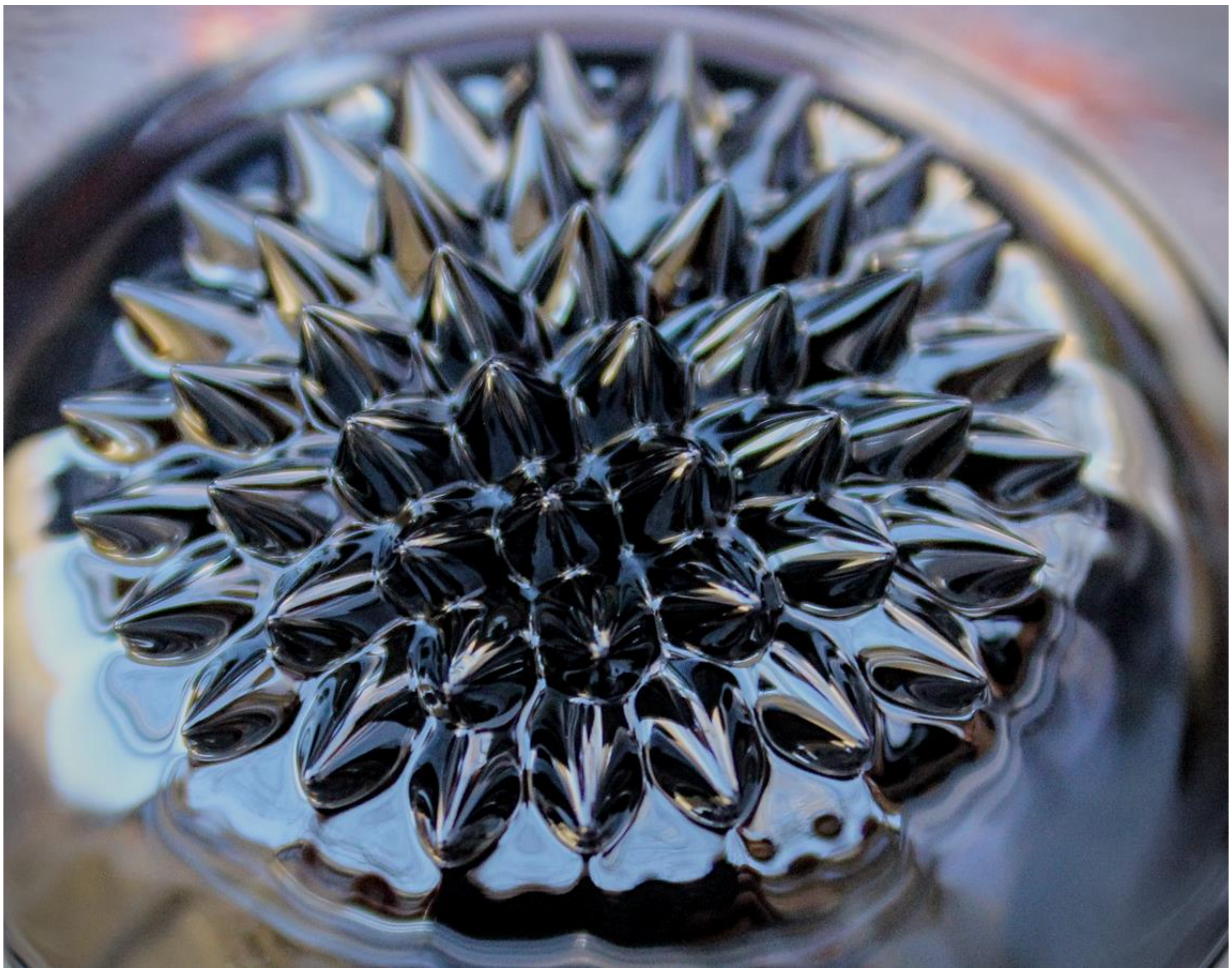

Figure 1, front view of magnetic waves through magnetized ferrofluid.

Introduction

The image in figure 1 was captured for the Team Second assignment for MCEN 5151. This is a Flow Visualization course at the University of Colorado Boulder. The goal of this course is to focus on making the physics of fluid flow more visible to the human eye [1]. The intent of this image was to show how ferrofluids work and explain the physics behind it. Ferrofluids are a special liquid with tiny magnetic particles. In the presence of a magnetic field, the tiny particles condense into a solid and waves occur. This image was shot with the help of Team Kohlrabi (Hannah DelGuercio, Sam Lippincott, Kenneth Olavarria). In the following report, I will discuss the phenomena and techniques used to capture this image.

Fluid Physics

Below in figure 2 is a diagram of the flow visualization apparatus used for this photo.

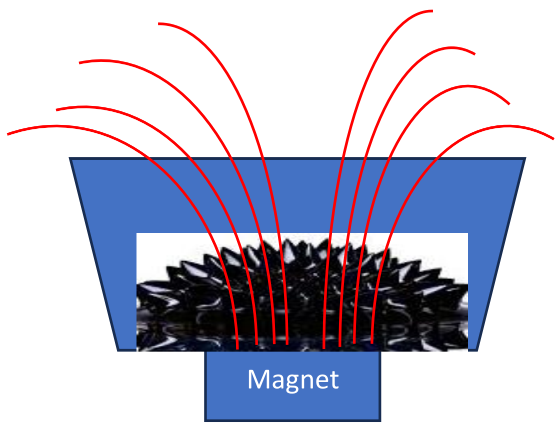

Figure 2, diagram of flow visualization apparatus.

Ferrofluids are composed of nanoscale particles of magnetite, hematite, or other compounds containing iron and a liquid. The particles are small enough for thermal agitation which allows them to disperse evenly within a carrier fluid. This contributes to the magnetic response of the fluids. When a ferrofluid is subjected to a strong magnetic field, the surface will form waves. This can be seen above in figure 2, which approximates the magnetic field. The effect is known as Rosensweig. The instability occurs because of the magnetic field [2]. A fascinating way the Rosensweig effect is used in technological applications is for heat dissipation. To extract heat from equipment that gets too hot, a good heat conductor is connected to a mass on the equipment that has a much bigger heat capacity. In some instances, the heat conductor can’t be solid as it can block the operation of the equipment. A way to achieve this is by using a ferrofluid heat conductor. A nonmagnetic fluid will flow away from the place where the equipment operates. An example of this is a speaker, whose coils heat up and the ferrofluid is kept in place by the magnetic field of a magnet. The presence of the fluid around the coil can also improve the quality of the audio as it can act as a damper [3].

Experiment Setup

Figure 3, experimental setup.

We shot a series of photographs outside the engineering center. It was shot around noon so there was plenty of natural light for our image. A 4” x 4” tupperware was used to pour the ferrofluid into. Then a magnet was placed underneath the tupperware, and we immediately saw the waves formed.

The following camera settings were used on the Canon EOS Rebel T3I

1/80 • f/5.6 • 55.0 mm • 2000 ISO

We used a high shutter speed of 1/80. A low shutter speed would have allowed for more light to enter the image, but this wasn’t necessary as it was taken outside during the day. The picture was taken approximately 15 cm from ferrofluid. A 55 mm zoom lens and 5.6 aperture were used for this specific image. Finally, a high iso of 2000 was used to create a higher sensitivity to the light.

Image processing

Figure 4, after editing (Left), before editing (Right)

Dark Table was the editing software used to process my original image. Some notable edits to the image were increasing the sharpness. This helped the circular waves stand out more. I cropped the image to hide the stable ferrofluid resting on the surface. I also played with the white balance and local contrast to make the colors appear more vivid. Lens correction caused a slight zoom as well that helped capture a “closer” image and it helped make the image less flat. I also did some color correction to make the shadows less evident. Overall, I believe my editing helped create a color contrast and sharpened the image without taking away from the picture.

Conclusion:

Overall, the team was able to photograph magnetic waves using ferrofluids. I believe I was able to capture an aesthetically pleasing image, while also showing the physics occurring between the fluid and the magnet. Another approach to this image to make it more aesthetically pleasing would be to incorporate more colors. For simplicity however, we thought that the ferrofluid waves were aesthetic enough while also showing the physics occurring.

References

[1] Hertzberg, Jean. “SYLLABUS MCEN 4151/5151/ FILM 4200/ ARTF 5200/ ATLS 4151/5151 Flow Visualization: The Physics and Art of Fluid Flow Fall 2023.” FLOW VISUALIZATION A Course in the Physics and Art of Fluid Flow, 23 Aug. 2023, https://www.flowvis.org/wp/content/uploads/2023/08/syllabusF23.pdf.

[2] “Smart Materials : Ferrofluids & Magnetic Levitation.” PhysicsOpenLab, 3 Apr. 2017, physicsopenlab.org/2017/04/03/smart-materials-ferrofluids-magnetic-levitation/.

[3] (PDF) Ferrofluids: Properties and Applications - Researchgate, www.researchgate.net/publication/260863044_Ferrofluids_Properties_and_Applications. Accessed 24 Nov. 2023.