Cameron Sprenger

MCEN 5151

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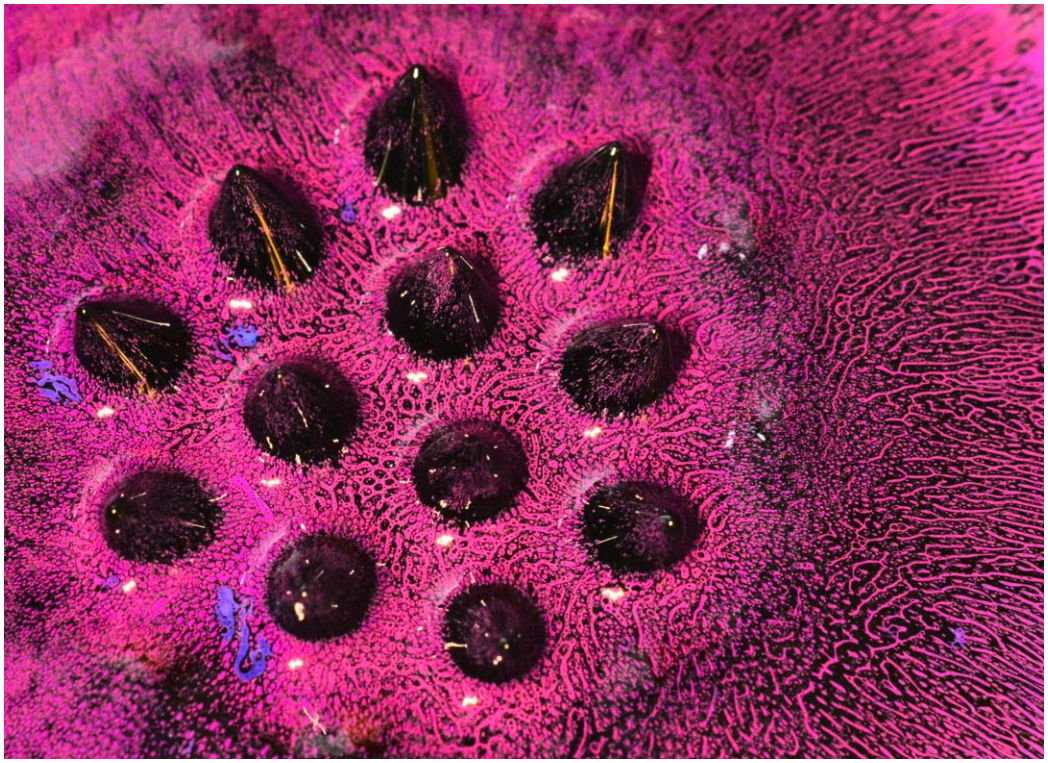
Team Second Report



Ferro fluid with pink and purple water-based paint on the surface

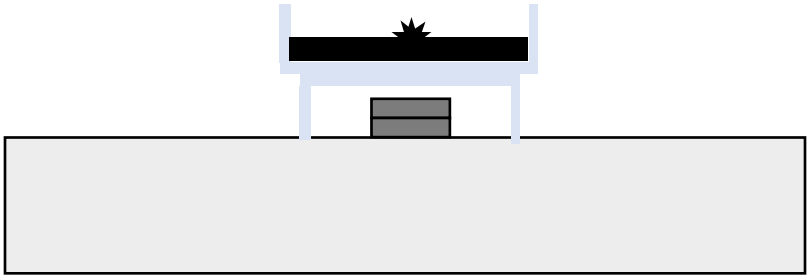
Introduction

Our group decided to experiment with ferro fluid because of its interesting properties and potential to create unique flow. We were inspired by some of the past projects in the class gallery because of the brilliant colors, and the flow was beautiful and unfamiliar to most people. The set up was relatively simple but it took some fine tuning to get the results we wanted. The spikes in the ferro fluid are caused by the normal field instability and are a result of the magnetic field lines from a magnet placed below the fluid. The ferro fluid is made of magnetic particles suspended in an oil which gives it properties of a fluid and magnetic filings.

Experimental Set Up

The ferro fluid was contained in a petri dish with a diameter of 2 inches and was placed on top of two circular disk magnets stacked on top of each other. The petri dish was held slightly above the magnet to get the best resulting spikes. If the petri dish was placed directly on the magnet, the fields would be too strong, and the normal instability would break up the ferro fluid spikes into smaller spikes that didn't look as good. We found that flipping the lid of the petri dish upside down and using that as a stand to hold the petri dish a few millimeters above the magnet worked well and created the largest ferro fluid spikes. The figure below shows the experimental set up that was used by our group.

Figure 1.



Petri dish set up on a chair in basement of the ITLL with as much direct overhead light blocked as possible. Ferro fluid was poured into the petri dish, then water-based paint from a paint market was poured on top.

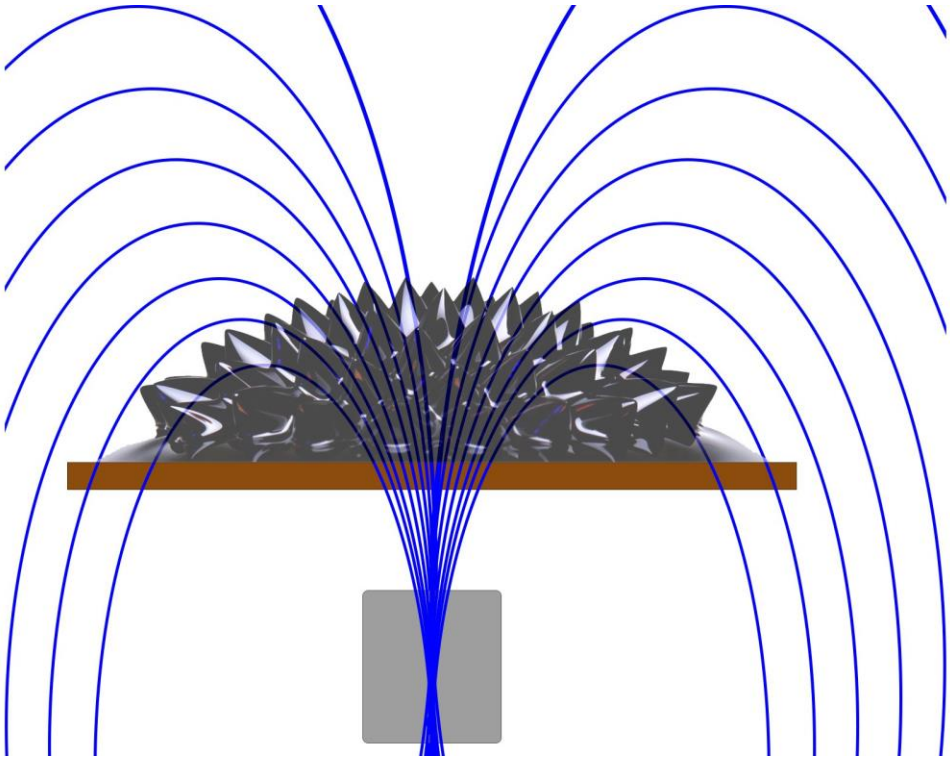
After taking a few pictures, we found that the ferro fluid is incredibly reflective and overexposed some areas of the images, so we went into a dark room in the basement of the ITLL where the lights could be turned off and the door could be opened a bit to control the amount of ambient light entering the room. The ferro fluid spikes don't move once they are formed, so we were able make the room really dark to reduce the amount of direct light and we used a 4 second exposure to gather enough light for the image to look bright.

Flow Mechanisms

The spikes in the ferro fluid are formed because of the normal field instability induced by the magnetic field lines of the magnet. The instability arises because the iron particles in the ferro fluid channel magnetic field lines and create areas of greater concentration. This can be seen in the valleys and peaks of the ferro fluid. The peaks are where the magnetic field lines are the strongest, and the valleys are where they are the weakest. The spikes originate from the center because the magnets that we used were circular magnets, and the magnetic field lines are radially symmetrical from the center (Figure 2). There are three main forces acting on the fluid in the image. There is gravity acting downward on the fluid and the spikes, surface tension which mainly is acting on the spikes, and the magnetic force from below. The ferro fluid reaches

equilibrium almost instantly once placed on the magnet, so the components from each type of force balance out and the fluid remains stationary. Magnetic energy is minimized when peaks and valleys are formed, even though the gravitational energy and surface tension energy increase. Technically, when our group added paint onto the surface of the ferro fluid, the paint added another force to the surface of the ferro fluid. Before we added the paint, the spikes were clumped more closely together and were almost touching at the base, but once we added the paint, the spikes became more spread out as you can see in the title image above. This is because the paint dried a little bit due to the paint layer being so thin, and the paint acted as a slight barrier between the spikes. This acted againts the normal field instability and spaced the spikes out slightly.

Figure 2.



The magnetic field lines originating from a magnet placed under a body of ferro fluid. The iron particles channel the field lines, and the peaks form where the magnetic fields are the strongest.

Flow Set Up

We began by adding around 25 mL of ferro fluid into a petri dish from a bottle using a syringe. Water-based paint from a paint market was collected in another petri dish and poured onto the top of the ferro fluid. There was just enough paint to cover most of the ferro fluid, but not so much that it obstructed the properties of the ferro fluid. The petri dish with the paint and ferro

fluid was placed on top of the magnet which was under the lid of the petri dish as seen in figure 1. We then turned off the lights in the room and took pictures using a macro lens and a tripod since we needed such long exposures. We could reset the paint and the spikes by lifting the petri dish and placing it back down which allowed each member of our group to get different results. In addition to that, we had 4 different color markers, so people could add the colors they wanted to into the dish and photograph that setup. Macro lenses have a shallow depth of field which made photographing the spikes slightly difficult. The shallower the angle of the camera is to the fluid, the more you can see the spikes, but as a result, the more of the image is out of focus. We found an angle that showed the prominence of the sikes as well as having most of the magnetically effected area in focus.

Photographing Techniques

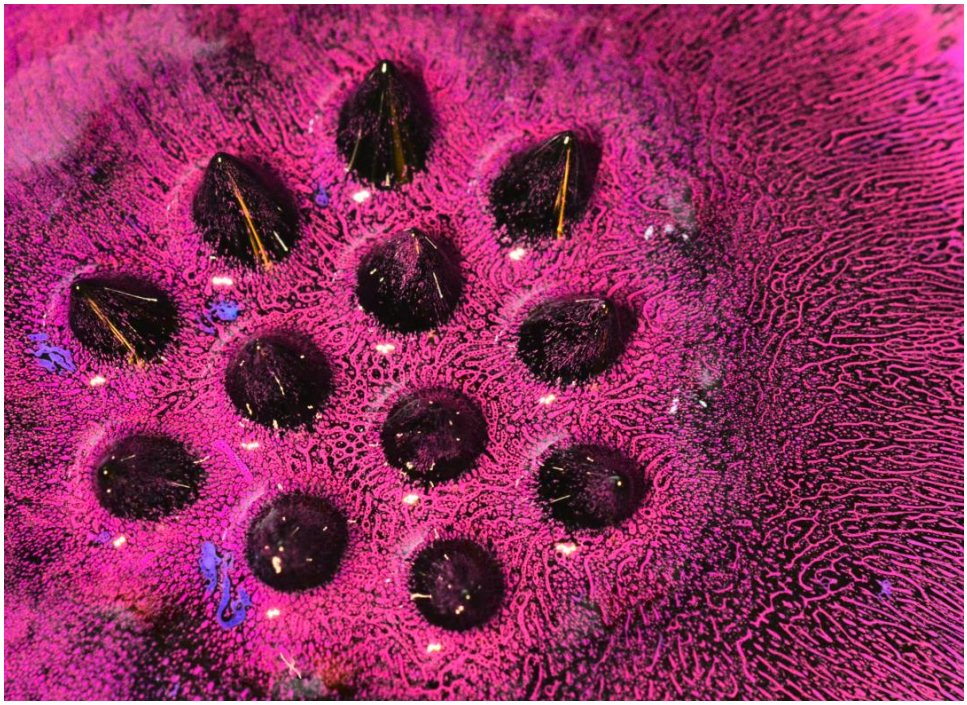
Ferro fluid stains everything it touches, so we kept the camera as far away from the petri dish as possible in the case that is splashed, but we also wanted to be close enough to get a close-up view of the spikes which were only a few millimeters tall. To accomplish this, we used a 200 mm macro lens which has a very narrow field of view and can zoom in incredibly close from 2-3 feet away. Once the experiment was set up and ready to be photographed, we used a remote trigger to activate the shutter without having to touch the camera body and risk blurring the image during the 4 second exposure. We repeated this until the paint on the surface dried and had to be cleaned off and reapplied. Below is a table of the camera setting used.

Setting	Value
Camera	Nikon D800
F-stop	f/18
Exposure	4
ISO	1250
Focal Length	200 mm

Post Processing

I cropped the image into the spiked area because that was the focus of the image, and the foreground and background were slightly blurry and didn't add to the image. The original image had a resolution of 7360 x 4912 and the post processed image had a resolution of 3367 x 2442. The original image was also too dark, so I increased the color values to get more contrast between the paint and the ferro fluid. I did this by adding an s-curve to the tone curve and adding a hump in the color curve for pink and red. Below is the original image compared to the post processed image.

Original image



Conclusion

Overall, I think the image is interesting and shows a cool fluid phenomenon. Cropping a circular flow into a rectangular image is always tough because you either crop out part of the flow or include some of the background which is less interesting and sometimes blurry. In my image, the top left has a reflective area that doesn't show any particularly interesting interaction but had to be included because I wanted to capture the full spikey area of the ferro fluid and the pattern the paint forms on the surface of the oil based ferro fluid. If I were to remake this image, I would have made a different container to hold the ferro fluid that is closer to the size of the spikey area so there is less background paint that is distracting to the focus of the image. It could have been interesting to experiment with florescent paint because it would further highlight the contrast between the black of the ferro fluid, and the paint on the surface. But in the end, the image still shows the spikes of the ferro fluid very well and is a good example of what can be done with ferro fluid and a magnet.

Sources:

"Smart Materials : Ferrofluids & Magnetic Levitation." *PhysicsOpenLab*, 3 Apr. 2017, physicsopenlab.org/2017/04/03/smart-materials-ferrofluids-magnetic-levitation/.

"Ferromagnetism." *Wikipedia*, Wikimedia Foundation, 27 Oct. 2023, en.wikipedia.org/wiki/Ferromagnetism.