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Flow Visualization Project #3
Ferrofluid

For the third project I decided to image a ferrofluid. Ferrofluids are colloidal mixtures composed of nanoscale ferromagnetic particles suspended in a carrier fluid.

The flow apparatus was a plastic Petri dish lid measuring 4 inches in diameter. It was turned upside down and neodymium magnets were placed directly under the screw. The fluid contains superparamagnetic nanoparticles. The nanoparticles are suspended by Brownian motion and never come out of suspension from the carrier fluid. The carrier fluid itself is an organic solvent or water. The particles must also be coated with surfactants to prevent nanoparticle agglomeration which would make them too heavy to be held in suspension by Brownian motion (1). The fluid also produces a spiked crown effect when placed in a magnetic field oriented normally to the fluid surface as shown in one of the captured images below:

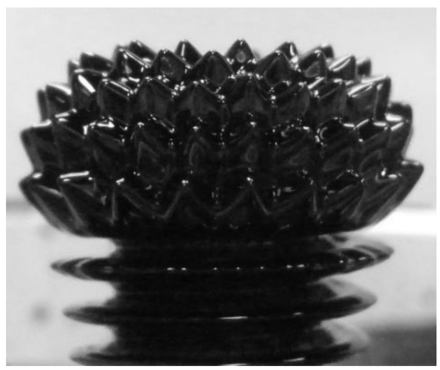

Figure 1 - Ferrofluid Crown

This crown is the result of the Rosensweig instability. The Rosensweig instability shows that when the magnetic strength reaches a critical value, a sudden transition from an original flat surface to a hexagonal pattern of three dimensional liquid crests occurs (2). This effect is mathematically modeled by the Maxwell equations. The Maxwell equations are a set of four partial differential equations that describe the properties of the electric and magnetic fields and relate them to their sources, charge density and current density (3). Studying these crowns has practical applications in the considering interface instabilities, such as the Rayleigh-Taylor configuration. This configuration is used to study the electrohydrodynamic instability of a polymer liquid/air interface effect on the growth rate for thin films. These thin films show a monotonic dispersion relation. However, the situation is different for thick layers, where the weight of the liquid has to be taken into account (2). When studying the Rayleigh-Taylor instability one cannot simply turn the gravitational field on and off which makes the modeling extremely difficult. Researchers hope to create a numerical simulation tool with the ferrofluid to account for the different layer thicknesses in the presence of fields they can control and produce a tool able to create the desired thin films (4).

The fluid was applied to a screw after the magnetic field was already present. The screw was a half inch long with 12 threads per inch and a flat top and bottom surface. A pipette was used to apply the ferrofluid to the screw. The fluid was pulled from the pipette from about four inches away due to the attraction. The fluid assumed the crown shape atop the screw immediately but the definition of the crown points varied by magnetic strength. The stronger the field the smaller and more frequent the points while if the field were weaker the points appeared larger and less defined which agreed with the research presented (2).

The landscape was lit using an overhead workbench light on a moveable arm and photographed from the front side using the following settings

Saturation: 0
DigitalZoomRatio: 0/100
FocalLength: 77/10
MaxApertureValue: 362/100
FNumber: 40/10
ExposureTime: 10/800
ExposureBiasValue: 0/10
ExifVersion: 0221
ExposureProgram: 5
ProgramMode: 5
WhiteBalance: 0
DateTimeOriginal: 2009-03-30T09:22:00Z
MeteringMode: 5
LightSource: 0
ISOSpeed: 320
Contrast: 0
Sharpness: 0
FlashpixVersion: 0100
ColorSpace: 1
CompressedBitsPerPixel: 3/1
PixelXDimension: 3264
PixelYDimension: 1710
DateTimeDigitized: 2009-03-30T03:22-06:00

All photographs were taken using an Olympus FE-370 8.0 megapixel digital camera. This camera has a focal length range of 6.3-31.5mm and an aperture range of 1:3.5-5.6. All photographs utilized the camera's "indoor" setting in conjunction with the "super macro" setting with the flash disabled. The camera was placed on a tripod for all photographs. The image was captured 6 inches away from the screw and at a 30 degree angle from the backdrop to avoid glare. Photoshop was used to adjust the color balance and crop the photo.

I captured many images and this was just one of my favorites. This fluid presents a seemingly limitless amount of possibilities for creative pictures. For a follow up project I would like to create a video using the same fluid and try to capture the motion as it scales a sculpture or this screw.

Works Cited

1. **Brown, Robert.** A BRIEF ACCOUNT OF MICROSCOPICAL OBSERVATIONS. *reprint of the manuscript.* 1827. http://sciweb.nybg.org/science2/pdfs/dws/Brownian.pdf.

2. *Growth of surface undulations at the Rosensweig instability.* **Holger Knieling, Reinhard Richter, Ingo Rehberg, Gunar Matthies, and Adrian Lange.** Dresden, Germany : Fraunhofer Institute for Material and Beam Technology, 4 Dezember 2007. PACS numbers: 47.20.Ma, 47.54.-r, 75.50.Mm.

3. **Signell, Peter.** ELECTROMAGNETIC WAVES FROM MAXWELL'S EQUATIONS. s.l. : Michigan State University.

4. *An experimental study on Rosensweig instability of a ferrofluid droplet.* **Ching-Yao Chen, and Z.-Y. Cheng.** 20, Taiwan, Republic of China : American Institute of Physics, 2008. 1070-6631/2008/25/054105/8/$23.00.