Oil Bubbles in Water

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Flow Visualization, MCEN 5051
Image / Video Assignment #1
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Introduction

The purpose of this video was to image fluid dynamics in an aesthetic and creative way. The goal for this first assignment was to practice and gain a better understanding of how to use the photography medium with fluid dynamics in an artistic manner. For this first assignment, the fluid concept of surface tension and buoyancy was used to create a visually interesting composition. In the video colored oil is shot into a beaker of water. The oil forms into large beads and droplets and rises to the surface of the water. Lastly, in the video, the powder dye falls out of the oil and into the water.

Fluid Dynamics Used

Surface Tension and Polarity

Oil is made up of nonpolar molecules, while water is made up of polar molecules. The polarity of the molecules determines if the solutions will dissolve or not and that difference is the reason why the oil resists combining with the water. This can be seen in the image below.

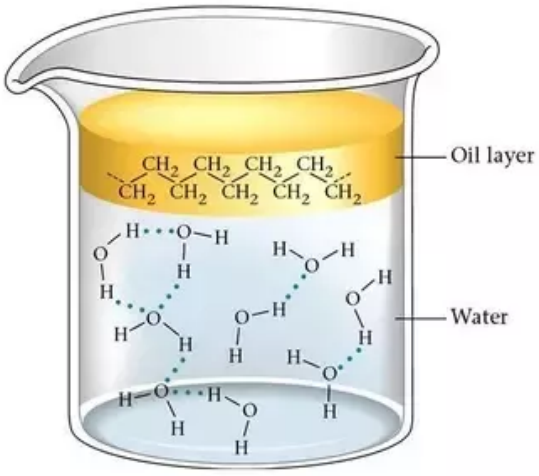

Fig.1 Oil vs Water Molecule Polarity

Secondly, the strength of a surface in a fluid can be described as the surface tension of that fluid. In water, the surface tension is created by the attractive forces between the hydrogen and oxygen atoms in different molecules.

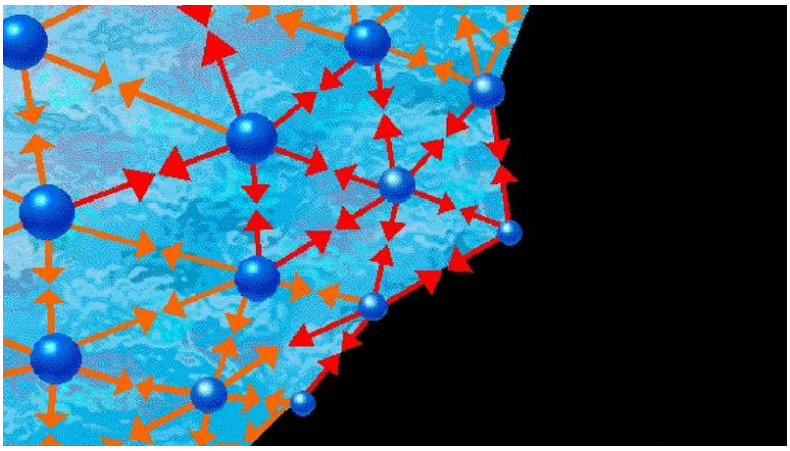

Fig.2 Surface Tension Diagram

When the oil is submerged in the water it creates a boundary between the oil and water. That boundary creates a surface within the water volume. That surface has tension and applies a compressive force on the oil. This combined with the buoyant forces shapes the oil into spherical and smooth droplets.

Buoyancy & Fluid Density Gradients

The other large set of forces at play in this experiment is buoyant forces and density gradients. Buoyant forces are fundamentally due to internal pressure gradients within a fluid. This gradient comes from the fact that the fluid at the bottom of the volume has the weight of all the fluid above it acting on it, while the fluid at the top of the volume is only weighed down by its own weight. This means that the fluid at the bottom of the volume will be slightly denser and under more pressure than the fluid at the top. This can be represented in the equation below to calculate the net buoyant force.

$$F_{buoyant} = \rho g V_f$$

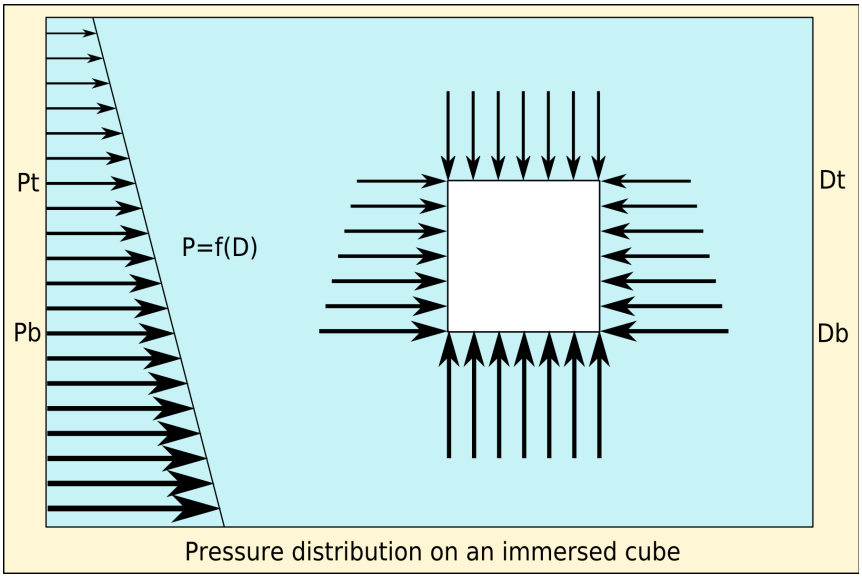

Fig.3 Buoyant Force Gradient

This pressure gradient creates uneven forces on objects submerged in the fluid and this contributes to why the oil in the water beads up and floats. The oil also floats because it has a lower density than the water. Also seen in the image is the higher density pigment falling out of the oil. As the pigment falls out of the oil it dissolves with the water, leaving behind colored streamlines in the water volume.

Producing the Flow

This flow was created fairly easily. The important parts are a clear beaker of clean water, colored oil, and lastly something to shoot the oil into the water with. I used a squirt bottle that was originally used for hand sanitizer to shoot the oil. Before I began the experiment I submerged a pencil into the beaker of water to get the focus right on my camera. I then began the recording on my camera and began squirting the oil into the water. I recommend waiting until the oil from the previous shot rises before putting more oil into the beaker.

Camera Setup and Image Acquisition

The setup for this video was a little bit complicated. I used a short table to hold the beaker and I had my camera on a tripod. I used a tarp to get an even colored background and I laid paper towels under the beaker in case of spillage. For lighting I underlit the beaker with an Aputure AL-M9 wireless photography light and I turned off the overhead lighting in my room. The video was taken at 60fps in 4k resolution. I used a Canon 1dx mark II to film and the iso was set to around 400,

although I adjusted it through filming. I set the shutter speed to auto and set my aperture and exposure comp so that the background was completely dark and only the subject beaker was lit by the underlighting. I used a variety of lenses ranging from a 16mm to a 50mm lens. Here is a photo of the setup.

Fig.4 Camera Setup

The video was post processed and edited in Adobe Premiere Rush. The main edits were to the time scale and color grading. I sped up most of the footage to meet the 2 minute requirement and also to show the entirety of the flow. Most of the color grading done was to increase the contrast and darken the background. This was done to highlight the subject beaker and give the colored oil a luminant pop in color and saturation.

Conclusion

The purpose of this project was met with this experiment. I learned a lot about focusing on close objects and focusing on fluid elements. I gained practice with my understanding of lighting and exposure by using an uplighting technique and finding an exposure setting that blacked out the background. I am very pleased with the result and I personally think the video came out very visually interesting and artistic.

References

Music Rights: *Adobe Media Library*

Buoyant Forces and Images: Wikipedia Commons

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- ^ Note: In the absence of surface tension, the mass of fluid displaced is equal to the submerged volume multiplied by the fluid density. High repulsive surface tension will cause the body to float higher than expected, though the same total volume will be displaced, but at a greater distance from the object. Where there is doubt about the meaning of "volume of fluid displaced", this should be interpreted as the overflow from a full container when the object is floated in it, or as the volume of the object below the average level of the fluid.
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