Flow Visualization of a Headless InnoGear Essential Oil Diffuser

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Assignment: Get Wet

Course: MCEN 5151-001, Flow Visualization

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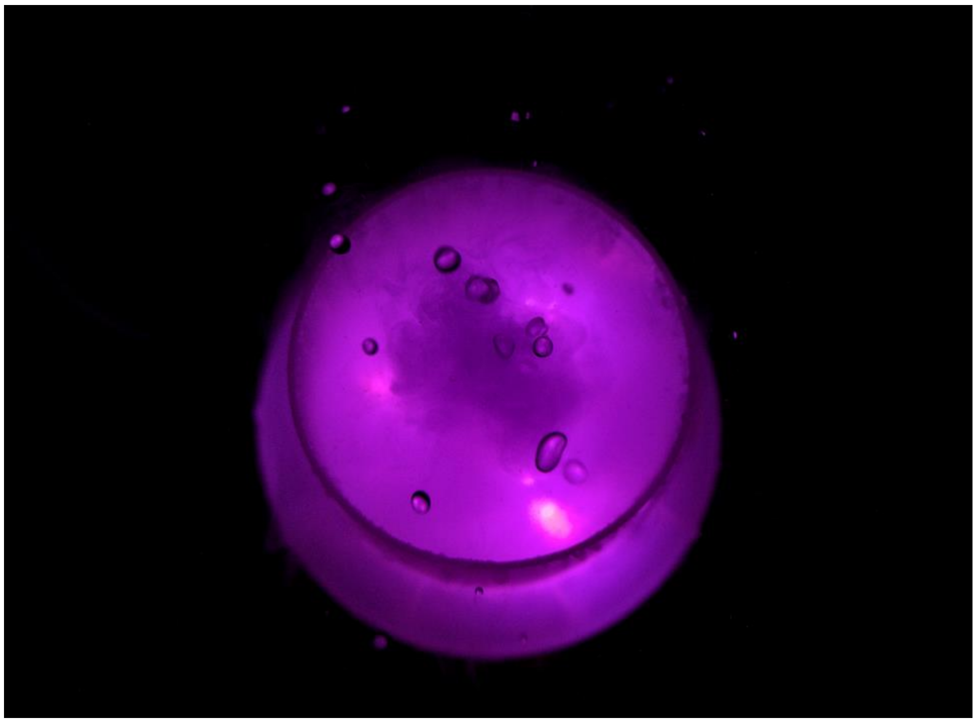

Figure 1, Top-down view of water droplets bubbling inside an innogear essential oil diffuser. The lid of the diffuser was taken off to visualize this.

Introduction

The image in figure 1 was captured for the Get Wet 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 capture microparticles occurring inside the oil diffuser. When the diffuser is turned on, ultrasonic discs at base cause vibration at ultrasonic frequency. The frequency is measured at 20kHz, which is inaudible to the human ear. The vibrations agitate the water at a high speed, which causes particles to break down into micro-particles. The mixture of water and micro-particles turns into a mist [2]. As seen in the image, the cloudy area is the mist forming from the mixture of the water and microparticles. The droplets above the mist are the microparticles bouncing inside the oil diffuser.

Fluid Physics

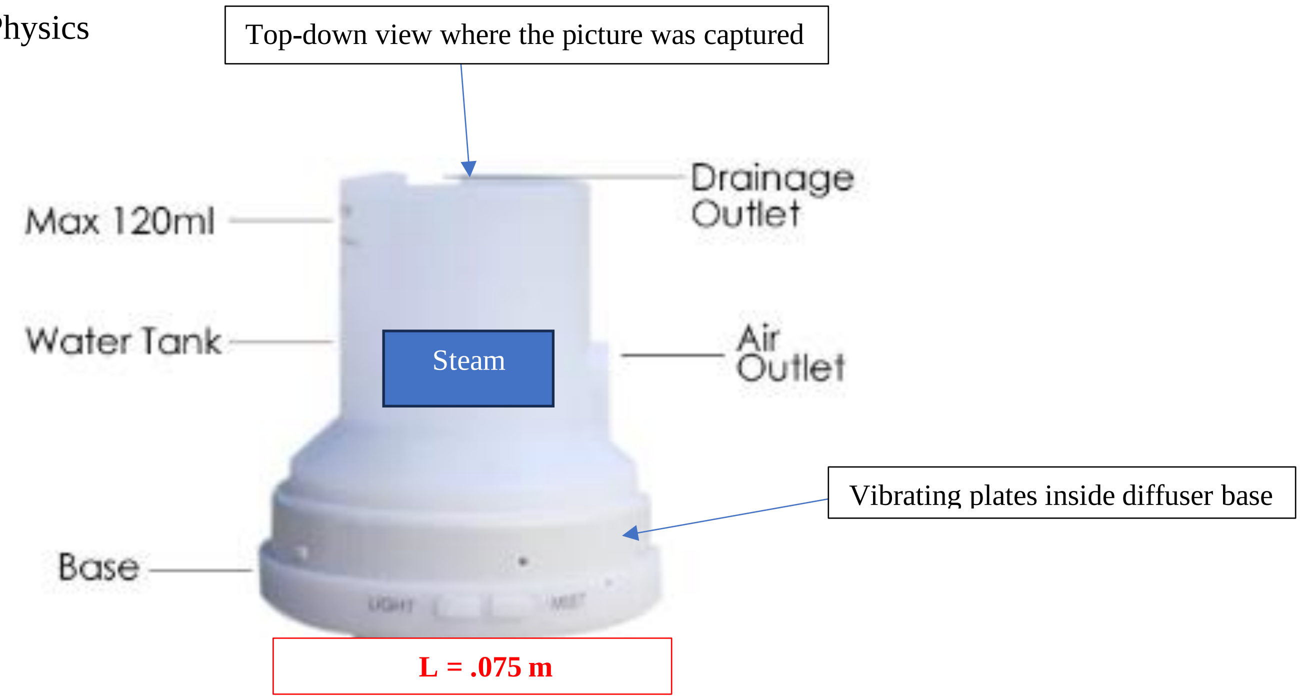

Figure 2, Essential Oil Diffuser

Flow can be described using Reynold's number. A Reynold's number below 2300 is considered laminar, or a smooth flow. A Reynold's number above 4000, is considered turbulent, or a flow that's agitated. A Reynold's number between 2300-4000, is transitional, or a mix of both. As seen in our image from figure 1, a transitional flow assumption can be made occurring inside the diffuser. "Wall-bounded flows experience a transition to turbulence characterized by the coexistence of laminar and turbulent domains in some range of Reynolds number R, the natural control parameter. This transitional regime takes place between an upper threshold Rt above which turbulence is uniform (featureless) and a lower threshold Rg below which any form of turbulence decays, possibly at the end of overlong chaotic transients" [3]. In our case, the upper threshold of our Reynolds number are the microparticles captured in the image. The lower threshold is the steam forming. The following variables were used to calculate the transitional flow occurring in the diffuser:

Density of water vapor at STP	.7618 kg/m^3 [4]
Velocity	.075 m/s (Manufacturers notes)
Length of vibrating plates at base	.075 m
Dynamic viscosity of steam	1.299 x 10^-6 [Pa s] [5]

Reynolds number can be expressed as:

$$\text{Re} = \frac{\rho \text{uL}}{\mu}$$

Plugging in the variables above achieves a Reynold's number of 3299. This falls directly between the transitional flow criteria of 2300-4000. Expanding conical and planal diffusers incorporate low Reynolds numbers. This allows for flow rectification and leads to pumping action in one preferential direction [6]. In the case of our diffuser, our steam is a product of microparticles and water mixture. The expanding conical section allows for the rectification and eventually allows the steam to escape out of the nozzle.

Experiment Setup

Figure 3, Experimental setup

The visualization technique used in this image was capturing steam and microparticles inside a headless InnoGear essential oil diffuser. The setup involved a dark background to capture a better-quality image. At first, I used a white sheet, but the image wasn't as clear.

With respect to lighting, I attempted to have a light source directly on the oil diffuser. However, this captured a duller image. Instead, I bounced the light of my mirror which had a much softer visualization. I also used the built in LED feature of the diffuser to create a colorful display of the steam. I did not use any flash from the camera.

The following camera settings on my Canon EOS Rebel T3i were used:

1/500 • f/4.5 • 35.0 mm • 1600 ISO

The 1/500 is considered a fast shutter speed. This helped capture the moving bubbles. A lower shutter speed resulted in a blurry image. The picture was taken top down four inches from the diffuser. A 35.0 mm lens zoom, and 4.5 aperture were used for this specific image. Various zooms and aperture were used, but these settings created the best quality image. Finally, a 1600 ISO was used to create a higher sensitivity to the light.

Image processing

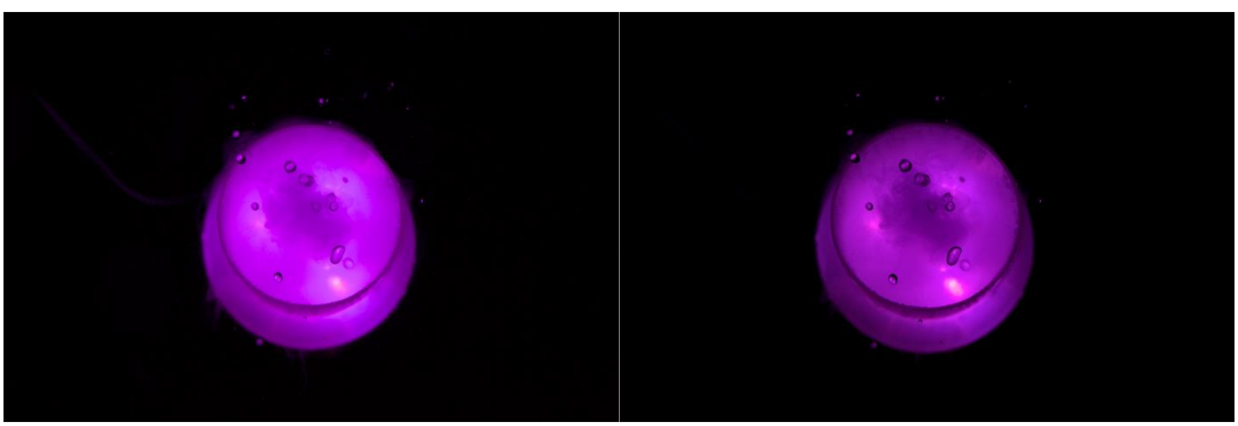

Figure 4, Before and after editing

DarkTable was the editing software used to process my original image. Some notable edits to the image were increasing the sharpness. This helped the microparticles stand out more. I also played with the white balance and local contrast to make the steam and bubbles appear more vivid. Lens correction caused a slight zoom as well that helped capture a “closer” image.

Conclusion:

Overall, I was able to capture microparticles occurring inside the InnoGear essential oil diffuser. I believe I was able to capture an aesthetically pleasing image, while also showing the physics occurring inside the diffuser. Another approach to this image could have been a side view. This would have captured induvial microparticles bouncing up, without any visual steam. I attempted to do this at first, but I was getting very fuzzy images.

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.

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Figure 2. [Photograph of Aromatherapy Essential Oil Diffuser- The Daisy]. (n.d.). https://store.smileydaisy.com/products/smiley-daisy-essential-oil-diffuser-mini-cool-mist-humidifier-energy-saving-quiet-electric-ultrasonic-technology-best-fragrance-scented-oil-aromatherapy-diffuser-with-7-color-changing-led-lamps-and-mist-mode-adjustment-waterless-auto-shut-off

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