Ultrasonic Nebulizer

Team Project 2 Flow Vis

Justin Simmons 3/28/2011

Team: Jaewon Kim, Davis Fogerty,
Brittany Feddersen, Lisa Logel

Our inspiration for this second group project came from the ultrasonic nebulizer (a.k.a. humidifier) that was demonstrated one day in lecture. An ultrasonic nebulizer creates a mystic fog surrounding the device as well as shoot tiny droplets of water straight into the air. We intended to utilize the high speed camera to capture these effects. Unfortunately, the camera was not functional at the same so we stayed with using still photography. The device created several types of fluid flow which allowed for a wide variety of image capturing techniques to be explored. The fog created that overflowed from the bowl looked lively against a black background. The other interesting flow was created directly above the nebulizer. This is the flow that I chose to capture.

The device used to create the flow was a commercial ultrasonic nebulizer. The picture below shows the exact device which we used. It is labeled as a 12 LED mist maker that uses electro and ultrasonic technology.

Figure 1: 12 LED Mist Maker

The above device is roughly 1.5 inches in diameter and not more than an inch tall. This is a small device which is nice since the water level must be above the entire device for it to start misting. A more complete image of our setup is shown in Figure 2 in which the device is sitting in dyed yellow water and has been recently turned off.

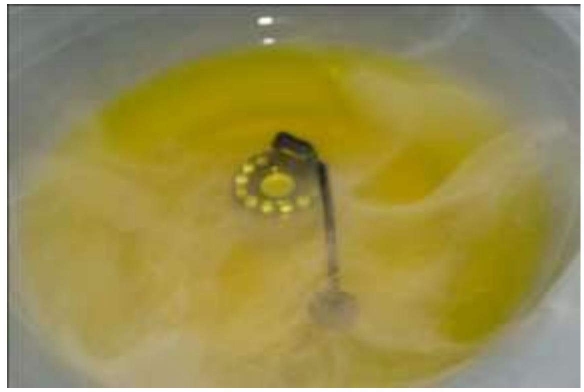

Figure 2: Ultrasonic Nebulizer in Dyed Water

This device is ultrasonic because it creates sound waves above 20 kHz, which is beyond human hearing capabilities. The transducer is piezoelectric meaning electrical energy is required to create any form of mechanical motion. A fixed voltage is applied to a piezoelectric crystal, and based on the native properties of that crystal, it vibrates at a high frequency creating ultrasonic sound waves.[1] Since this sensor is immersed in water, the water molecules are excited by this oscillation and try to match this frequency. Because the frequency is too high for water, it follows the transducer at a lower frequency and is thus met with rapid changes in pressure. These changes in pressure cause the water molecules to cavitate into water vapor. Cavitation is the formation of vapor from a liquid in a region where the pressure of the liquid falls below its vapor pressure.[2] Cavitation caused by ultrasonic waves is referred to as non-inertial cavitation. The resulting water vapor molecules are very small in size which causes the mist to be created in the bowl. When many of these water vapor molecules became concentrated directly above the transducer they formed back into visible water droplets. Some of them were larger than others, but this is the effect that was captured in the final image shown in Figure 3.

Figure 3: Final Image of Water Droplets & Mist

As can be seen in the image above, there was no dye used in the final image. There were attempts to use dye, however it was slightly tricky. If dye was dropped directly onto the ultrasonic transducer then the subsequent water droplets were dyed that color. This effect quickly subdued and even if the water was dyed, both the droplets and the mist were un-dyed. Thus plain tap water was used in an indoor setting so there was no breeze. The image was taken using a flash with a black poster board background. The flash and quick shutter time was sufficient to freeze the flow of the water droplets in air. The presence of water droplets in air was fairly consistent but the size and amount varied.

The final image was roughly three inches across and five inches tall. Since the mist maker was constantly spraying tiny droplets of water, the image was taken from a distance of about two feet with a maximum focal length of 55 mm. Auto focus did not work well at all when trying to focus on fog, thus manual focus was used and set to focus on the center of the mist maker. The image was taken using a Pentax K2000 Digital SLR. The exposure mode was set to aperture priority. The aperture was set to a fairly high value to capture great depth of field. The fog was moving in all directions and I did not want parts of it to be out of focus. Since a flashed was being used, ISO 200 seemed like a reasonable choice for sensitivity. Using a flash defaults the shutter speed to 1/60s. The final image had a resolution of 2109 pixels wide by 2175 pixels high. This was cropped down from the original size of 3872 x 2592 pixels. The cropping was done such that the water droplets were the center of the image along with creating a vertically symmetric background of white versus black. There was not a great deal of image processing done. Minor adjustments in the contrast and saturation were done to enhance and brighten the details in the fog. Also, the black background was cleaned up with spots being removed to make it a solid black color.

Figure 4: Original Image before Processing

The final image shown in Figure 3 reveals the fluid flow occurring at the source of the device. Though it was interesting to view the fog on a black background, I found it more interesting to see what was happening above the ultrasonic transducer. The fluid physics are shown well. The image shows how most of the vapor created stays as vapor and flows outwards; whereas some of the vapor becomes highly concentrated and returns to form visible water droplets. I did fulfill the intent that I was aiming for. I would have liked to get closer to the object to take the picture, but I did not want my camera to get too wet. The color aspects of only black and white are pleasant, but it would be nice to have more color in the image if possible. This would be a cool flow to capture in high speed as well. Overall I am satisfied with the image and really enjoy the symmetry and contrast of black and white.

References

[1] Banner Engineering. "Banner iKnow(TM) - Photoelectrics - Online Training." *The Undisputed Leader in Sensors » Banner Engineering Corp.* Web. 22 Mar. 2011. <http://www.bannerengineering.com/training/faq.php?faqID=34&div=1>.

[2] "Cavitation." *The American Heritage Science Dictionary*. 2010. Print.