# Project 3: "Boo Bubbles"

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March 19th, 2013

MCEN 5151 - Flow Visualization
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Spring 2013

# 1 Introduction

MCEN 5151: Flow Visualization's Project 3 involved utilizing teamwork to obtain visuals that might be too difficult to achieve for a solo endeavor. Multiple minds increase the numbers of flow visualization concepts to choose from;having additional people also means individuals have better access to more resources.

The focus of the project was dry ice encased in soap bubbles, also called boo bubbles. If the dry ice bubbles held together during formation, the bubbles would slowly leak to non-existence. They could be popped, however, which caused the contained dry ice smoke to disperse in a wave-like, circular pattern. It was attempted to capture this phenomenon, but proved too difficult due to the unpredictable timing of the boo bubbles lifespan. Instead, the formation of a boo bubble was captured and used as the final photograph, shown on the cover and in Figure 5.

# 2 Flow Physics

The flow physics of the boo bubbles is centered on their formation through the nozzle of a canister built specifically for the experiment. The canister was constructed by fellow teammate Shea Zmerzlikar, and is shown in Figure 1. The canister's materials include a 64 oz. Nalgene© container, 30 inches of 5/8" OD x 1/2" ID vinyl tubing, and a pair of PVC connector pieces for the canister and tubing exits. A hole was cut in the Nalgene© canister to insert a PVC connector; the surrounding gap was plugged with hot glue to prevent leaking.

Figure 1: Bubbles Canister

In the canister, dry ice smoke was funneled through a soap film. To create the smoke, the canister was filled with hot water, approximately half the distance between the bottom and the inserted PVC connector. A block of dry ice, approximately 2 inches in all dimensions, was placed into the water. The canister lid was then reattached, and the canister nozzle was placed in a container of water and dishsoap (Ivory© dishsoap for this specific experiment). In order to form bubbles with high surface tension, the water had to be almost saturated with the dishsoap. This created a film of dishsoap on the end of the second PVC connector. The dry ice smoke would then pass through the film, creating filled bubbles. This is shown, in schematic form, in Figure 2.

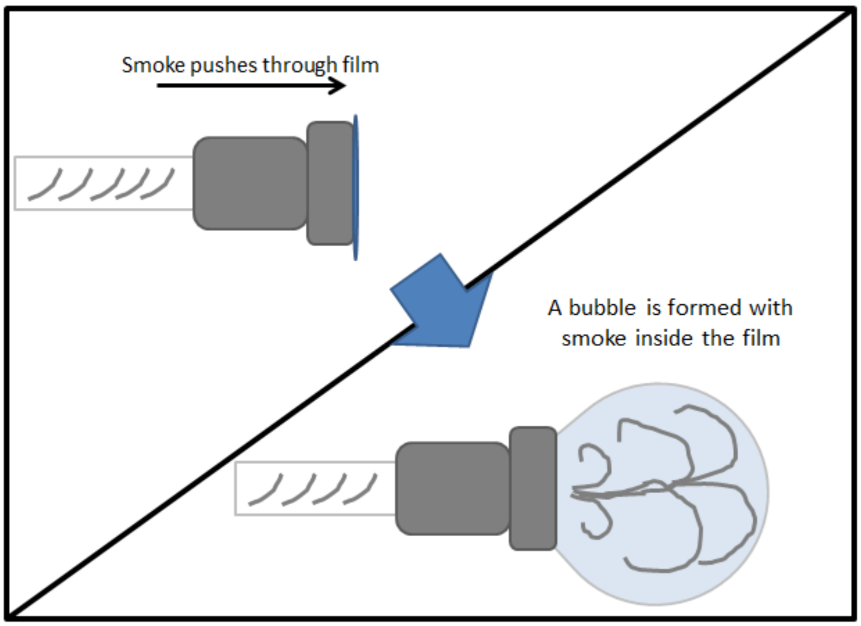


Figure 2: Flow Schematic

The outer surfaces of the boo bubbles are constructed from a thin film of dishsoap. These bubbles are extremely fragile, with the slightest amount of oil or dirt causing them to burst. If the bubble is not popped prematurely by the user, the bubble will eventually give way as the water in the thin film drains to the bottom, straining the surface tension of the bubble to beyond its capacity. The swirling seen on the surface of the bubble is caused by the varying thickness due to the drifting water molecules, and the color shift of the bubble faces are attributed to different amounts of light diffraction (Katz).

Surface tension is the predominant force behind the formation of the soap bubble, causing pressure differences across curved planes. The static force of the bubbles is represented by Equation 1, where $p_i$ is the inner bubble pressure.

$$\sigma(2\pi R) = (p_i - p_o)\pi R^2 \tag{1}$$

From this equation, it can be seen that the inner pressure ($p_i$) is higher (Kundu, Cohen, and Dowling 8-9). If we assume the bubble has a water-air interface, $\sigma \approx 0.0050 lbf/ft$ (White 31-34). Looking at the final photograph on the cover and in Figure 5, the bubble forming on the nozzle has a $R \approx 1$ in. If the inner and outer radius are nearly the same, the pressure difference (or Laplace pressure) is: (White 31-34)

$$\Delta p_{bubble} \approx 2\Delta p_{droplet} = \frac{4\sigma}{R} \tag{2}$$

$$\Delta p_{bubble} = \frac{4 * 0.0050 \text{ lbf/ft} * \frac{1ft}{12in}}{1in} = 0.00167 \text{ lbf/in}^2 \tag{3}$$

$$0.00167 \text{ lbf/in}^2 \approx 11.4 \text{ Pa}$$

However, the boo bubbles are filled with $CO_2$, not air. This makes the bubbles heavier than air (moreso than just air in dishsoap bubbles). The bubbles should expand and release from the nozzle at the breaking point when the nozzle is aimed downward, breaking the bubble (SMU). However, $CO_2$'s ability to diffuse through the bubble allows it to stabilize. Eventually, the $CO_2$ will expand the bubble too much, creating thinner walls and larger leaks. $CO_2$ can then escape, and the bubble will restabilize. This will last until the smoke source is pulled away or the bubble breaks away from gravity, at which point the bubbles will stay intact (if the impact surface is a good receptor) and begin to shrink (Helmenstine).

# 3 Photograph Setup

As mentioned in Section 2, the smoke was created with dry ice and hot water. Ivory© dishsoap was used to make the soap bubbles, in heavy concentration. For lighting, a white box was used. This white box was courtesy of the manufacturing shop in the Mechanical Engineering graduate project area of Fleming. The white box contained a pair of daylight fluorescent bulbs suspended between two walls, the two walls and the floor was joined by a seamless fillet. As expected, however, the white box was white; to counter this, pieces of black fabric were laid on the white box to alter the background. The white box is shown in Figure 3.

Figure 3: White Box

# 4 Photograph Specifics

The final photograph was taken with an Olympus Stylus XZ-2 digital camera. To prevent camera shake and unintended soft-focus, the camera was mounted on a table-top tripod. The field of view encompassed the size of the white box, with distance to lens measuring 12 inches. Manual shooting mode was used; the specific camera information is shown in Table 1.

| Camera: Olympus XZ-2 | | | | |
|---|---|---|---|---|
| Focal Length | 10.7 | | Focal Length (35 mm) | 50.0 mm |
| F.No | F2.1 | | Shutter Speed | 1/320 s |
| ISO | 800 | | Temperature | 5600 K |
| Image Format | Olympus RAW (.orf) | | Image Ratio | 16:9 |

Table 1: Final Photograph Camera Specifics

The original photograph was .orf format, and measured 3968 x 2232 pixels (16:9 ratio), and in shown in Figure 4. The final photograph was in .tif format and measured 3591 x 2232 pixels.

Figure 4: Original Photograph - Boo Bubbles

A number of post-processing steps were completed in Photoshop CS6 to create to the final photograph, shown in Figure 5. First, the soapdish was removed from the photograph using the clone tool, where the bottom left corner provided the color template. The brown hues were reset as blues using CS6's predefined Photo Filter function. The blacks were then darkened using the Curves tool, and the white were adjusted using the Hue/Saturation tool. Specifically, red was removed from the whites by adjusting the jue and saturation of the red control marker. The final image was cropped to negate the excess black background on the right side of the photograph. This also placed the PVC connector nozzle closer to center. The final image is shown in 5.

Figure 5: Final Photograph - Boo Bubbles

# 5 Conclusions

Although I am somewhat disappointed at not being able to capture the dry ice smoke dispersion when a boo bubble pops, I still appreciate my final photograph. The photograph shows how the boo bubbles formed, and stacked, well. Along with stacking, the boo bubbles could also bounce off one another when released from the canister nozzle. This was another excellent photograph opportunity, but again proved too difficult to catch due to unpredictability.

However, there is always room for improvement to capture the perfect image. The smoke in the boo bubbles could have been less opaque, in order to better observe the fluid flow within the bubbles. A macro image of the bubble surface would have also shown the movement of the film more clearly. Additional post-processing work is necessary to further fine-tune, including removing the thin blue line surrounding the bubbles and smoothing the transition between the bubbles and background. Still, this photograph marked a new level of post-processing knowledge and ability. I was able to remove the soapdish with minimal color differences, and I learned how to affect certain portions of the photograph with the lasso tool and layers. I consider this photograph a success, as it shows both my growth and where I can improve; I can utilize this information for the second team project (Project 4).

# 6 References


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