Dry Ice Vapor

Image-Video 1
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Introduction

The report will discuss the flow phenomenon, experimental setup, photographic technique, and conclusions about the flow image. This report is for Image-Video 1 assignment in MCEN 5151 Flow Visualization, and the purpose is to allow students to explore and capture a fluid flow phenomenon. The image needs to be appealing and interesting, while being able to explain the phenomenon with physics. The intent for this photo is to visualize the flow of dry ice vapor as it is poured from a wine glass. The motivation comes from the usage of dry ice in alcoholic drinks, in which the purpose is to make the drinks more entertaining.

Flow Phenomena

The vapor that occurs from the dry ice goes through a process called sublimation. It is the conversion of solid phase to gaseous phase without the intermediate liquid phase. Dry ice is solid, frozen carbon dioxide, that sublimates at -109.3 degrees Fahrenheit [1]. As you can see, this is a lot lower than the normal freezer temperatures of around 0 degrees Fahrenheit. This means proper storage is important for dry ice, because it sublimates at a very low temperature, and the carbon dioxide gas can be harmful in small and unventilated areas. The fog or vapor you see from dry ice is a mixture of carbon dioxide gas and air [1]. The fog intensifies as you mix the dry ice with water because of the increase in product for the reaction, and an accelerated process of sublimation.

To set up for the photo, black poster board was used for the background and other materials include a pound of dry ice, water, and wine glass. The pound of dry ice was broken down into pieces that are the size of a golf ball and are placed in the wine glass. The Wine glass was tilted at a 45 degrees angle as soon as water was added to let the vapor flow out. Numerous attempts were made as I tried to get the best photo, which includes a good volume of vapor. The flow of vapor in the wine glass can be described as laminar flow (smooth flow), and as it gets poured out it becomes turbulent flow.

The Reynolds number for the fluid flow is:

$$Re = \frac{uL}{v} = \frac{(0.5\frac{m}{s})(0.0762\ m)}{(8\ x\ 10^{-6})m^2/s} = 4762$$

Here, Re is the Reynolds number, u is the velocity of fluid flow, L is the characterized length (the approximate length or spread of the fluid), and v is the kinematic viscosity of carbon dioxide [2]. The wine glass has an approximate diameter of 3 inches or 0.0762 meters. From the photo, you can see that the flow of the fluid going down is spread about the diameter of the wine glass, so L is 0.0762 m. The velocity was approximated by knowing the distance between the wine glass pour and the top of the table, which was about 0.5 meters and approximated one second of travel time. Some forces acting on the fluid include gravity and a little bit of wind. If the Reynolds number is less than 2000, than it is laminar flow [3]. If it is greater than 3500, then it is turbulent flow. [3] Since the Reynolds number is 4762, it is turbulent flow. This is also shown in the photo captured (chaotic flow).

Experimental Setup

The objective is to visualize the flow of dry ice vapor from a wine glass pour as shown in figure 1. The equipment list includes dry ice, water, wine glass, DSLR camera, black poster board, and a table outside. The dry ice was purchased from King Soopers. The table, water, and wine glass (3 inches in diameter) were sourced in-house. The DSLR camera is a Canon PowerShot SX540 HS purchased from Best Buy. The black poster was purchased from Office Depot.

The black poster board is set up on the table as a background for the photo. Be sure that the sunlight isn't too direct, or you may get glares from the wine glass. The pound of dry ice was a large block, so I had to break it apart to fit into the wine glass. Once that is done, Estefania poured water into the wine glass (a quarter up the glass) and poured the dry ice vapor out at a 45-degree angle. The initial pours were not great because there wasn't enough vapor, or the wind would blow it away. I repeated this experiment 4-5 times and adjusted the amount of dry ice and water to get the right amount of vapor and aesthetics for the photo. This can vary depending on the size of the wine glass and the conditions outside.

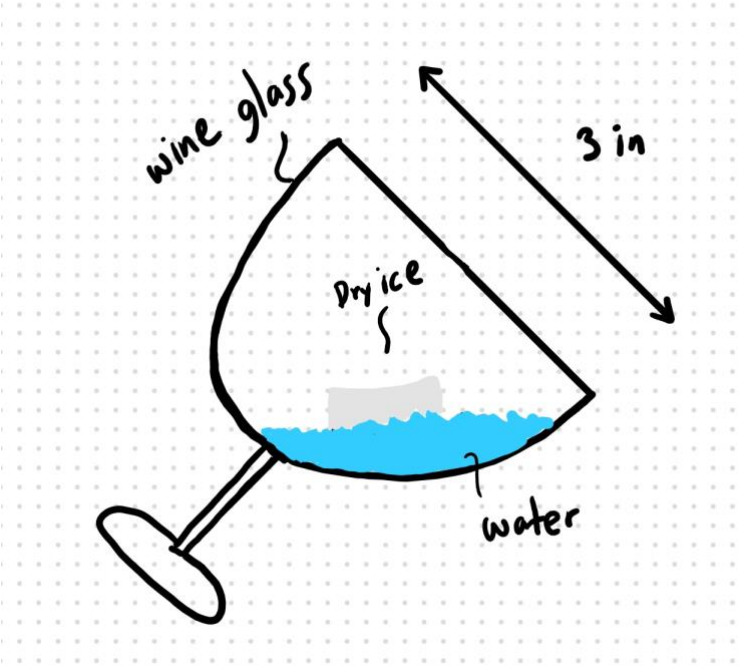

Figure 1. Pouring dry ice vapor out of wine glass

Photographic Technique

The dry ice vapor moves very rapidly, so pictures needed to be taken quickly. Before the pour, the camera is positioned about 5 inches from the wine glass and settings on the camera were adjusted manually to get the best quality. The focus, shutter speed, aperture, and ISO were adjusted manually. Since it was bright outside, I did not have trouble with lighting and used low ISO with higher shutter speed. Table 1. shows the camera that was used, and the exposure for the photo.

Camera	Canon PowerShot SX540 HS (DSLR)
Aperture	F3.4
Focal Length	35mm Equivalent
ISO	100
Shutter Speed	1/250
Height	3888 pixels
Width	5184 pixels
Photo Size	3.58 MB

Table 1. Photo specifications

The photo was edited on Gimp. My intent was to make the vapor very apparent and contrast it with the black background. The first adjustment was to crop the photo so that I only got the black background. The color balance was adjusted by moving it towards cyan. This created the bright blue color on the vapor. The exposure was also increased to brighten up the overall photo. Black levels were increased to make the background darker. The contrast was also increased to make the vapor more apparent, and the background darker. Finally, I tweaked the RGB curve so that the colors were just right. Figure 2. shows the unedited and edited photos.

Figure 2. Before and after photo edit on Gimp

Conclusion

The image reveals the turbulent flow of dry ice vapor from a wine glass. I like the volume of the vapor that I captured, and the edit choice to add color to make it more apparent and interesting. A weakness of the photo is that I cropped out some of the fluid flow to eliminate the non-black background. In addition, the edits erased a small part of the vapor, particularly the lighter vapor on the bottom. Overall, fluid flow physics was depicted well because you can see the disorderly spread of the vapor which shows turbulent flow. I had fulfilled my intent but could improve on the location of the pour. It would be more beneficial if I had captured the entire extent of the fluid flow. I could further develop this idea by visualizing a more linear flow of vapor rather than a spread. I would add an element of wind to blow it in one direction and capture it flowing horizontally from the tip of the wine glass. This will add a floating effect to the visual which I think would be fascinating.

Reference

[1]: “Frozen Carbon Dioxide (Dry Ice) Sublimates Directly into a Vapor.”, https://www.usgs.gov/media/images/frozen-carbon-dioxide-dry-ice-sublimates-directly-a-vapor.

[2]: “Carbon Dioxide - Dynamic and Kinematic Viscosity.” *Engineering ToolBox*, https://www.engineeringtoolbox.com/carbon-dioxide-dynamic-kinematic-viscosity-temperature-pressure-d_2074.html.

[3]: “Laminar and Turbulent Flow.” *Laminar and Turbulent Flow | Engineering Library*, https://engineeringlibrary.org/reference/laminar-and-turbulent-fluid-flow-doe-handbook.