Dry Ice Streamlines

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Figure 1. *Dry sublimation forming laminar streamlines against a dark background.*

I. Introduction

DRY ice is a solid form of carbon-dioxide gas kept at temperatures below -78.5 °C under atmospheric pressure. At temperatures above -78.5 °C, dry ice sublimates or changes from a solid to gas without going through any discernable liquid state. Under normal room temperature of 20 °C, the gas from dry ice sublimation is still significantly cooler than the surrounding air causing any moisture in the air to condense and form the visible streamlines emanating from the dry ice solid.[1] Please note that dry ice is dangerous to handle without gloves and could result in severe burns due to the extremely low temperature.

II. Experimental Setup and Analysis

Figure 1 consisted of a triangular piece of dry ice approximately 3-4 cm on each side sitting at the bottom of a open channel water flume located in the Integrated Teaching & Learning Laboratory (ITLL) at the University of Colorado Boulder campus. The water flume has a 2.5m x 76mm x 250mm water channel with a jacking arrangement that permits the slope of the bed to be adjusted between -1 to +3%.[3] The flume was not in operation and devoid of water when the image was taken.

The most interesting aspect of this image is that the streamlines appear to be flowing and interacting with the walls of the flume in manner that is similar to water coming out of a faucet and hitting the bottom of a sink. However in this case, the flow is coming from both the top and bottom of the dry ice piece. This is not a special effect and is completely agreeable with the nature of gravity given that this is a top down image. However the direction of the streamlines indicates some type of thermal effect or flow gradient occurring in the flume. The number and spacing of the streamlines is most likely due to the porous structure of the dry ice as it sublimes. This is discernable from Figure 1 if one closely examines the surface texture of the dry ice. The actual flow structure being generated is more of mystery since one would expect the lines to flow in a single direction.

III. Visualization Technique

No special flow field visualization technique was required for the imagery in Figure 1 other than placing a small pool of water underneath the dry ice piece to speed up the sublimation process. Lighting was provided by two halogen work lamps sitting off to the lower left hand corner of image outside of the water channel.

IV. Photographic Details

Figure 2. *Source image for Figure 1 prior to post-processing.*

Figure 1 is a cropped and post-processed version of Figure 2. Figure 2 was taken with a Samsung NX-10 interchangeable lens digital camera featuring a 14.6-megapixel 23.4mm x 15.6mm APS-C CMOS imaging sensor producing a 4592×3056 pixel resolution image.[2] The image was captured using the full resolution capabilities of the camera and stored in the camera's RAW unprocessed image format. Exposure was 1/20 of a second at a focal length of 33mm, aperture setting of f/4.5, and sensor sensitivity of ISO 200 at a lens distance of approximately 8 inches from the subject. The photo was taken at angle normal to the bottom surface of the flume.

Post-processing of the image was conducted using Pixelmator (http://www.pixelmator.com/) image editing software available for the Mac OS operating system. The image was subsequently cropped and converted to a black-and-white color spectrum to produce the final image seen in Figure 1. Image brightness was reduced to enhance the contrast between the dry ice streamlines and the background. Highlights were also boosted to increase the details in the dry ice sample.

V. Conclusion

Dry ice generates some of the most interesting fluid flows that I have seen to date. The streamlines it generates produce some awesome fluid flow visualizations and the white color of the material lends itself to black-and-white photography. With more time, I would explore techniques to increase the appearance of the streamlines so that they contrast more heavily with the background.

References

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