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Flow Visualization
Team Project #2
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Team Project #2 – Ice on Car

The image taken for the second team assignment shows interesting ice structures on the side of my car. The ice formed on the door panels during the drive from Breckenridge to A-Basin. Somehow, the water/slush on the road was splattered onto the doors to form small spindles of ice closely packed together. Perhaps the dirt in the slush gave the ice nucleation sites where the small spindles could then form. The conditions also had to be perfect to allow for the formation of the ice; warm enough to allow liquid water to be sprayed on the doors, but cold enough to freeze the water upon impact.

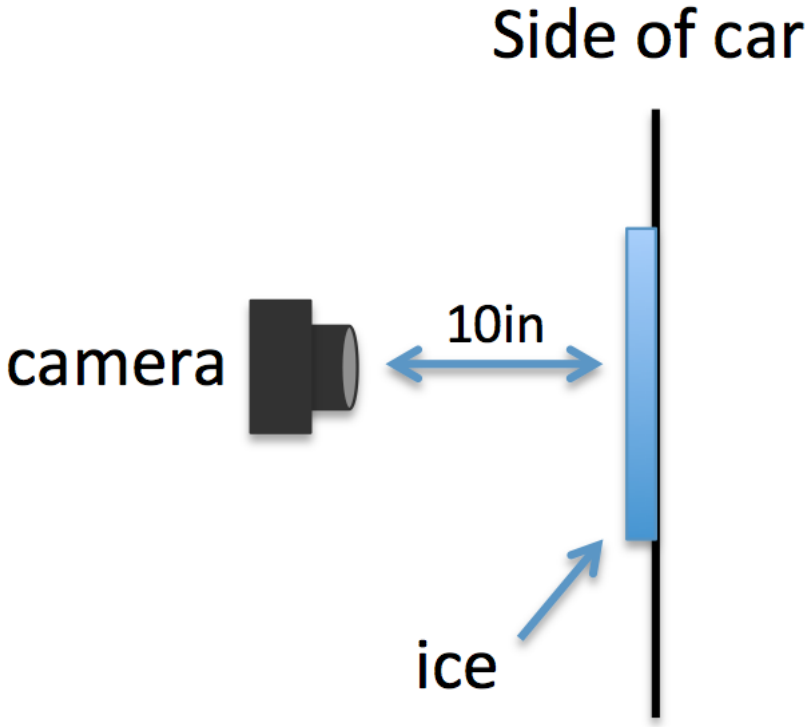

Figure 1: Flow Visualization Setup

Figure 1 shows the orientation of the camera relative to the car door. The camera was in macro mode to allow for closer shots. Figure 2 shows the ice on the side of the car. At first glance, the ice doesn't look very interesting, but I noticed the spindles as I got out of the car. Figure 2 shows that the ice covered the entire bottom half of the door panels. The ice was also present on the other side of the car, but it wasn't as visually appealing.

Figure 2: Ice on car

The formation of the ice was rather strange. The small spires of ice were horizontal with respect to the ground and pointed towards the front of the car, as shown in Figure 2. I hypothesize that water/slush from the road was sprayed onto the doors by the front tires. Dirt from the road was also mixed with the water sprayed onto the doors (as see by the brown color in Figure 2). The dirt in the water then acted as nucleation sites for the formation of ice. After ice began to form, more spray from the front tires built up the ice spindles, freezing on impact. Obviously, this process is very sensitive to ambient temperature; cold enough to freeze the water spray on impact, but warm enough to allow the snow to melt on the road.

Kanji[1] performed experiments to determine how relative humidity with respect to ice and surface area affect ice formation using various particles for nucleation. Using dust from Arizona, the researchers found that increasing the total surface area of the dust decreased the relative humidity at which ice would form. As the total surface area of the tiny dust particles increases, more nucleation sites are available for ice formation, thereby allowing the relative humidity to be lower at the formation point. It's important to note that the experiments were performed at -40°F, much lower than the ambient 15°F at the time the image was taken. But, I believe the same concept still applies. The significant amount of dirt in the water provided a large number of nucleation sites, and the humidity close to the surface of the road was probably quite high from the sun melting the snow. These two factors allowed ice to form on the door panels and further spray built up the ice spires.

The water could have formed into the unique ice spindles in a much simpler manner. Figure 3[2] shows the formation of ice on a surface of hydrophobic silicone rubber. The painted door panel of my car can also be considered hydrophobic, and water sprayed onto the surface looks similar to Figure 3 (Top). As the temperature decrease, the water droplets form ice "balls" as seen in Figure 3 (Bottom). After the "balls" formed, further spray from the front tires could have built up them up vertically to form the individual ice spires.

Figure 3: Ice Formation[2]:
Top) 25˚F
Bottom) 18˚F

To produce the final image, I drove from Breckenridge to A-Basin on the morning of March 22nd, 2011. The road was slushy and wet with a small amount of snow. The ambient temperature was 15˚F with partly cloudy skies, allowing the sun to heat the road surface and melt the snow. I was driving at approximately 50mph. I believe the ice formed on the last section of the road, from Keystone to A-Basin. In the A-Basin parking lot, I noticed that other cars had the same ice on their side panels. Therefore, the conditions were responsible for the ice instead of something specific about my car.

The original image field of view was approximately 6in in width and 8in in height, and the distance from the camera lens was ~10in. A Canon SD870 digital camera with a 4.6-17.3mm focal length lens was used to take the picture. The camera was in macro mode, resulting in slight loss in focus around the edge of the image.

Camera:	Canon SD870 IS
Focal Length:	4.6mm
ISO:	ISO 400
Shutter Speed:	1/500 s
Aperture:	*f*/2.8
Original Pixel Size:	3264 x 2448
Final Pixel Size:	2476 x 2141

Aperture 3 was used to modify the original image. The original image was significantly cropped to emphasize the unique features in the ice spindles. The cropping also allowed me to eliminate most of the soft focus around the edges of the image. The original was a bit dark, so the brightness was increased along with the exposure setting. Then, the contrast was slightly increased to compensate for the

increase in brightness. The edge sharpening tool was also applied to the entire image to compensate for the loss inn focus around the edges of the image. Finally, the image was rotated 90° clockwise to give the ice a more geological feel.

Overall, I was very pleased with the final image. I had several quality images that I could have submitted, but in the end I decided to use a macro shot to enhance the features of the individual ice spires. Once again, I was lucky enough to find a unique image without trying to use a specific flow visualization apparatus.

References

[1] Kanji, Zamin A., Octavian Florea, and Jonathan P D. Abbatt. "Ice Formation via Deposition Nucleation on Mineral Dust and Organics: Dependence of Onset Relative Humidity on Total Particulate Surface Area." *Environmental Research Letters* 3.2 (2008): n. pag. Print.

[2] Xu, Zhihai, Zhong Wang, Cuiru Yang, Zhidong Jia, and Zhicheng Guan. "Impact of Surface Characteristics on The Micro Process of Ice Formation." *Annual Report Conference on Electrical Insulation and Dielectric Phenomena* (2009): 254-57. Print.