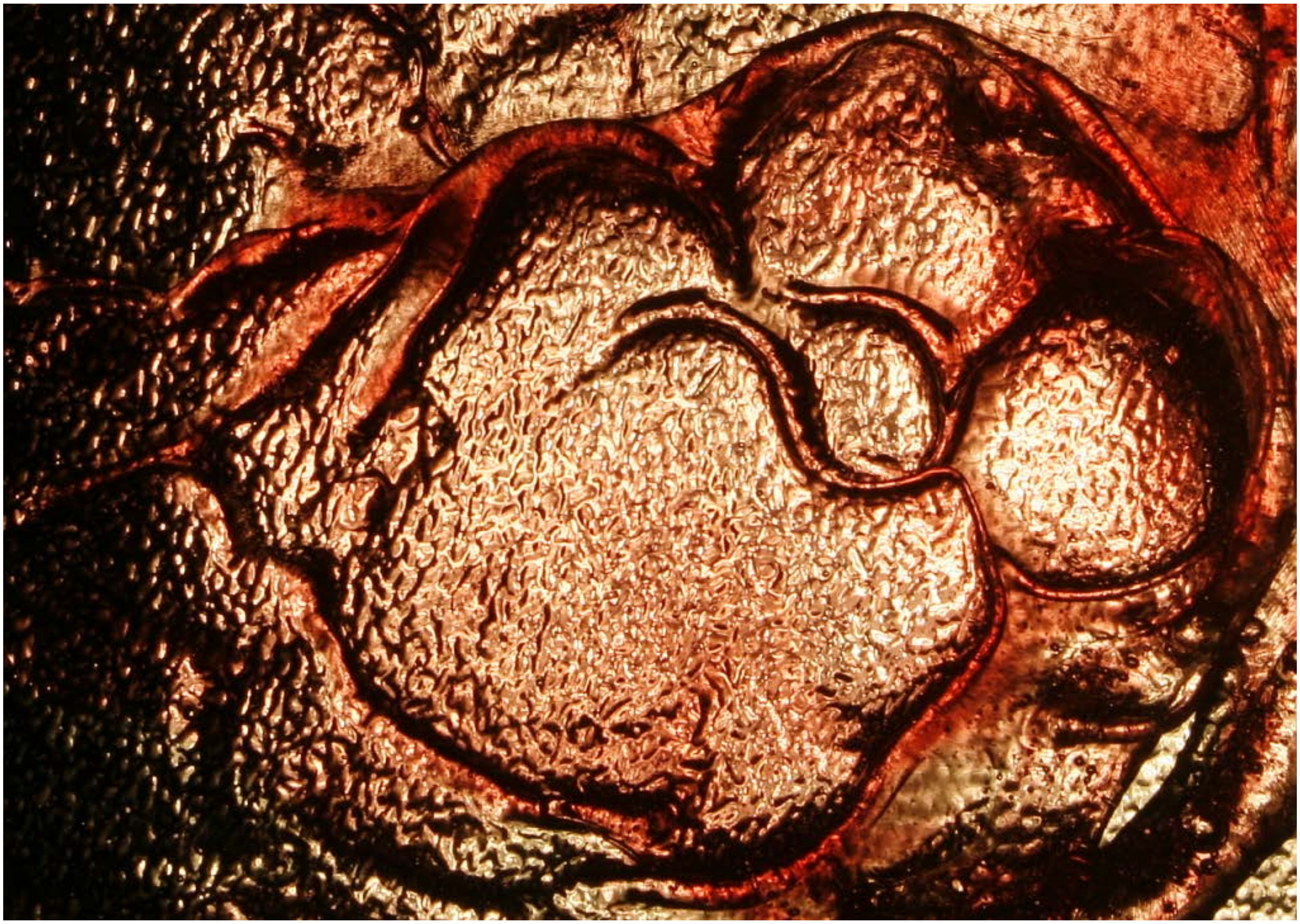

GET WET

MCEN 5151

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I. Introduction

The purpose of the Get Wet assignment was to expose students to elementary fluid flows and to introduce them to photographic techniques used for capturing fluid flow. The image that will be discussed in this report was intended to capture the phenomena of ripples and waves of a viscous fluid via an impinging jet. The effect of a fluid jet on a surface or another fluid, particularly an air jet on a viscous liquid, produces complex and interesting contours. Therefore, the intent of this image was to capture unique and stimulating surface effects of air on corn syrup. The scientific quality of this project was to visualize the turbulent nature of a high velocity jet on a surface. This is an especially important phenomenon to understand for aircraft, where vertical take-offs and landings can produce dangerous ground effects from propellers or jet exhaust.

II. Experimental Setup

In order to visualize a high velocity impinging jet on a surface, a 100 psi air compressor was used to produce the air jet. This jet of air was directed from above towards a flat plate at varying angles. The plate was covered in a viscous fluid (red-dyed corn syrup). The solution was two cups of corn syrup and two drops of red dye. The camera was placed directly above the plate and corn syrup. A light was used to illuminate the glass plate from the bottom. Since the corn syrup was transparent, the light was able to illuminate the fluid as well. The compressor hose was moved around the fluid continuously at a constant distance of approximately 6 inches, in an attempt to not let the fluid settle. A schematic of the experimental set up can be seen in Figure 1.

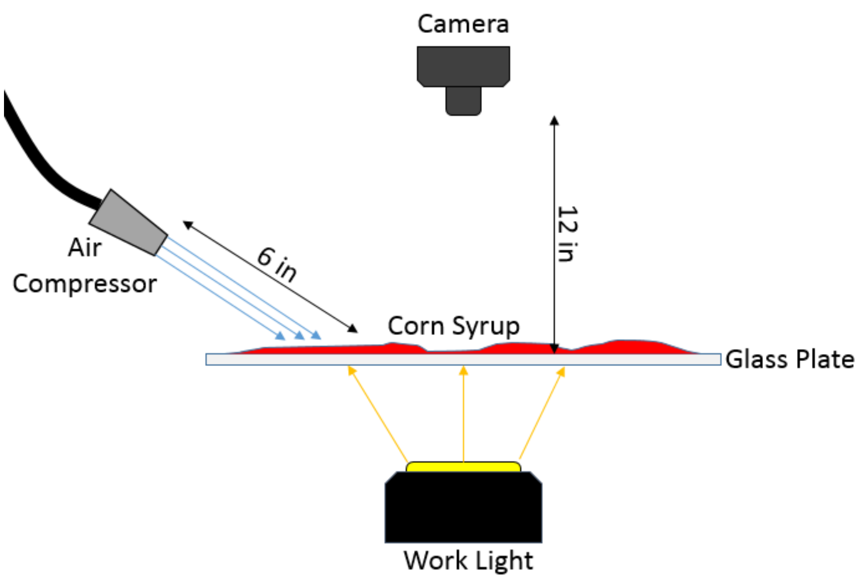

Figure 1: Flow Apparatus

The effect of the impinging jet on the corn syrup was that the turbulent (Re = 89765) and high velocity air (≈ 40 m/s) flow swirled on the surface of the corn syrup. This caused the corn syrup to move from areas where high velocity air was present, to areas of low velocity air. This can be explained by shear forces on the corn syrup surface that were caused by the air. In steady state flow, shear forces caused by air can be seen in the form of oscillating ripples on the surface of the water[1]. These ripple patterns on the surface of the fluid tend to be sinusoidal and somewhat predictable. This was demonstrated on the corn syrup by holding the impinging air jet at a constant position. An example of these nicely patterned waves in the corn syrup were captured as seen in Figure 2. The wavelength of the ripples was about 0.5 inches.

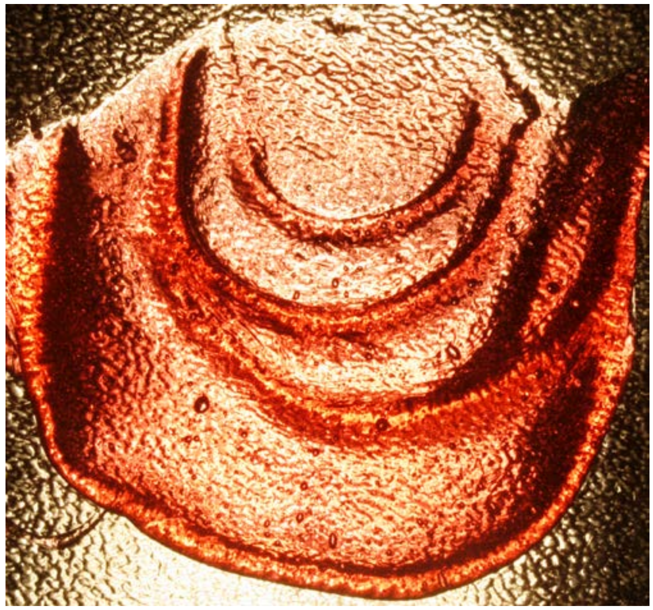

Figure 2: Corn Syrup Ripples

This pattern can be explained physically as the shear forces tend to move the crests of the wave over the top of themselves, while the troughs are pushed upwards to form new crests. Simultaneously, small vortices form on the front side of the waves, further “removing” fluid in the troughs and essentially scooping fluid to the crests[3]. This wave propagated at around 2 inches per second. A physical diagram of air formed ripple waves can be seen in Figure 3:

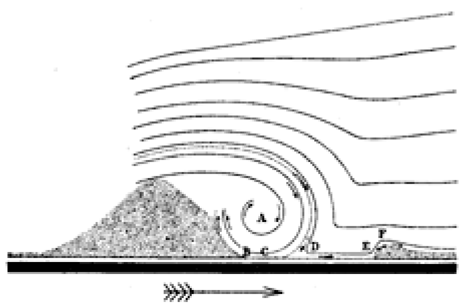

Figure 3: Ripples formed by fluid flow vortices[3]

This creates a nice dynamic and fairly predictable pattern. In the case of the report image, the flow of air was not impinging from a constant direction. This prevented the corn syrup from reaching a steady state ripple pattern. Instead, because of the varying angle of the impinging jet, the fluid continuously collected in areas of low velocity and shear at any instantaneous time. Because corn syrup has a high viscosity (5,000 cps at 70° F) [2], there is a high amount of friction at the boundary between the flat plate and the corn syrup. This high friction causes the syrup to resist change in the horizontal direction, while the constant restoring force of gravity resists changes vertically. Between these forces, the corn syrup would hold its shape for about 0.25 seconds and then return to a flat and even distribution. Thus, in order to capture the report image, the impinging jet moved the fluid into a certain position, then the jet would change locations quickly and move the syrup into a new position. This produced interesting shapes on the fluid surface because the air would continuously move the fluid with different initial conditions. The compounded effect of the variable air-flow conditions produced extremely complex patterned ridges and troughs, which are difficult to quantify or explain physically.

III. Photographic Technique

A. Image Capture

In order to capture this image a Canon Rebel XTi DSLR camera was placed 12 inches above the flat plate holding the corn syrup with a focal length on the lens of 55 mm (lens is 18-55 mm). The size of the field of view was roughly

12 x 8 inches (the image was cropped). The camera settings were set to an ISO of 200, exposure time of 1/1250 seconds, and aperture of F 20.0. The exposure time was able to be quite fast even with a high aperture value because of the amount of light being produced by the 500 watt shop light under the plate. Additionally, no flash was used in the picture.

B. Post Processing

Post processing of the image included increasing the sharpness to define the ridges of the syrup, increasing the red color values, and increasing contrast to improve depth. Additionally, the image was cropped from the full field of view image, which can be found in the Appendix. This cropped image had a resolution of 1021 x 723 Pixels.

IV. Conclusion

Overall, this image turned out well. The depth and sharpness of the fluid truly stand out. The best particular part of the image is the fascinating shapes formed by the impinging jet. The shapes resemble roots of a tree and therefore bring personifying qualities to the corn syrup. Physically speaking, the fluid physics of viscous fluids can be seen clearly, but are not that well understood. This particular photo would almost be impossible to repeat, due to the variable nature of the impinging jet. Therefore, it was very difficult to explain the physics of this particular instant when the photo was taken. Therefore, one would have to sacrifice artistic qualities and uniqueness of the flow for better physical understanding. Perhaps this photo could open up research in the topic of variable oblique impinging jets on a surface, but that is outside of the scope of this project.

V. References

[1]Charru, F., and E. J. Hinch. *J. Fluid Mech. (2006), vol. 550, pp. 111–121: Ripple Formation on a Particle Bed Sheared by a Viscous Liquid. Part 1. Steady flow*. Tech. N.p.: Cambridge UP, 2006. Print.

[2]"Viscosity Tables." Viscosity Tables. N.p., n.d. Web. 10 Feb. 2014.

[3]Ayrton, H. "The Origin and Growth of Ripple-Mark." *Proceedings of the Royal Society A: Mathematical, Physical and Engineering Sciences* 84.571 (1910): 285-310. Print.

VI. Appendix

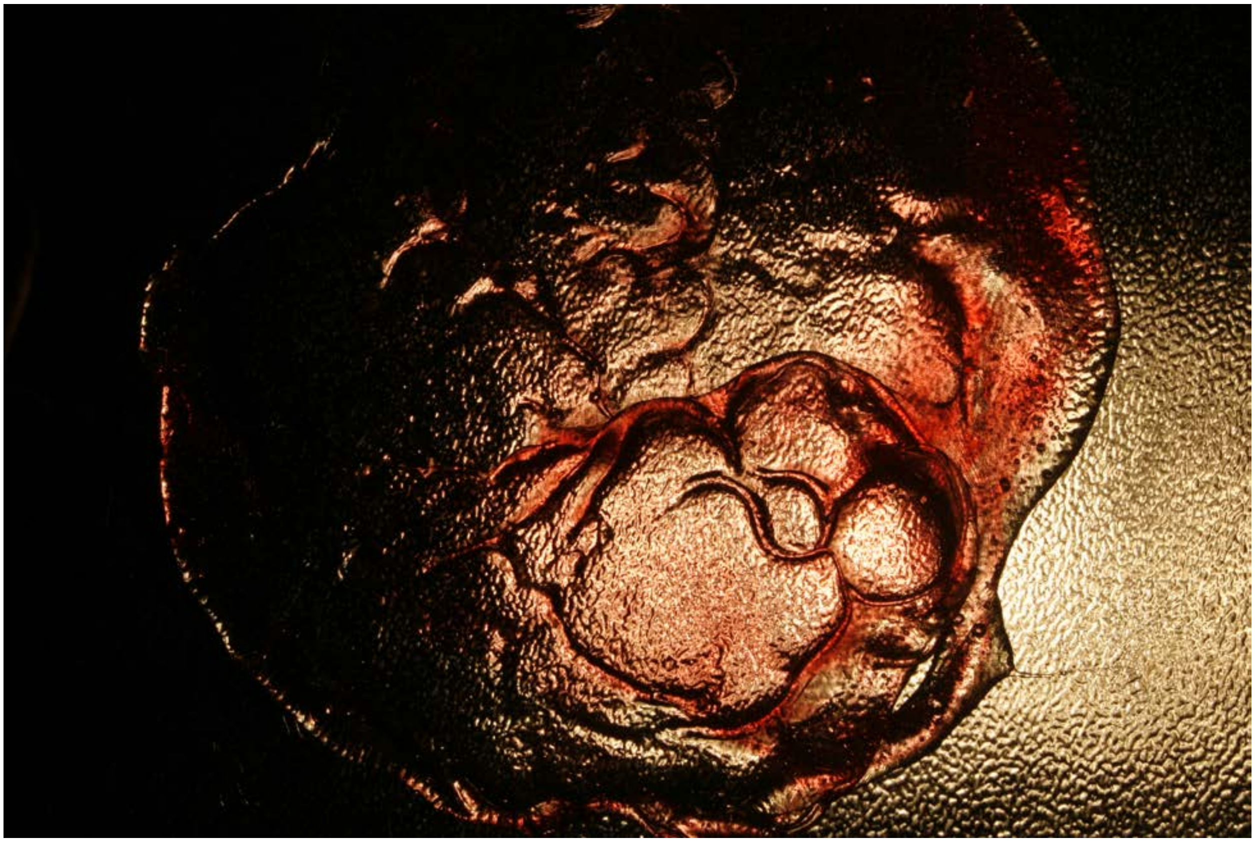

Figure 4: Original photograph (unaltered)