J.T. Balling
Team First Report
Flow Visualization
Section – 001
02/28/18
Assisted by Wesley Caruso, Mason Gray, Jake Lanier, and Julian Quick

Water Into Milk

Context, Purpose, & Circumstance

The purpose of my image was to visually demonstrate the behavior of a water to milk droplet-droplet collision. Achieving this idea was brought to life by the team and I checking out the auto dropper apparatus from Professor Hertzberg. As shown below, this apparatus has a liquid storage tank, metal support system, and dropper with wireless communication controller. The team set up the apparatus in the basement of the *Integrate Technology Learning Lab* in the chemical room, this is because we needed to capture the droplet images in a pitch-black setting due to flash effects and exposure. We used a timer to trigger the dropper and the flash (with white diffusing plate) that was linked wirelessly to a smart phone operated by Mason.

Figure 1: Experimental set-up of dropper apparatus

The liquid tank was suspended 29.5" (second bar) and the automatic dropper lifted to 20.5" (first bar). With the mug containing the milk in place inside the pan the distance between the dropper nozzle and surface of liquid was fixed at 9.5". The timer settings are displayed in the figures below.

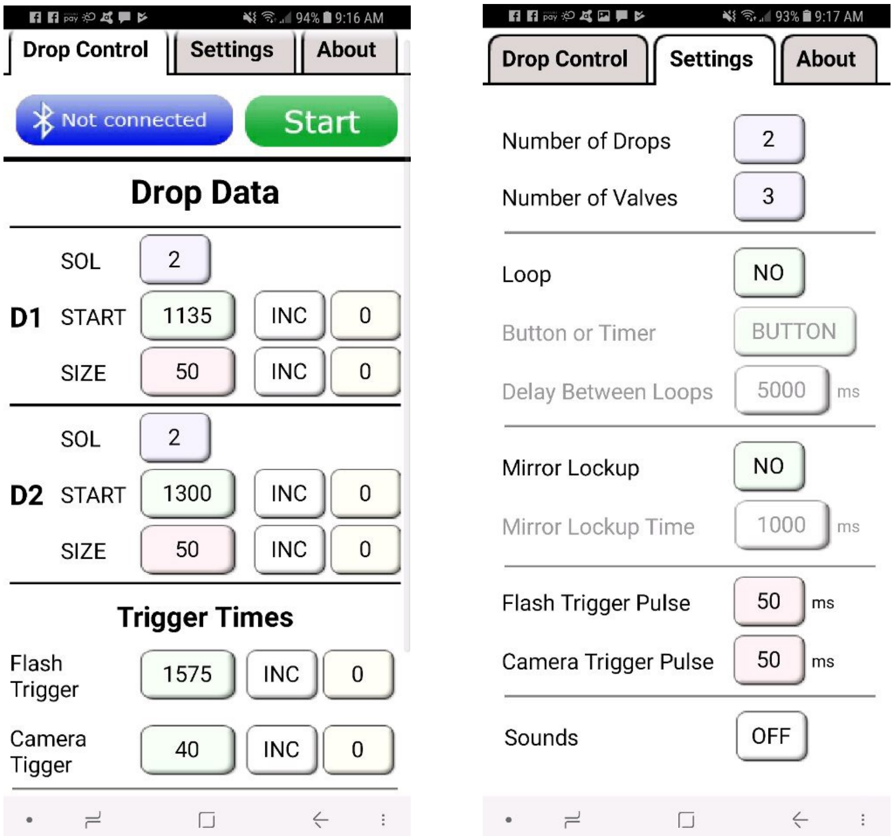

Figure 2: Dropper timing settings

The timing of each of the two drops was 1135 & 1300 (ms), the flash triggered slightly after that at 1575 (ms).

Analysis

The technology required to acquire the measurements of the droplets is specialized and sold at a high premium. This equipment was not available, however, when performing analysis on droplet-droplet collision one would calculate the Weber number, impact parameter, and Ohnesorge number (Finotello 2017). All droplet collision analysis equations were derived from *The dynamics of milk droplet-droplet collision* published in late 2017 referenced below.

The weber number, defined as the ratio between inertia forces and surface tension requires the droplet density, $\rho_{d,}$ diameter of smallest droplet, $d_{s,}$ relative velocity, v_{rel}, and surface tension σ.

$$We = \frac{\rho_d d_s |v_{rel}|^2}{\sigma}$$

Figure 3: Weber number equation

The impact parameter B is defined as the distance b between the two droplet centers in the plan perpendicular to the relative velocity vector, normalized by the average droplet diameter. When B is equal to 0, a head-on collision is taking place, when equal to 1 the collision is considered to be grazing (Finotello 2017).

$$B = \frac{2b}{d_s + d_l}$$

Figure 4: Impact parameter B equation

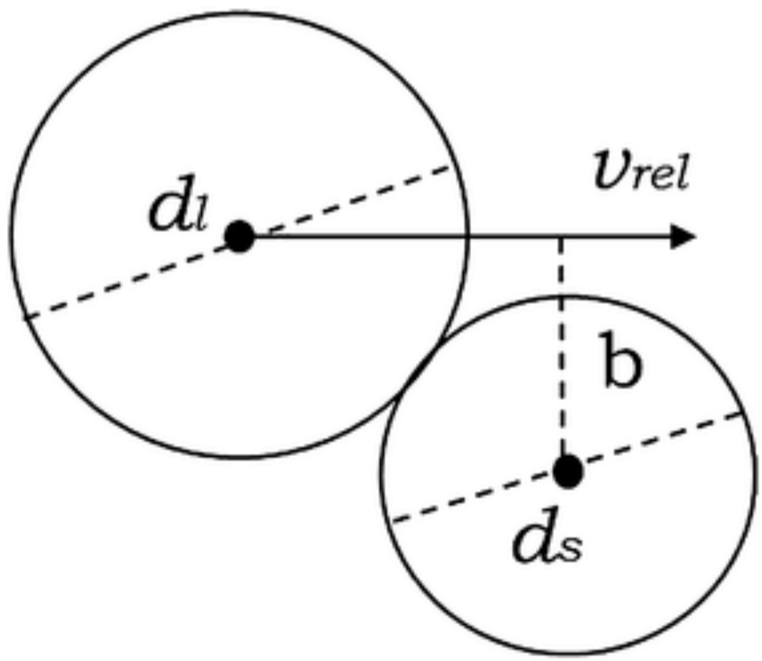

Figure 5: Droplet collision geometry

The Ohnesorge number represents the ratio of viscous forces, μ_d, to the combined effect of inertia forces and surface attention (Finotello 2017).

$$Oh = \frac{\mu_d}{\sqrt{\rho_d d_s \sigma}}$$

Figure 6: The Ohnesorge number equation

Environment and Technical Parameters

It’s apparent that the subject of the image is a head–on collision occurring when the first droplet rebounded back off the surface of the milk inside the mug to collide with the second drop moments later. The stem in the center is caused by the first droplet’s rebound and the planet-like wrapping/edging formed when the droplets met. The second droplet has more mass and a higher velocity, therefore acts with stronger force on the first droplet’s rebound. The dropper tank was filled with regular tap water dyed with blue food coloring and the cup was filled with white dairy milk. The flash was provided by two separate remote flashes linked to the timer in the dropper. The camera used was a Nikon D700 with the settings listed below.

Nikon D700 Droplet Settings:

- Exposure time – 0.5
- F-Number - 16
- ISO – 200
- Shutter Speed – 0.5
- Max aperture – 3.2
- Focal length – 105 mm
- Lens – 105mm f/2.8

Conclusion

The image reveals the beauty in droplet-droplet collision. I like how the difference in droplet force is made apparent by the collision in addition to both droplets’ origins on display as well. The collision between the two droplets beautifully demonstrates the physics of the fluidity by providing a unique planet-like moment. In the future, I think experimenting with different lighting filters and a higher viscous fluid could provide a more explosive collision and powerful image.

References

- Finotello, Giulia, et al. “The Dynamics of Milk Droplet–Droplet Collisions.” *SpringerLink*, Springer Berlin Heidelberg, 12 Dec. 2017, link.springer.com/article/10.1007/s00348-017-2471-2.