Team Image 2: Honey

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Introduction

This image was created for the second team image in the University of Colorado's Flow Visualization course. The team members involved in its creation were Rachel Sobke, Alexandra Banks, Jonathan Fraker and Taylor Powers. This image showcases coiling of high viscosity fluids in the inertial regime using honey, which is a high viscosity Newtonian fluid.

Visualization and Photographic Technique

The materials used include white poster board, white paper, honey, a Nikon DSLR camera, an incandescent overhead lamp, and a tripod. The lighting was provided by an overhead incandescent lamp. The honey was dropped from approximately 2 feet onto a white sheet of paper with a white poster board background. The diameter of the honey stream at coming out of the bottle was approximately 2-3 mm, and it decreased to approximately 1/3 mm when it coiled at the bottom. A camera on a tripod level with the honey about 6 inches away from the edge of the paper took the image. A schematic for the setup is shown in Figure 1.

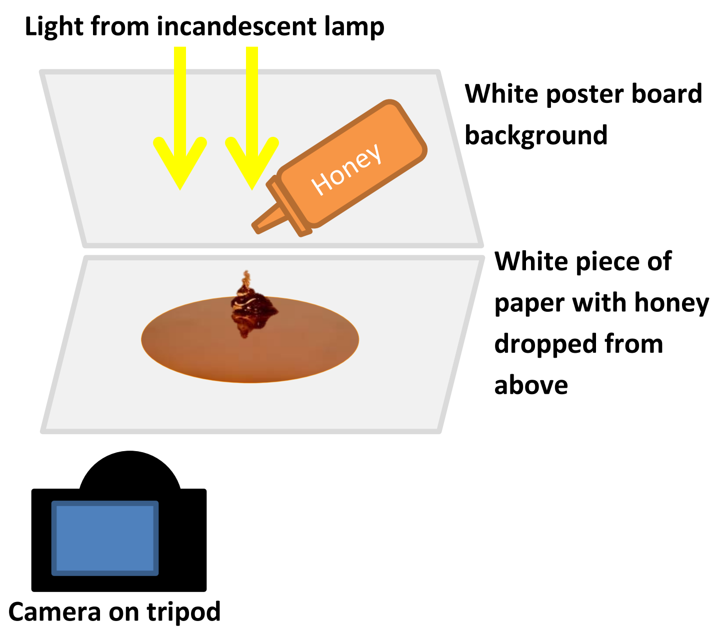

Figure 1: Setup

This image was shot using a Nikon D5200 DSLR camera. It was shot in manual mode with an f-stop of f/6.3, exposure time of 1/200 seconds, ISO of 250, and focal length of 55 mm. The camera was on a tripod for added stability. The unedited image, shown below, is 6000 x 4000 pixels with a resolution of 72 dpi.

Figure 2: Original Image

The image ended up being slightly overexposed. In post-processing in Gimp 2.8, the curves function was used to adjust the saturation of the image. Unsharp mask was used to further define the image reflection and bring out the edges of the coils. It was cropped to be completely centered and have a vertical concept that highlighted the reflection of the honey. Vertically, the image was cropped using the rule of thirds such that the horizon of the honey pool was a third of the total vertical height of the image. There is some motion blur in the honey coiling, but the unstable nature of the coils can be seen.

Description of Flow

Coiling occurs in high viscosity fluids in three regimes dependent on drop height: viscous, gravitational, and inertial[1]. The viscous regime occurs at very low heights and is driven by fluid extrusion. Viscous forces are dominant. Gravitational forces are dominant in the gravitational regime, which occurs with a drop height of up to 9 cm. There is slow, stable and predictable coiling in this regime. The regime captured in the image is in the inertial regime, which occurs with drop heights above 10 cm. Inertial forces are dominant, and the coiling is unstable. Buckling of the coil often occurs if there is a disturbance in the stream (change in position, force applied to the stream, etc.), which can be seen in the uneven distribution of honey in the image. This instability was likely caused by imperfect position when dropping the honey because a person does not stay in the same position. Buckling also causes larger coils to be formed from the smaller coils that have buckled, as also seen in the image. The new, larger coils are formed in the viscous regime because their drop height is very small (from the top of the buckling.) A visual diagram showing this phenomenon is shown below.

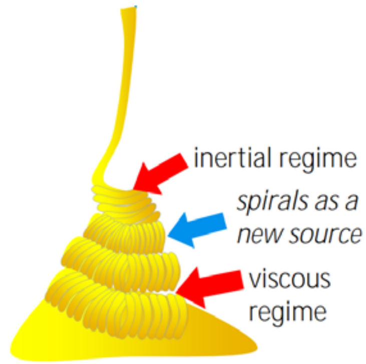

Figure 3: Large Coils formed from Buckling of Small Coils[1]

The coiling frequency is determined not only by drop height, but also final stream diameter, flow rate, and coil radius. The coiling frequency generally increases with drop height. The equation for coiling frequency is shown below.

$$\Omega = \frac{Q}{\pi {a_1}^2 R}$$

Where Ω represents the coiling frequency, Q is the flow rate, a_1 is the stream diameter at the top of the coil and R is the diameter of the coil. With an estimated Q of 0.0038 cm^3s^{-1} (based on a rope coiling experiment by Habibi, Maleki, Golestanian, Ribe, and Bonn[2]), a_1 of 0.033 cm and R of 0.05 cm, the coiling frequency is approximately 0.022 Hz.

Discussion and Reflection

The image successfully fulfilled the intent of capturing different regimes of honey coiling, capturing both the inertial regime with the smaller coils and the viscous regime with the larger coils. Artistically, it used a vertical concept that highlighted the reflection of the coils in the honey. If the image were to be replicated, a faster shutter speed should be used in order to prevent motion blur and overexposure.

References

[1] Souckova, Kamila. "Honey Coils." International Young Physicists' Tournament. Bratislava, Slovakia. 7 Apr. 2014. Lecture.

[2] Habibi, Mehdi, Maniya Maleki, Ramin Golestanian, Neil Ribe, and Daniel Bonn. "Dynamics of Liquid Rope Coiling." *Physical Review E* 74.6 (2006): n. pag. Print.