Team 3: Bouncing Jet

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Bouncing Jet was created as a part of a team assignment for the Spring 2012 University of Colorado MCEN 4151: Flow Visualization course. A team of 4 mixed disciplinary (engineering and art) students came together to create this image. This assignment was designed to challenge students to go beyond what they are capable of capturing on their own, and to utilize resources, specifically other people, as an aid in creating an image of higher-level fluid phenomenon. This was the final assignment of the Spring 2012 semester. This image shows a bouncing jet, a phenomenon where a fluid impinging on a bath of the same fluid bounces off a thin layer of air between the two (Center 2012).

To create a bouncing jet, acrylic was held at an angle and covered in a layer of shampoo. A jet of shampoo was then directed towards the acrylic and bounced off the surface of the shampoo. The schematic in Figure 1 shows that there were two layers of acrylic supporting the thin bed of shampoo.

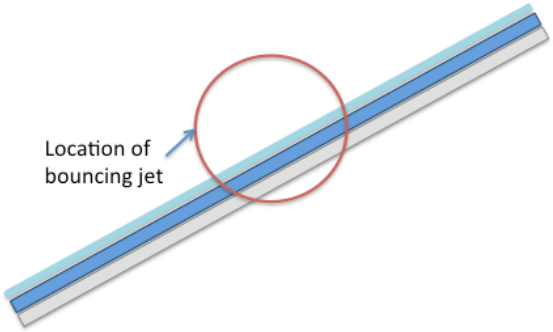

Figure 1: Method schematic

By examining the photograph of the setup shown in Figure 2 it is possible to determine many of the constants required to recreate this image. The angle of the supporting acrylic beams was approximately 45º. The jet was ¼" diameter and fell from a height of approximately 18 inches.

Figure 2: Experimental setup

When a jet bounces off a bath or a surface, it does not mix with the fluid in the bath or surface (Thrasher 2007). Instead, it is separated from the bath by a thin layer of air that serves to lubricate the outside of the jet, allowing it to bounce (Thrasher 2007). This is similar to the behavior exhibited by a paper as it slides across a

tabletop (Center 2012). Often when a jet impinges on a bath, it plunges into the bath and mixes with the liquid. The bouncing phenomenon occurs when the energy required to plunge a jet through the surface of the bath equilibrates with the energy required to reform the surface of the bath (Thrasher 2007). Equation 1 shows the energy of a bouncing jet where S is the arc length of the bath impingement and A is the area of the jet.

Equation 1

$$E_{bouncing} = \int \sigma \, dA \sim \sigma S^2,$$

In contrast to the energy of the bouncing jet, Equation 2 shows the energy of a plunging jet where F_{drag} is given by Equation 3 and l is the horizontal distance over which the jet becomes parallel to the liquid surface. The Reynolds number seen in Equation 3 is given by Equation 4.

Equation 2

$$E_{plunging} = \int F_{drag} dx \propto F_{drag} \ell,$$

Equation 3

$$F_{drag} = \frac{4\pi\mu V_{bath} L}{\ln(7.4/\mathrm{Re}_{bath})},$$

Equation 4

$$\mathrm{Re}_{bath} = d_{jet} \rho V_{bath} / \mu$$

The setup was lit from the same side as the camera using two high-wattage incandescent lights. This lighting served to highlight the side of the jet, helping it to come into focus. The shampoo used for this experiment was the Walgreens generic brand of men's shampoo. Different orifices for the jet exiting the bottle were experimented with, however, the best seemed to be the original hole in the shampoo bottle. This is perhaps due to the surface geometry at the exit.

The size of the field of view was approximately 15 inches across. The distance from the camera to the first bounce was approximately 8 inches and the focal length of the lens was 5.9 mm. This was the optimal distance given the physical constraints of the experimental setup. The original image was capture with a Canon Digital IXUS 100 IS and was 4000 x 3000 pixels. This image was then cropped to 2000 x 1000 pixels after a rotation that caused the impinging jet to be in the same vertical orientation as the edges of the frame. The exposure settings include an aperture of

(f/3.2), a shutter speed of 6.92 and an ISO setting of 100. The low ISO helped eliminate noise in this low-light situation while the high shutter speed allowed for good spatial and time resolution for a fast-moving jet.

Figure 3: Original image

This image was post-processed using Photoshop. A rotation grid was used to align the jet vertically and then crop the image. The background could not be improved or faded without compromising the integrity of the focus on the impinging jet.

This image captures a phenomenon that was not widely researched until the past few years. I was unable to find another bouncing jet with as many bounces as capture in this image – in the submitted image there are four bounces and the closest number of bounces I could find was two. The jet itself is beautiful – the focus on the first bounce gives the viewer the feeling of motion, that the jet is moving away from the camera with time.

Sources

Thrasher, Matthew. “Bouncing of a jet off a Newtonian liquid surface" Phys. Fluids 19, 091110 (2007)

"Center for Nonlinear Dynamics » The Bouncing Jet." *Center for Nonlinear Dynamics* . N.p., n.d. Web. 8 May 2012. <http://chaos.utexas.edu/people/faculty/harry-l-swinney/the-bouncing-jet>.

Thrasher, Matthew. "Geometry and dynamics of liquid-liquid interfaces." *Center for Nonlinear Dynamics Thesis*1 (2007): 13. Print.