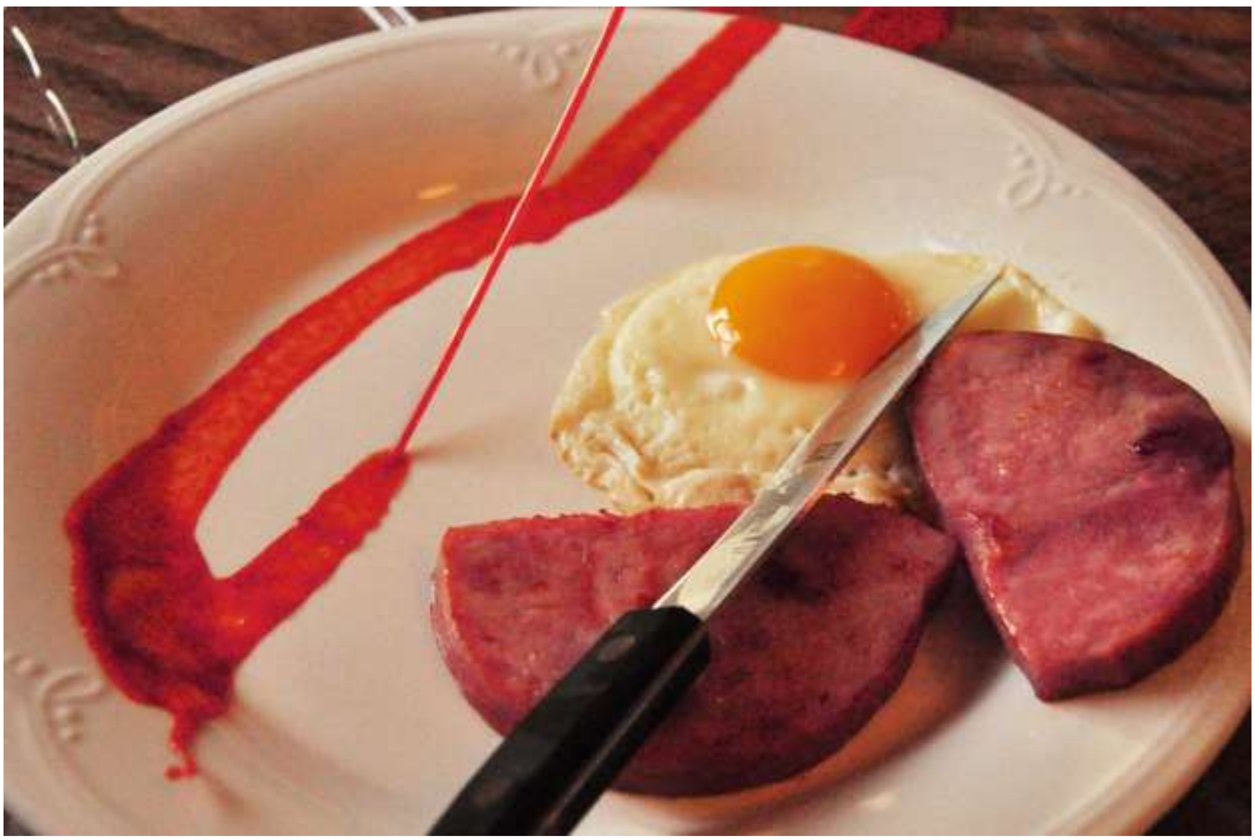
Get Wet Image – Impinging Jet



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Flow Visualization
Get Wet Assignment

The image is a homage to the Showtime® series Dexter, which tells the story of a protagonist serial killer who exclusively kills other serial killers. The title sequence of this series features the morning routine of the main character, Dexter, as he gets dressed, makes breakfast, brews coffee, et cetera. Dexter eats over-easy eggs and ham steak with hot sauce during the sequence, and there is a shot in which hot sauce splatters on the plate with the eggs and ham. My image is intended to recreate this shot (Figure 1), with more of a focus on the fluid phenomenon that is occurring; which is a jet impinging on a planar surface at an angle.

Figure 1: Still from Dexter Title Sequence[1]

The apparatus used to create the image consists of three critical components. The first is the object of the image: the plate with the food and hot sauce. The second is the camera, set up on a tripod. Both of these are shown in Figure 2.

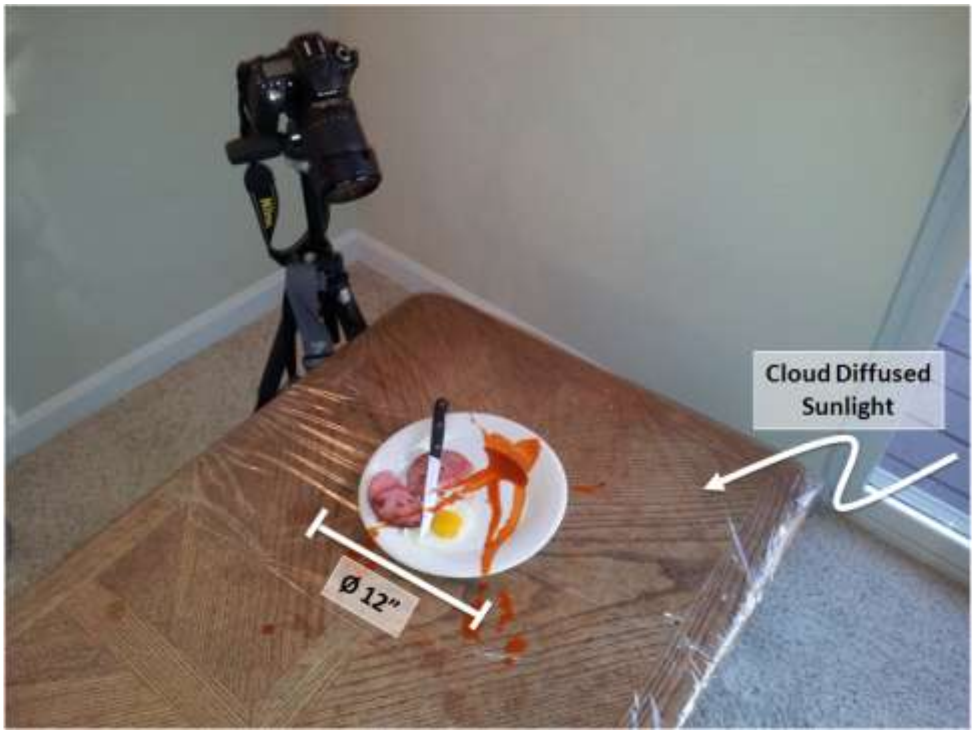


Figure 2: Image Set Up

The third component is the mechanism by which the jet of fluid was created, a compressible fluid reservoir with a nozzle. In this circumstance the reservoir was a plastic sandwich bag and the nozzle was a metal cone generally used to frost pastries (shown in Figure 3). The plastic bag was filled with the fluid, and once compressed; the fluid was forced out of the nozzle, creating a jet.

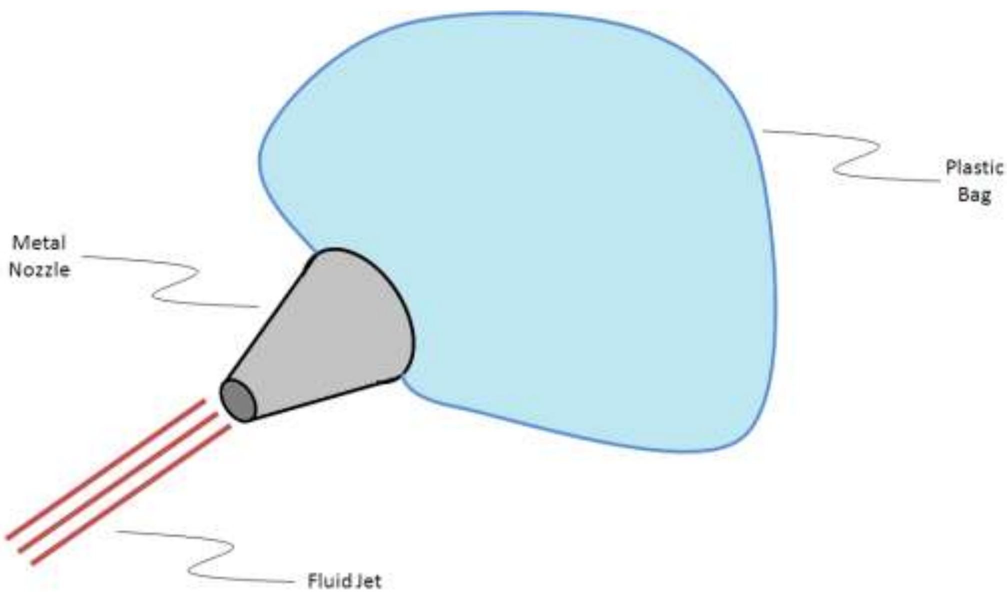


Figure 3: Jet Mechanism

The basic flow of the fluid is a jet, which is defined by Kundu as an efflux [a flow outward] of fluid from an orifice[2]. The jet impinges on a planar surface at an angle, which interrupts the integrity of the stream and therefore the velocity profile of the jet. A general 2D velocity profile of a jet is shown in Figure 4.

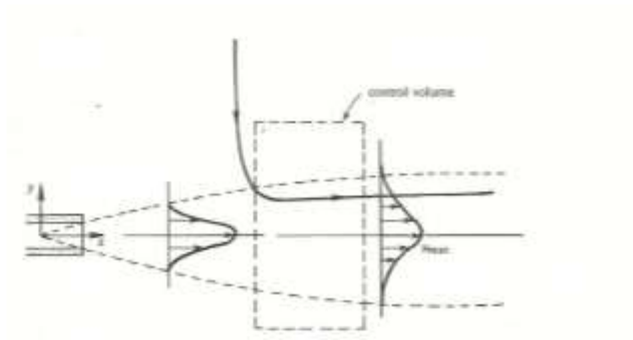


Figure 4: Laminar Two-Dimensional Jet. Velocity Profiles Shown[2]

The flow takes the form of a jet as a product of the nozzle. The nozzle converges the fluid from a large cross-sectional diameter to a small one, and by conservation of momentum, the velocity of the fluid must increase as its cross-sectional area decreases. The jet that is in the image has a diameter of approximately 1/8", and exists for 6 or 7 inches before impacting the plate. By far the most dominant force acting on the fluid is that which is forcing it through the nozzle. The only body force on this fluid, gravitational force, is present but not dominating the fluid flow. This can be seen as the jet is almost linear in its trajectory, indicating that the fluid is moving quickly enough at a downward trajectory that gravity doesn't have enough time to significantly affect the path of the jet. The viscous effects of the fluid are important, as they contribute to the laminar nature of the flow. Intuitively, it can be determined that the flow is laminar, because it is a clean, cylindrical volume of fluid. If the jet were turbulent, it would dissipate into a mist, similar to the turbulent jet shown in Figure 5.

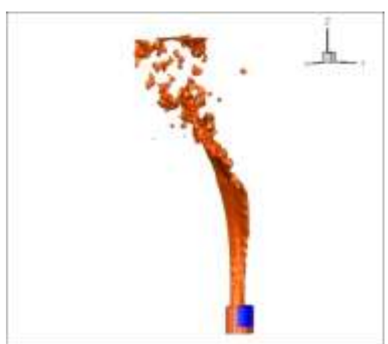


Figure 5: Turbulent Jet[3]

Numerically, it can be confirmed that the flow is laminar by an estimation of the Reynolds' Number of the flow. Reynolds' Number is a dimensionless number that relates inertial to viscous forces[2]. Reynolds' Numbers below 50,000 are considered laminar, while those above 50,000 are considered turbulent. The estimation of this flow's Reynolds' Number is shown below.

$$Re = \frac{UD}{\upsilon} = \frac{\left(0.85\frac{m}{s}\right)(.0032m)}{2x10^{-6}\frac{m^2}{s}} = 1360$$

Estimating the velocity of the jet, using the 1/8" diameter of the nozzle, and approximating the viscosity of the hot sauce as being twice that of water at STP, a Reynolds' Number of severely under 50,000 is obtained, confirming that the flow is laminar.

Investigation of the effects of jet impingement on flat surfaces is extensive, with particular emphases on the shear stress that it creates on the impingement plane. The jet, even if it impinges normal to the surface, creates shear stress on the surface because it bends at the surface and travels along the surface, similarly to the diagram in Figure 6.

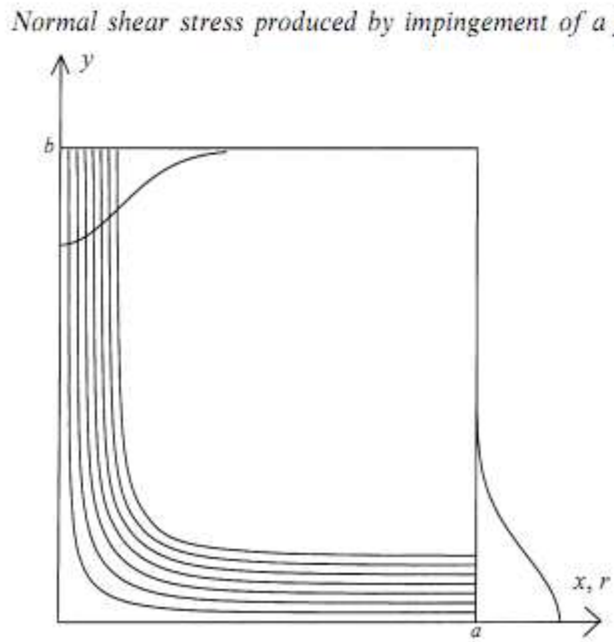


Figure 6: Fluid Streamlines at Jet Impingement[4]

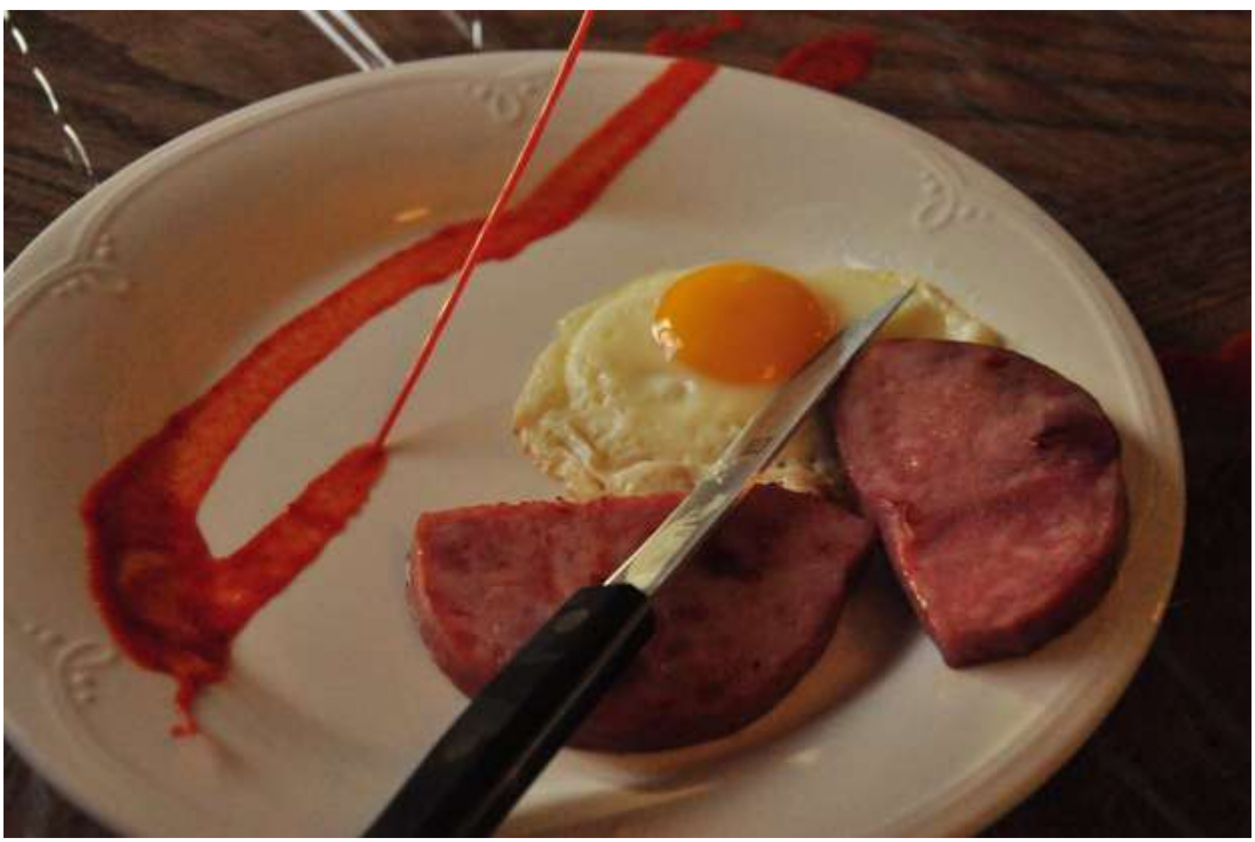
As the fluid travels along the planar surface, it creates friction that creates shear stress on the surface. It is very difficult to fully characterize what happens once the impingement of the jet occurs, because the boundary layer of the fluid along the plate is turbulent while the bulk of the fluid flow is laminar. The complex interface between the two modalities of flow leads to inaccuracies in both analytical and computer models. It has been generally concluded, however, that the shear stress on the plate is chiefly due to the compressibility effects for various Mach numbers[4]. While the fluid in the image is impinging on the plate and therefore creating shear stress, the majority of that energy is used to disrupt the integrity of the jet geometry and splatter the fluid. The energy is used in this way because the mass of the plate is so much greater than that of the fluid, so it is far less affected by the impact than the fluid is.

The visualization technique used is accentuating the contrast in colors between the fluid and its background. The fluid is Tapatío® Hot Sauce, which is a dark red color, and therefore did not need to be colored as it contrasts starkly with the visually transparent air that it is traveling through. Therefore, in order to more clearly see the fluid phenomenon, the jet of sauce is set in front of a clean, white dinner plate. The food items in the image are common eggs and ham steak found in a local grocery store and cooked immediately before the image was captured. The lighting in the image is natural sunlight, diffused by cloud cover. The image was taken at about 4:00pm in January in Colorado, so the sun was low in the sky. No artificial lighting was used.

The field of view for the image is approximately 11in wide by 10in tall. The object was approximately 2 feet from the lens of the camera. The lens that was used is a AF-S Nikkor 18-105mm, with its focal length at 42.0mm. The shutter speed for the shot was 1/640 sec; the aperture was 4.8; and ISO was set to AUTO. The camera used is digital, producing an original picture size of 4288 x 2848 pixels. The camera used is a Nikon D90 DSLR. The post processing of the image was done in Adobe Photoshop. The image was cropped, brightened, and the temperature was shifted warmer.

The image clearly shows the jet and its impact upon the plate, which I like a lot. It is very easy to tell what is going on. I do not like, however, that the image is inexplicably grainy in areas, despite the fact that is high resolution. The camera took the photo in a JPEG, which I didn't notice until days later, when I no longer had an opportunity to re-create the image. The fact that the image was originally stored as a JPEG could account for the grainy spots in the image, which would be artifacts of file compression. The image does fulfill my intent; it is very similar to the image that I set out to create. If I were to do it again, I would pay more attention to camera settings, making sure that it was not creating images in JPEG form, and I would like to get more splatter in the image. The image does a great job of showing the jet and its impact, but doesn't show much splatter, which would make for a more interesting image.

Original Image:



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