Team Second

Flow Visualization: The Art of Fluid Flow

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Background: The goal of this image was to reproduce youtube's Slow Mo Guys' video of Jell-0 being diced by a tennis racket. While they present some incredible imagery through the form of video, we had hoped to capture the same phenomena but with a still. Because we lack a 4K camera capable of 10,000 fps, we hoped a still and some timing could get similar results. By capturing the moment of Jell-O being sheared by the racket strings, we hope to shine some light on the physical characteristics of this phenomena. With the assistance of Liz Whitman, slicing Jell-O while it falls to the ground with a tennis racket is captured in a still image. This project "Team Second" was also done with the help of teammate Michael Bruha, in a collection of Jell-O images. While many images were captured, this was one of the few that recorded the exact moment the Jell-O is being diced, and captures both the physics and artistic appeal of fluid motion.

Image Capture: This image was captured during the day outside. The outside venue provided ideal lighting and minimized the post capture cleanup. Material included were 6 oz of red cherry flavored Jell-O and a tennis racket. The Jell-O branded gelatin was produced using the instructions on their website and poured into 600 ml bowls where it settled in a refrigerator. Because of the destructive nature of the experiment, 6 sets of Jell-O samples were made. The experiment was straight forward and in this case like with the Slow Mo Guys, the Jell-O was dropped from a height of nearly 2 meters and sliced by swinging tennis racket as it fell. The camera was positioned at elevation, above and behind the axis of racket rotation. Many trials were conducted until a suitable image was captured. Given the short shutter speed, camera delay, and speed of the racket head many trials were missed completely, until this image.

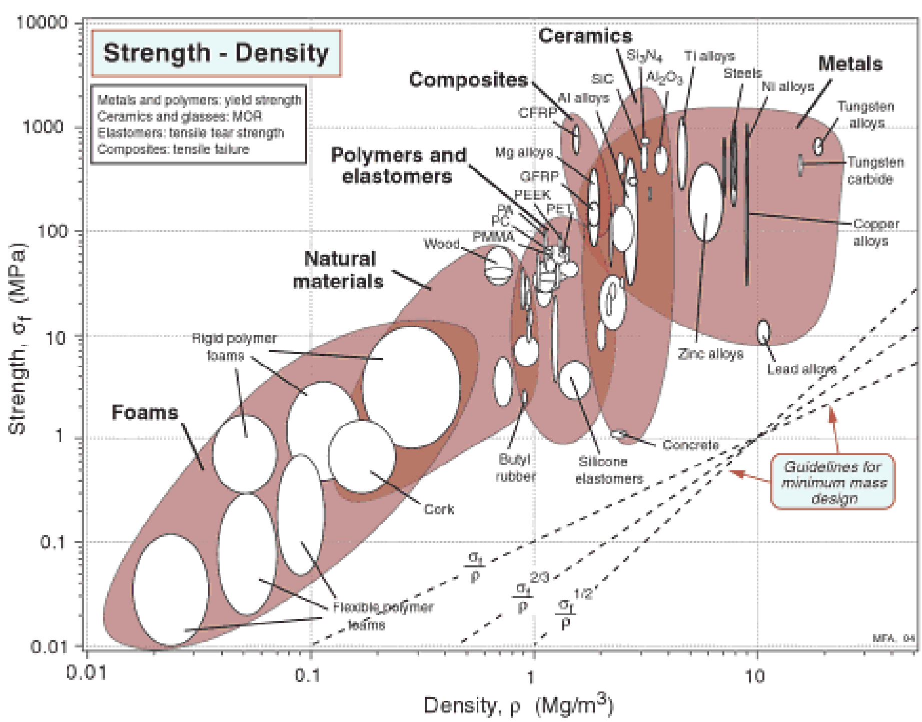

Figure 1: Strength, plotted against density (Ashby)

The image captures the moment that the Jell-O is being sheared by the strings of the tennis racket. It is clear there is some resistance to the shearing seen in the blob being carried forward by the racket motion, but eventually the Jell-O is diced and broken into the smaller components. In Michael Ashby's textbook Materials Selection and Mechanical design, the material strength of materials is plotted relative to their densities (figure 2). Because of its low density, foams can have very low strength, like "gelatin (as in jello) has a modulus of about 10 kPa. Their strengths and fracture toughness, can be below the lower limit of the charts." Such material properties explain why Jell-O shears easily but as a foam, it does so with characteristics of a solid.

$$F = ma \quad and \quad \tau = \frac{F}{A} = 5.4\ [\mathrm{kPa}]$$

m = ρ*V

V = cube volume ($1E-6$ [m^3])
ρ = Jell-O Density (~900 [kg/m^3])
a = acceleration of Jello (1800 [m/s^2])
m = mass of Jell-o
A = shear area (3E-4)

Equation 1: Shear force calculation

Using an estimated amateur tennis player's swing acceleration on a tennis ball, the applied force was calculated to give an idea of the shear stress subjected to the Jell-O. The finding of 5.4 [kPa] is within the magnitude of the shear stress of deformation in foams like gelatin. Because we used Jell-O brand gelatin, and followed the making instructions, a large proportion of this sample was water. This gives some resolve for the lower shear stress, that a more watery foam would shear more easily.

Photographic Technique: This image was captured using a Canon EOS Digital Rebel. With ideal lighting and proper timing we were able to capture the image. To minimize motion blur a 1/4000 sec shutter speed was used. A small large aperture was used to maximize the light given the short shutter speed with an f/5.6. With the outdoor conditions and taking samples with other pictures, the ISO-400 setting gave suitable light sensitivity. The focal length was 49 for the capture, with a center weighted average setting. The result was a 4272 x 2848 pixel image. That original image was process using GIMP to emphasize the contrast by distributing the red spectrum. This gave a final image focused on the Jell-O fluid movement.

Image 2: Original Image

Takeaways: By far the biggest struggle to capturing this image was the limited amount of Jell-O available to use for each picture. There were lots of images of sliced Jell-O falling to the ground, but few of the moment it was being split. A more sophisticated apparatus would have been ideal to maximize the timing given the limited Jell-O supply. The result nonetheless is this wonderful image capturing the moment Jell-O is split by a swinging tennis racket.

References:

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