Flow Visualization

Team Project 1

Fall 2015

https://vimeo.com/142893815

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The purpose of this project is to work as a team to set up and photograph a flow experiment. For the first team project, we hoped to capture a Worthington jet using a steel ball and sand. This phenomenon was captured using slow motion video. The slow motion video allows us to examine the impact in more detail then what the naked human eye can see. When we actually set up the experiment, Joanna Bugajska set up the lighting and camera settings, Robert VanCleave and Luke McMullan poured and arranged sand and Quyncie Grenis dropped the steel balls. As a team, we were unable to capture a Worthington jet but we did see a crown wave. We obtained the Worthington jet effect by dropping paint into a shallow bed of water.

For this specific video, we used a white background with fine black sand. The sand had a diameter of approximately 1/8 mm and the air gaps between the particles make the sand act as a fluid. The sand was held in a glass pan and was approximately 40 mm deep and 10 cubic centimeters. The steel ball was 1.25 cm in diameter and was dropped from 30 cm above the sand. The velocity at the impact can be calculated by the following:

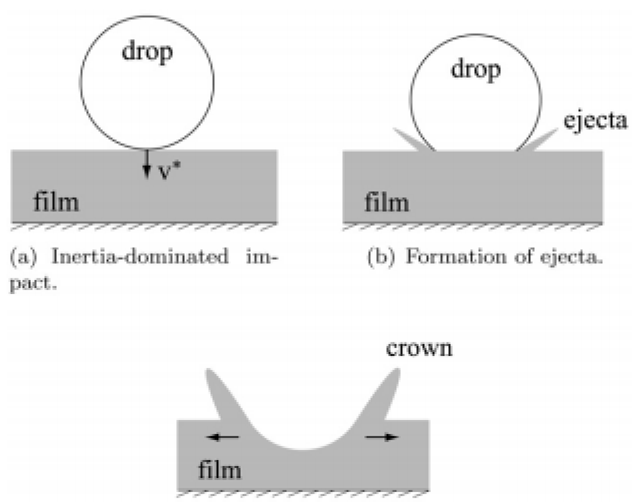
$$mgh = \frac{1}{2}mv^2$$

$$v = \sqrt{2gh}$$

$$v = \sqrt{2 * \frac{9.81m}{s^2} * 0.3m}$$

$$v = 2.43\ m/s$$

Although we did not capture a Worthington jet with the sand, other physics were shown. Upon initial viewing of this process it appears that there are multiple different phenomena happening. With the initial impact we see the ball creating a crown-like image, various shock-waves being sent through the sand, and finally ending with a crater. [1] However, all of this can be attributed to a single phenomena called “Granular Eruption.” [2] What you see on the video is only half of this phenomena.



(a) Inertia-dominated impact.
(b) Formation of ejecta.
(c) Crown evolution.

Granular eruption occurs when a steel ball is dropped into loosely packed, fine sand. Upon impact the sand is blown in all directions forming the splash and crown-like image you see in the video. [5] However, for our experiment, at this point the force is transferred to neighboring sand particles and the bottom of the apparatus where the force eventually dissipates and settles. If our sand had been deep enough then we would've seen the completion of the granular eruption. After the impact a void is created in the sand and once this void collapses, a granular jet is formed. [3] This is the jet you see that pushes the sand particles straight up into the air, very similar to a Worthington jet when objects are dropped in liquid. [4] For high enough velocities, the void collapses towards the middle of the sand trapping air in the middle of the sand. This air bubble will eventually make its way to the top of the sand, completing the granular eruption. [5] From research and experiment it seems that the finer the sand, the better visual phenomena one can achieve. **

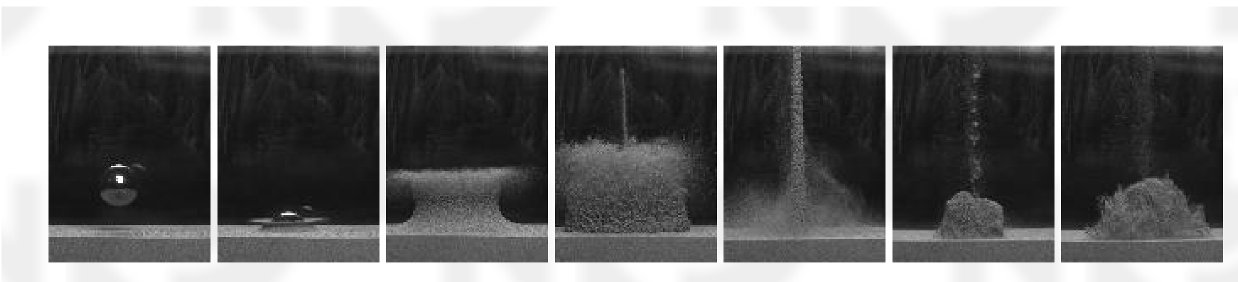


Figure 2: Granular Eruption [5]

The following images show how the experiment was set up in the lighting studio. The two floodlights were pointed at 45 degree angles toward the sand. The camera was mounted on a tripod at a 15 degree angle. This angle allows us to view the hole in the sand when the ball impacts the bottom of the glass dish. The camera was about 20 cm from the front of the sand pile and the field of view stretched about 5 cm.

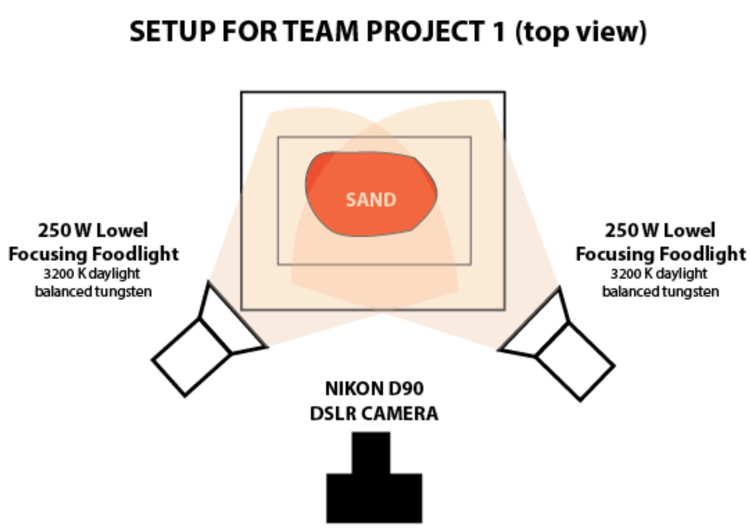


Figure 3: How the experiment was set up (provided by Joanna Bugajska)

** Written by Robert VanCleave

Figure 4: Image of experimental setup (provided by Luke McMulllan)

The following table shows what the camera settings were to capture this video.

Camera	Sony NEX-FS700	Allowed us to capture enough frames per second while maintaining a high enough resolution
ISO	2200	Large to get correct exposure with the minimal lighting
F-stop	5.6	
Shutter Speed	Auto	Only option in high speed mode
HD Format	1080p30 video	Greatest resolution allowed
Frame rate	960 fps	Largest rate for this camera
Flash	None	
Lighting	Two Lowel Pro-Light Focusing Floodlights, 250 Watts each, tungsten balanced	Tilted at 45 degree angle

During post processing, Windows Movie Maker was used to crop the video. No other effects were added.

I like the sand used in this video because when the light catches it right, it glitters. I also like being able to see the crown wave form. The fluid flow is very clear in this image because in slow motion, the human eye can see the sand grains move. If we were to set up this experiment again, I would like to use a deeper bed of sand with a slightly larger ball. I think it would also help to drop the ball from higher up but there is a lot of uncertainty about where the ball will impact.