Team Project 1: Impact

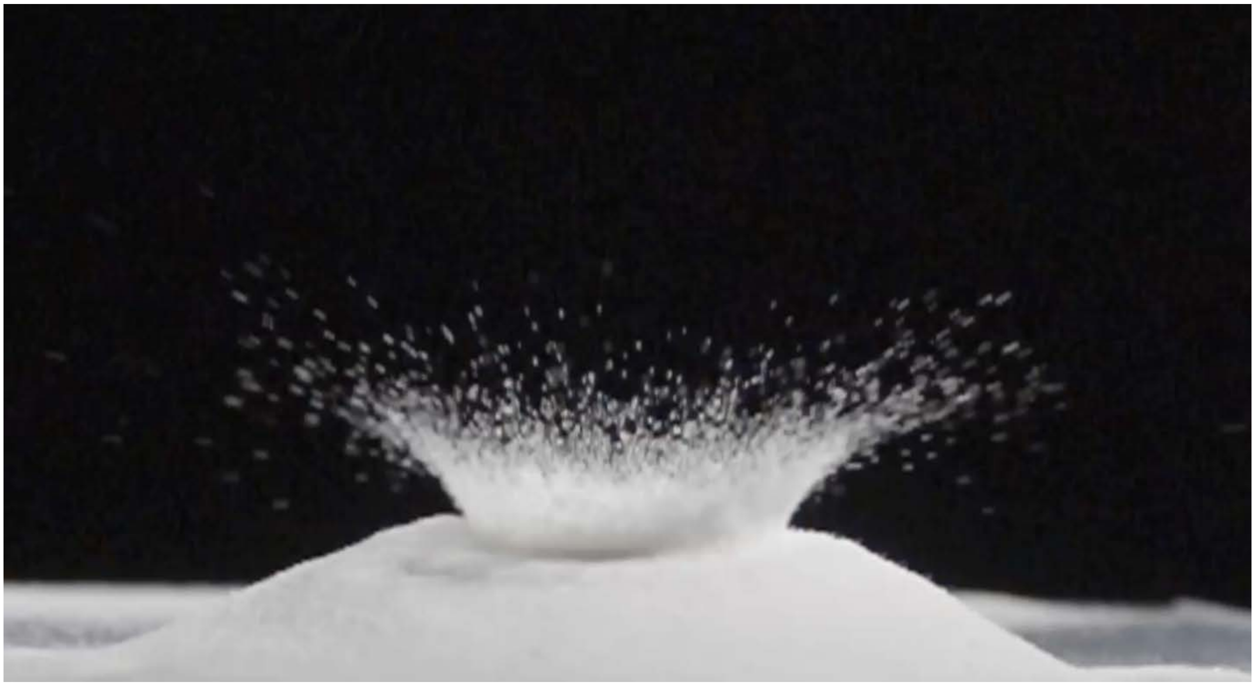

Figure 1: Single frame from video shows the granular crown splash.

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Introduction

The goal of this project is to visualize the flow of sand particles when a ball bearing is dropped onto them. The photograph above is a still image taken from the video that shows the white sand crown splash that was created by the ball bearing. Joanna Bugajska is credited with the camera use and Rob VanCleave is credited with doing most of the research behind this phenomena.

Physics

The beginning of the video shows a mound of white sand about two inches tall and a ball bearing that is dropping from about 12 inches high. What happens next is the ball impacts the sand and ejects the sand in a crown-like shape. This motion is known as "Granular Eruption"[1] and describes a mass that impacts loosely-packed, fine sand, creates shockwaves, and leaves a crater behind[2]. The following figure shows the eruption.

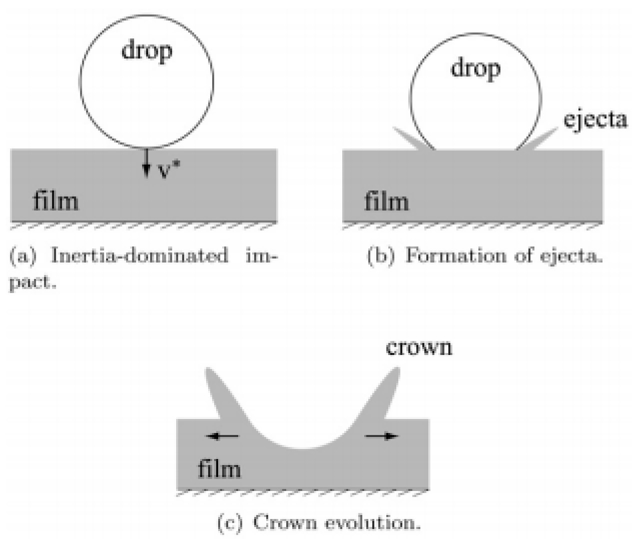

Figure 2: Evolution of a crown splash.

This video only shows the eruption of the crown splash and the resulting crater. There is another part to this fluid phenomena that is associated with impact on sand but our setup was unable to capture it. What we cannot see in the video is what happens after the ball sinks into the sand. After the impact, a void is created in the sand that quickly fills in to create a granular jet[3]. This granular jet is very similar to the Worthington Jet that we see in liquids[4]. At high enough velocities, the collapsing void traps a bubble of air underneath that eventually travels through the sand to complete the granular eruption[5]. The following sequence displays the final stages of granular eruption.

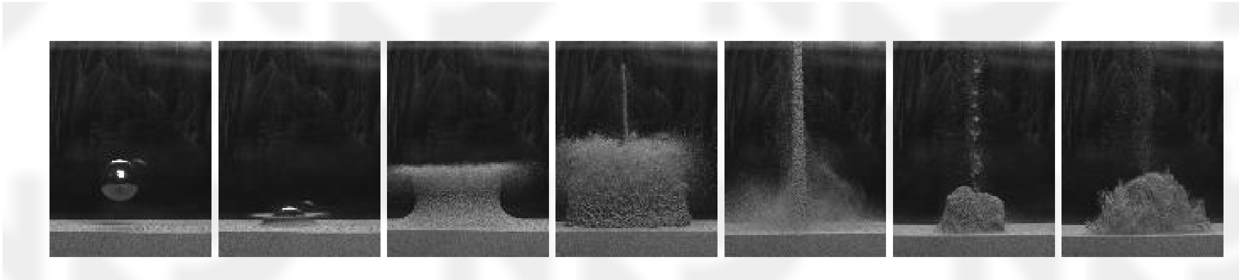

Figure 2: Granular eruption[5].

If our experiment had deep enough sand, the video would have captured the final stages. Also, it is important to use fine sand to help visualize the effects.

Experimental Setup

All of team members used the following setup for the granular eruption videos. The setup included the camera on a tripod facing the top of plastic tub that was flipped over. The lights were angled toward the center of the tub and white sand was placed in the spotlight. The ball was dropped from about 12 inches high. The following diagram and photograph show the setup.

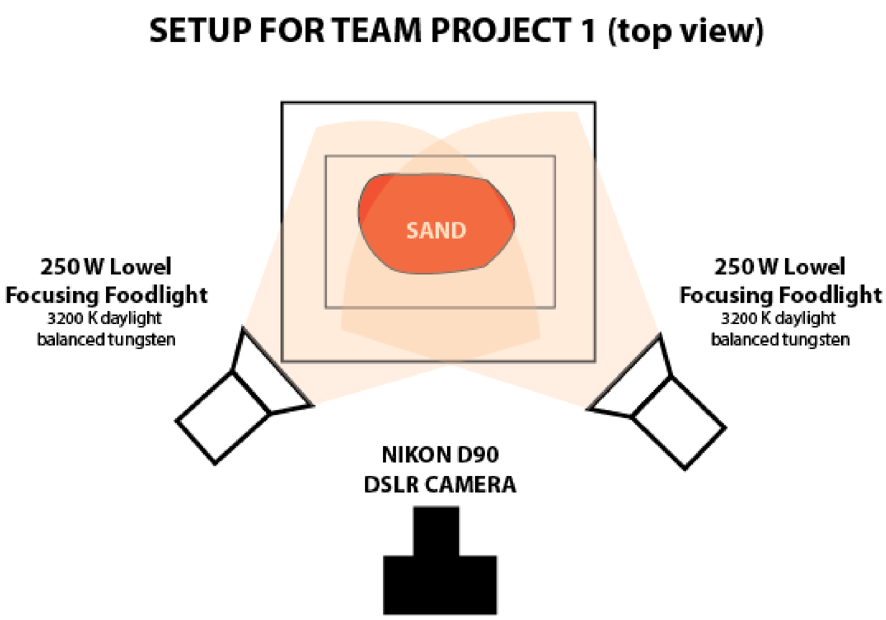

Figure 3: Diagram of setup.

Figure 4: Experimental setup for the video.

Image Capture

Camera/Lights Used

- Sony NEX-FS700 Camcorder with 18-200mm Power Zoom Lens
- Two Lowel Pro-Light Focusing Floodlights, 250 Watts each
- Tungsten balanced

Camera Settings

ISO	2200
F-stop	5.6
Shutter speed	Auto (only option in high speed mode)
HD Format:	1080p30 video*
Frame rate:	480 fps and 960 fps*

We preformed experiments at two different frame rates: 480 fps and 960 fps. The way FS700 camera works for slow motion video is that it records the frames to the memory for up to 12 seconds for 960 fps and 20 seconds for 480 fps, then the frames are transcoded as 1080p30 video (30 fps).

Frame rate buffered	Frame rate when record	Duration
960 fps	30 fps	32 sec
480	30 fps	16 sec

Average duration of the video clips recorded per take was between 1 and 4 minutes.

Conclusion

The team was effectively able to capture the crown splash phenomena by means of dropping a steel ball bearing into a pile of sand. While capturing the splash was nice, it would have been better to use a deeper sand pit with finer sand. This would have allowed the team to capture the second part of the granular eruption. Either way, we were able to visualize some very interesting fluid flow.

References

[1] Krechetnikov, Rouslan, and George M. Homsy. "Crown-forming Instability Phenomena in the Drop Splash Problem." *Journal of Colloid and Interface Science* (2008): 555-59. Web. 26 Oct. 2015. http://www.engineering.ucsb.edu/~rkrechet-lab/files/publications/jcis2009.pdf

[2] Mikkelsen, René, Michel Versluis, Elmer Koene, Gert-Wim Bruggert, Devaraj Van Der Meer, Ko Van Der Weele, and Detlef Lohse. "Granular Eruptions: Void Collapse and Jet Formation." Physics of Fluids. Web. 26 Oct. 2015. http://doc.utwente.nl/57533/.

[3] Thoroddsen, S. T., and Amy Q. Shen. "Granular Jets." *Physics of Fluids Phys. Fluids*: 4. Web. 26 Oct. 2015. http://citeseerx.ist.psu.edu/viewdoc/download?rep=rep1&type=pdf&doi=10.1.1.222.5612 .

[4] McKown, Jenna. "DSpaceMIT." *An Experimental Study of Worthington Jet Formation after Impact of Solid Spheres* (2011): 13-15. Print. http://dspace.mit.edu/handle/1721.1/67750.

[5] Mikkelsen, Rene, Michel Versluis, Elmer Koene, Devaraj Van Der Meer, Ko Van Der Weele, and Detlef Lohse. "Granular Matter Homepage." *Granular Matter Homepage.* 1 Sept. 2002. Web. 26 Oct. 2015. http://stilton.tnw.utwente.nl/people/rene/Granular.html.