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MCEN 5151

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Team Third Report

Introduction:

For the third and final group project our team wanted to experiment with the Olympus I-speed camera from the Idea Forge on the University of Colorado campus. Our initial intent was to capture the various phenomena associated with water and a sponge as a projectile. With the help of Luke McMullan, Joanna Bugajska, and Quyncie Grenis, we tried a multitude of different setups, ideas, and takes. Our inspiration and motivation for this project came from the “Gnarly Water Spirals” video from the Slow Mo Guys. The video can be found here: https://www.youtube.com/watch?v=FVo2qdXxQ7o My final product was a different approach that allowed for an exploration in the elasticity of human skin tissue.

Figure 1-6 : Sponge Flight Stills (Taken from edited video)

Physics:

In younger skin, collagen fibrils are high in volume and random in placement. They can also tend to appear in continuous strands. The rigidity and strength of skin is additionally heighted by the cross-linking between the collagen fibrils. In contrast, collagen fibrils of older skin show other properties. They have a lower volume and are more densely packed than younger skin. Generally, this is caused by a degradation of enzymes, allowing for open space to be filled with proteins. [1]

Human skin functions as a viscoelastic material which exhibits non-linear strain behavior. Viscoelasticity is the property of materials that exhibit both viscous and related characteristics when undergoing deformation. [1] The viscous component is associated with energy dissipation, and the elastic component is associated with energy storage. [2] This viscoelastic property can be seen all throughout the body in not only skin, but tendons for example. However, the mechanical behavior of skin and tendons are still slightly different. This is due to the differences in collagen types, fiber length, volume, and collagen molecular stretching. [3]

In this video the force behind the sponge is driving the movement of the skin tissue (predominantly the nose) and the head. The skin begins to move after impact and moves as far as it can while still being attached to the face. It stretches to its limit, and then utilizing the viscoelastic nature, it moves back to the right. [4] Almost like a wave, the shock or impact, travels through the skin to one side of the head and once it reaches the end it reflects back. However, due to frictional forces, this wave eventually dissipates and the skin and nose return to the natural position.

Doing some minor assumptions and calculations and having kinetic energy be the basis for the calculations. The force behind the sponge is roughly 65 Newtons. This was calculated by using the amount of water the sponge soaked up and an approximation for the velocity of the projectile.

$$F = Mass * (v)^2$$

Mass of wet sponge : 1.6 kg

Velocity of sponge : 8.9 m/s

Figure 7 : Calculations

To put this into perspective, the average bullet applies roughly 300-400 N of force upon impact. This amount of force is due to the low mass yet high speed at which the bullet is traveling (roughly 350 m/s). [6] The amount of 65 N was clearly enough force to move the head several centimeters and deform, albeit momentarily, the nose to nearly a 90 degree angle. I believe this video clearly illustrates the viscoelasticity of human skin tissue.

Procedure & Technique:

The following setup and items were used to acquire the photographs.

Table 1 - Items Used
Olympus i-Speed Camera
24 x 14 x 6 cm Yellow Sponge
Approximately 1 Gallon of Water
2-Gallon Bucket
White Collapsible Back-Drop
Tri-pod
Sun

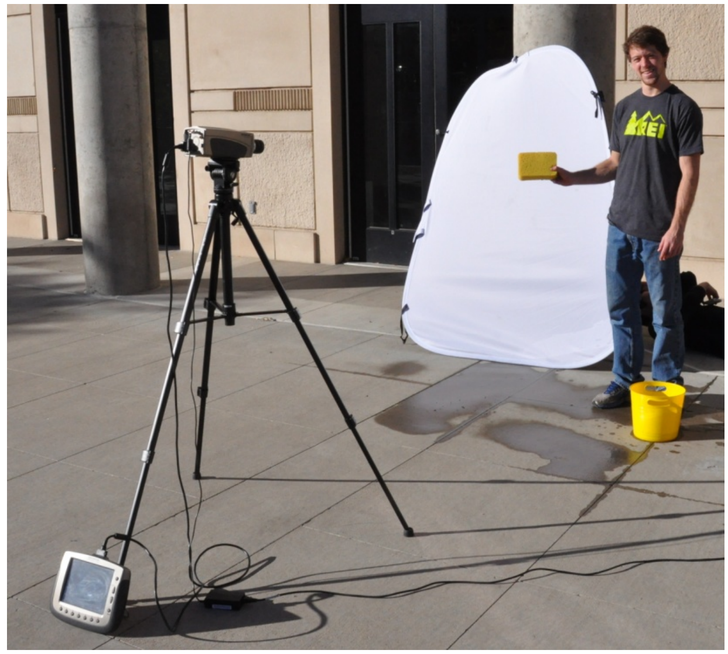

Figure 8: Setup

For this experiment we utilized the University of Colorado's campus to our benefit. We chose to do our experiments in front of the Visual Arts building as we had an open area that was sun-exposed for several hours. In the above picture you can see the setup we used for each trial. With the white back-drop in place, we didn't have to worry about any unnecessary images appearing in the background. Additionally, at around 2-3 pm, the sun provided adequate lighting for our experiments. We felt the natural light from the sun would illuminate the videos the best.

This particular experiment began by saturating the sponge with as much water as possible. This meant timing was key to capture as much water in the sponge as possible. Once everyone was confident everything was in place, at a distance of approximately 3 meters, one team member threw the sponge towards another seated team member's face. We were confident that with the size and soft nature of the sponge, no harm would come to the team member.

Camera Configuration & Processing:

The following were used for the camera Settings (Adapted from Joanna Bugajska)

Camera settings
Size of the field of view: Large depth of field because it's a wide lens
Distance from object to lens: 5-6 ft
Lens focal length and other lens specs: Prime 50mm lens
Type of camera: Olympus i-Speed, digital video
Image resolution (width and height in pixels): 800x600 px (WVGA)

Exposure specs:
Aperture: 1.4 f-stop
Shutter speed: Designated on the camera as 2x (see below explanation)
Based on the manual: The default shutter time is equal to the frame time, but this may be reduced by this control. The shutter time is measured as the ratio between frame time and shutter time, e.g. x10 means that the shutter is open for 1/10 of the frame period. The shutter period may range from the frame period (x1) to 1/200 of the frame period (x200).
ISO setting: This camera has a fixed ISO rate (not listed)

Utilizing the University of Colorado's high speed digital video camera made this video possible. This video was shot at 600 fps which allowed for a good visualization of the phenomena.

There was a moderate amount of post-processing done using Windows Movie Maker (v 6.0). Due to the video having poor coloring, the first alteration that was made was making the video black and white. I don't believe any information was lost, and it helps the viewer not be distracted by the poor colors. Additionally, there was quite a bit of excess video that was unnecessary that needed to be trimmed. To give the viewer an opportunity to view the strike multiple times, the same piece of video was copied and pasted several times. A few were altered using the "mirror" function to give a "barrage" feel to the video. Beyond adding a couple of title slides, credit slides, and some music (Epic – www.bensound.com), there were no other alterations made to this video.

Analysis & Opportunities for Improvements:

I believe we had a unique opportunity to attain some excellent video and I think we did just that. I consider our final product a good illustration of some interesting fluid mechanics of impact, skin, and water. Other videos focused more on the spiraling effect of water coming off of the sponge which could've possibly been enhanced by the use of a more round sponge. As seen in the "Slow Mo Guys" video, a sphere-shaped sponge might show a better illustration of what we were striving for.

This was probably the most entertaining group activity we had all semester because of the fun nature and at this point we all knew each other quite well. Obviously, there are some small areas to improve on to make the reproducibility higher. The first being the height and the velocity the sponge was thrown.

This could not be repeated precisely, but we strived to achieve very similar variables from one take to the next. We were also somewhat limited by time and technology as the videos took a substantial amount of time to buffer and be transcoded to be taken of the camera as a whole. By the end of the day we were not only fighting the technology, but also lighting as the sun began to set.

I think this particular video could be improved upon had the sponge not covered up the face as it impacted. At the very instant the sponge contacts the face you can see a slight ripple in the skin before the sponge blocks this viewpoint. Perhaps there is a way to have the sponge come off the other side of the head. There are also several videos on the internet showing this same phenomena with a slap to the face. This clearly shows the fluid-like motion of the skin without impairing any point of view.

In conclusion, I've really enjoyed diving into this topic as I've learned a lot about fluid motion within the human body. I really enjoyed learned about the viscoelastic nature of skin and all the strains and stressed it can withstand. It is truly amazing how much force and stress our skin, let alone the rest of our body, can withstand. This was a very educational experience that I will not take for granted.

Sources Used:

[1] "Skin Hardness & Elasticity Measurement Device." University of Michigan, 15 Dec. 2010. Web. 13 Dec. 2015. http://deepblue.lib.umich.edu/bitstream/handle/2027.42/86244/ME450%20Fall2010%20Final%20Report%20-%20Project%2017%20-%20Skin%20Hardness%20and%20Elasticity%20Measurement.pdf.

[2] Silver, Frederick, Joseph Freeman, and Dale DeVore. "Viscoelastic Properties of Human Skin and Processed Dermis." Rutgers University, 27 July 2000. Web. 13 Dec. 2015. http://www.rci.rutgers.edu/~motrlab/Publications/viscoelastic_prop_skin_(Skin%20Res%20Tech).pdf.

[3] Chen, Irene. "A Biomechanical Properties Overview of Skin & Muscle Tissue." Web. 13 Dec. 2015. http://www.meyersgroup.ucsd.edu/literature_reviews/2010/Literature%20Review_Chen.pdf.

[4] "Physics of a Slap to the Face." *Physics of a Slap to the Face*. Croom Physics Wiki, 7 June 2015. Web. 13 Dec. 2015. http://wiki.croomphysics.com/index.php?title=Physics_of_a_Slap_to_the_Face.

[5] "How Many Newtons of Force Would Kill a Person?" *Physics Forums*. Web. 13 Dec. 2015. https://www.physicsforums.com/threads/how-many-newtons-of-force-would-kill-a-person.296515/

[6] Wikipedia contributors. "Physics of firearms." *Wikipedia, The Free Encyclopedia*. Wikipedia, The Free Encyclopedia, 24 Jul. 2015. Web. 13 Dec. 2015. https://en.wikipedia.org/wiki/Physics_of_firearms.