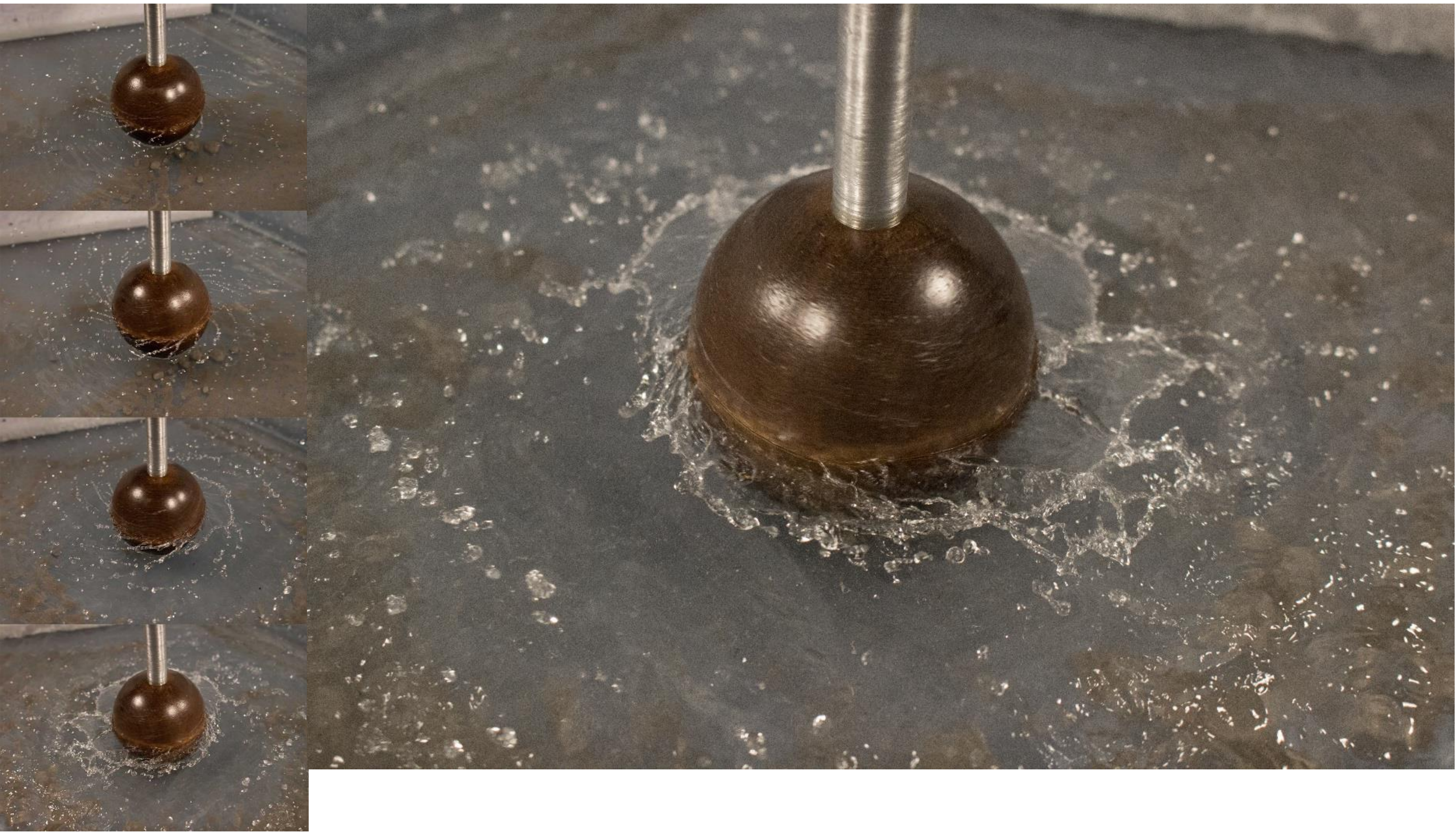
The Spinning Egg Experiment



By: Kenny Wine

This image is a recreation of the experiment Professor Tadd Truscott preformed in his *Eggs in Milk* experiment. Being fascinated with this unique type of pump while also being inspired by the visual effects occurring, Greg Lawson and myself decided to design our own spherical pump. The goal was to design something that was aesthetically pleasing while also enquiring on the phenomena at play. The initial intent of the image was to recreate the experiment and add a unique flavor to the piece. Recreating the experiment was simple, we ordered two, 2” spherical balls made of maple and obtained a 10” section of $\frac{1}{2}''$ aluminum rod. Two manufacture the part the ball was placed in a chuck on a lathe and drilled to size as to press fit the aluminum rod into place. Attempting to bring a uniqueness to the image we designed the sphere with two things in mind. First, we wanted to dye the flow being pumped up the sphere. Although this didn’t turned out as planned in the image there is confidence that this could be achieved in the future. The idea for the design was to create a system that would inject dye into the flow without being intrusive on the phenomena. To do this we decided to place a hole pattern on the bottom of the sphere that is connected to a reservoir in the aluminum

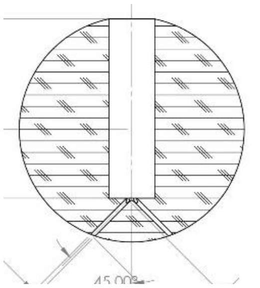


Figure 1

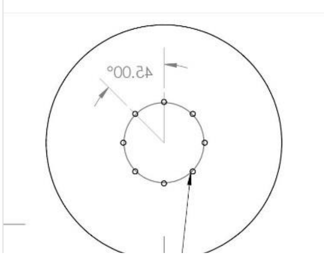


Figure 2

shaft. The goal was to allow a small amount of dye to enter the flow hopefully creating a visually inspiring image. This didn't work as planed because the group tried to use water as the fluid in the reservoir. With the small volume of the reservoir and the low viscosity of the fluid the liquid drained to quickly out of the sphere. To combat this, someone would need to determine a fluid that has the proper specifications in order to drain at the proper rate. This whole pattern was tricky to achieve, for the special geometry and the fact that the entrance to the holes are not normal to the surface of the sphere. The holes were drilled with a power drill while the sphere was held on a collet block while the holes were drilled. The other aesthetic decision was to stain the sphere with dark hard wood stain as to make the grains and the look of the sphere more interesting.

This series of images was created by connecting the spherical pump to a mill and on the saddle of the mill we placed a plastic container full of water. While spinning the sphere at 1200 RPM we began experimenting with plunging the sphere into the water at different depths. There is an interesting affect from the depth of plunge. Very similar to adjusting the rotational speed of the sphere or adjusting the size of the sphere the water begins to flow off the equator of the sphere in different manners. These image were taken at sphere depths of 0.1" to 0.7" at an incremental step of 0.2". This makes the sheet of water flow of the sphere in three distinct stages. First, one notices the flow is breaking apart into small droplets. This turns out to be visually intriguing because the flows projections appears to be following the pattern of the golden spiral or the Fibonacci sequence. Next, the flow is in a transitional phase from droplets into a sheet. This is the least visually gripping aspect of the transitional phases but is being caused by the difference in tangential velocities that is on the cusp of droplet and sheet flow. The last phase in the flow is the sheet of fluid flowing off the equator of the sphere. This occurs because the difference in tangential velocities is optimal for creating a volumetric flow rate large enough to for the fluid into a sheet having no separation.

Looking deeper into the phenomena it is necessary to explain the differentials in the tangential velocity of the sphere. The reason this is so important is because fluids obey the no slip condition. This means that layers of the fluid must be moving at the same velocity relative to one another to obey friction. With this in mind it was important to analyze the tangential velocity of the ball and with this the difference in velocities will be determined subtracting the velocity at the surface of the water from the velocity of the equator.

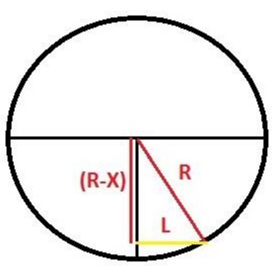


Figure 3

Starting with the Pythagoras theorem

$$R^2 = (R - X)^2 + L^2$$

Solving for the length of L will help determine the tangential velocity of the sphere at that point.

$$L = \sqrt{R^2 - (R - X)^2}$$

With this the tangential velocity is determined with,

$$V_{tangential} = R * \omega = L * \frac{RPM}{60\ s}$$

Calculated the tangential velocity at the different points using these two equation yields the velocities on the right.

Radial Length L	Tangent Velocity
0.19"	$8.72\frac{in}{s}$
0.71"	$14.3\frac{in}{s}$
0.87"	$17.3\frac{in}{s}$
0.95"	$19.1\frac{in}{s}$
1"	$20\frac{in}{s}$

Table 1

Now the goal is to determine if there is a correlation between the difference in the tangential velocities and the type of ejection away from the equator. Taking the difference as so,

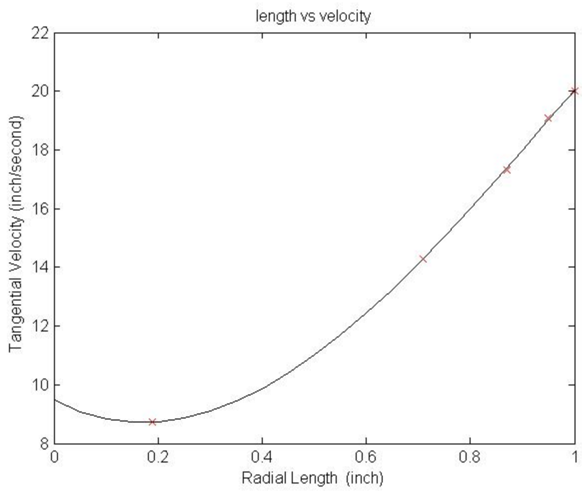
$$\Delta L_{radial} = L_1 - L_2$$

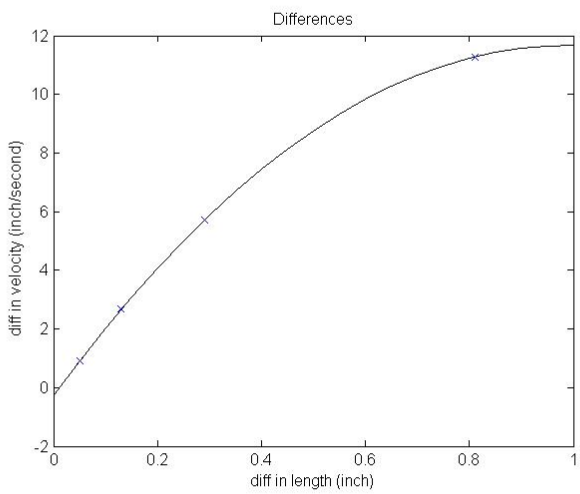
$$\Delta V_{tangential} = V_{\tan_{L_1}} - V_{\tan_{L_2}}$$

ΔL	ΔV
0.81"	$11.28\frac{in}{s}$
0.29"	$5.7\frac{in}{s}$
0.13"	$2.7\frac{in}{s}$
0.05"	$0.9\frac{in}{s}$

Table 2

Plotting the length vs. velocity and the differences above:





According to this information it appears that the smaller the difference in the tangential velocities the more likely the fluid flowing off the equator of the sphere will be a sheet. This is because the fluid is able to stay in contact with the ball and the other molecules for its not being spread so thinly over the sphere. This being said, it would be very interesting to investigate this phenomena further and attempt to create a pump that could be applicable to many industries in fluid processing and separations.

As far as the photography in the image the camera used was a Canon EOS Rebel T31 and the lens on the camera was a 18-55mm lens. For this particular set of photos the focal length was at 33mm. The aperture was set to f/ 5.6, the shutter speed was 1/4000 sec and the ISO was set to 3200 attempting to get more light in the image correcting for the extremely fast shutter speed.

This project was very satisfying and it would be very interesting to explore this further and see other students attempt to recreate this image with the use of the flow dye system. It would be interesting to see how the fluid mixes as it travels up the sphere. The phenomena Professor Truscott displayed as the potential to be applied to many industries and could potentially make processes more efficient collecting wasted fluids.