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MCEN 4228 Flow Vis

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For this assignment I made a video of the flow phenomenon called the Kaye effect, which involves pouring a stream of shear thinning fluid onto a flat surface, resulting in a streamer ejecting back up from the surface. I accidentally found this effect when I was searching on youtube.com for another video, and it really caught my eye. Part of the intrigue came from the fact that this flow effect was only discovered recently in 1963, and I was also drawn to the apparent simplicity of the effect. Because it could be reproduced with common household items and an easy technique, I wanted to give it a try for myself. The first attempts were made using the burst shot feature on my camera and taking continuous shots in hopes of catching a random jet in the photo. But on the rare occasion that this did work the image would be blurry and with high shutter speeds there was not enough light to make the effect obvious. I decided a video would be the next best approach, and the imaging and the effect's impact were much better.

I originally tried to capture this flow on a horizontal plane without much luck, so I moved to the sloped surface depicted in the setup drawing below. The slant helped facilitate the flow of the excess hand soap away from the pileup point where the falling soap stream hit the dish, and this thin layer of soap is pivotal to the success of the effect. At the beginning, the slanted surface controlled the jet direction from the pileup and it resulted in a stable Kaye effect. When this happens the soap stream appears to be bouncing down the surface of the dish. However, as I moved the position of the falling soap it struck the pileup at different incident angles and resulted in the random jets shooting out. As I mentioned before, the reason for this phenomenon is the shear thinning property of the fluid. This means that as the shear force rate on the fluid increases, the viscosity will decrease. This is important in the final result of the effect. The first step when pouring the fluid is the normal curling buildup that one observes when any viscous fluid is poured on itself. After the piled soap structure grows high enough gravity takes place and the incoming stream "slips" down the side. Because of the shear thinning properties and the localized shear stress concentration on the side of this mound, the viscosity decreases and the incoming soap tends this way. There is no transfer of mass anymore from the incoming stream to the original pileup, so the mound sinks into itself and starts to flow down the Pyrex dish. When the mound achieves a "favorable geometry," the force of the incoming stream will create a dimple in the soap layer and will be redirected away from the dish like a ski jump (Versluis). If the stream of incoming soap didn't move, this stable Kaye effect would continue on down the dish. But the later part of the video shows the impact location moving and dimples forming in different places, resulting in an unstable jetting effect.

Calculating a Reynolds number for this flow would be a tricky endeavor because of the soap's shear thinning properties. As the viscosity changed there would be a time varying Re for the flow. So I chose to calculate the Reynolds number of the poured stream, right before it makes contact with the mound. We know that $Re = \frac{\rho V L}{\mu}$, $\rho = 1030$ kg/m^3, and $\mu = 2$ kg/m*s (Pioneer Eclipse). Assuming an effective length of 30 cm, about how high the bottle was from the dish, and a velocity of about 0.3 m/s (based on the height of the bottle and how long it took the soap to reach the dish), we can calculate the Reynolds number, and it comes out to be 46.35. This is a fairly low Re, which implies a laminar flow.

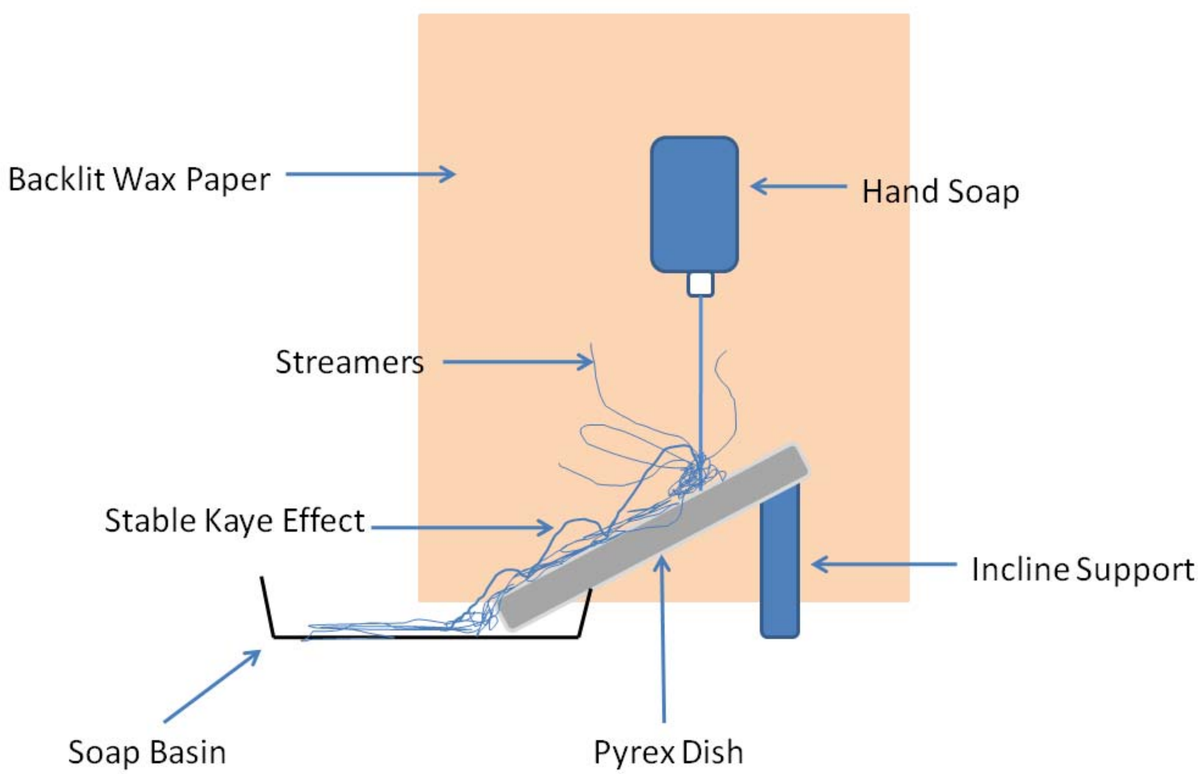
This makes sense because this soap is a fairly viscous fluid and it's not moving too fast between the bottle and the dish.

The key to the visualization of this effect was the lighting. The soap is a colorless hand soap from Target and was hard to bring out without a good backlight source. To make a light that wouldn't be overpowering I taped a piece of wax paper to the edge of the table that the setup was next to and had a couple lamps under the table behind the wax paper. This softer glow in the background brought out the shadows in the soap curls and really gave it all good definition.

The field of view for this video was only about 10 cm wide with the lens 8 cm away because I wanted to get a nice close shot of the effect. My camera is a Sony Cyber Shot H20 and I chose to use the fine 720p (1280 x 720 pixels) video setting with 9 Mbps. Overall I think it turned out nicely and fairly focused with great quality.

I believe this video is a good representation of the Kaye effect and all the different facets it can display. The up close aspect of the video was good and very revealing, but it did limit the view of the height of the streamers. One major improvement I would make to this would be to include some shots of the effect occurring on a horizontal surface, because that is another important part of the effect that is helpful for understanding it. It shows well the evolution of the streamers and portrays their development in a more obvious way. I tried somewhat to achieve this at first, but it didn't have near as good the results as the inclined Pyrex dish trial. If I had more time and a more precise way of pouring the soap, I would have definitely included that angle in the video. I am very pleased with the final video, however, and I think it encompasses the fluid phenomenon called the Kaye effect.

Experiment Setup



References

"Starshine Antimicrobial Hand Soap." Pioneer Eclipse. 2003. **Error! Hyperlink reference not valid.**

Versluis, Michel. "Leaping Shampoo and the Stable Kaye Effect." Physics of Fluids, Faculty of Science and Technology. 2005. http://arxiv.org/ftp/physics/papers/0603/0603183.pdf