Impinging Air Jet on Flour/Water Mixture

Flow Visualization

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For the third and final group project we conducted an experiment to attempt to visualize the air flow out of a device called an air knife. The idea for this experiment came about because Josh was using this device in his senior design project and was interested what the fluid profile would look like. Initially we wanted to visualize the phenomenon by using smoke generated from a stage fog machine but due to time limitations we were not able to attempt this. After some research we discovered a method for visualizing impinging jets by viewing the profile they created on a fluid layer. We used a mixture of flour and water as our fluid. The reason for this was that we could adjust the viscosity of the fluid to suit our needs. We wanted a fluid that was viscous enough to allow for a good visualization without being completely dispersed.

Three 4" air knives were attached to a parabolic arm, as seen in figure 1, and held over the flour/water mixture allow the air jet to disturb the fluid and create a visualization describing the phenomenon. The air knife set up is shown below. Since the air knives are straight but attached to a parabolic arm there are dead spots where there is no airflow as seen in figure 2.

Figure 1 – Parabolic arm with air knives attached

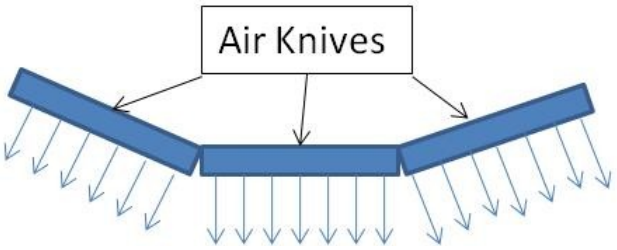


Figure 2 – Air flow from air knives

The field of view of the images created is slightly over a foot long and about four inches wide. The reason for it being slightly longer than a foot is that is the fluid expands along the ground when the air jet is impinging on it.

A Reynolds number calculation was conducted to determine if the flow was laminar or turbulent. The velocity of the air exiting the air knives was determined to be 4500 ft/min at 55 psi. This was determined by using a Kestrel 1000 pocket wind meter. The Reynolds number calculations are shown below assuming the air knives were held two inches above the fluid. The value of kinematic viscosity for air was taken at 70 ^{0}F.

Convert velocity from ft/min to ft/s

$$\left(4500\frac{ft}{\min}\right) * \left(\frac{1min}{60s}\right) = 75\ ft/s$$

Reynolds number calculation:

$$Re = \frac{u * x}{\vartheta} = \frac{75 * 2}{1.64 * 10^{-4}} = 914634$$

A Reynolds number on the order of 10^9 is very large and confirms our belief that the flow is indeed turbulent.

In order to clearly visualize and capture the shearing effects of the fluid due to the impinging jet the correct mixture of the fluid was necessary. The fluid mixture consisted of flour and water. A mixture consisting of too much water would not be viscous enough, while a mixture with too much flour would be too viscous. The mixture used consisted of 3 parts flour and 2 parts water. This created a fluid that was not overly viscous in that it reacted and sheared due to the forces of the impinging jet, but was viscous enough that the shearing due to the forces could be clearly observed. The forces applied to the fluid to cause the shearing effect was done by using an 'Airblade,' which was obtained from Josh Stockwell's senior design project (Figure 1). The Airblade created the effect of an impinging jet on the fluid and it was applied in various directions and orientations to the fluid surface in order to change the direction the forces were applied. The fluid was laid down on top of a cardboard surface. The

experiment was conducted in the University of Colorado at Boulder's ITLL. The overhead lighting of the ITLL provided the lighting for the experiment, which was approximately 8 ½ ft. above the fluid. No flash was used to take these images.

Levey's Image

The image was captured using a Canon Powershot SX 200 IS. The size of the field of view is approximately 3.5 inches wide and 2 inches tall. The distance from the fluid to the lens was approximately 3 inches. From the camera data given in Photoshop, the focal length of this photograph was 5 mm, an aperture value of f/3.3 was used, 1/25 sec shutter speed, ISO speed rating of 80, and no flash was utilized. For the final image, the pixel dimensions were 3844 in the X direction and 2214 in the Y direction. The final image was manipulated in Photoshop by cropping the original photo, using the RGB Curves adjustment tool to increase the shadows in the picture and adjust the lighting to how I desired, adding a Gradient Map layer, adjusting the Brightness value to +16, and adjusting the shadow tones of the Color Balance layer.

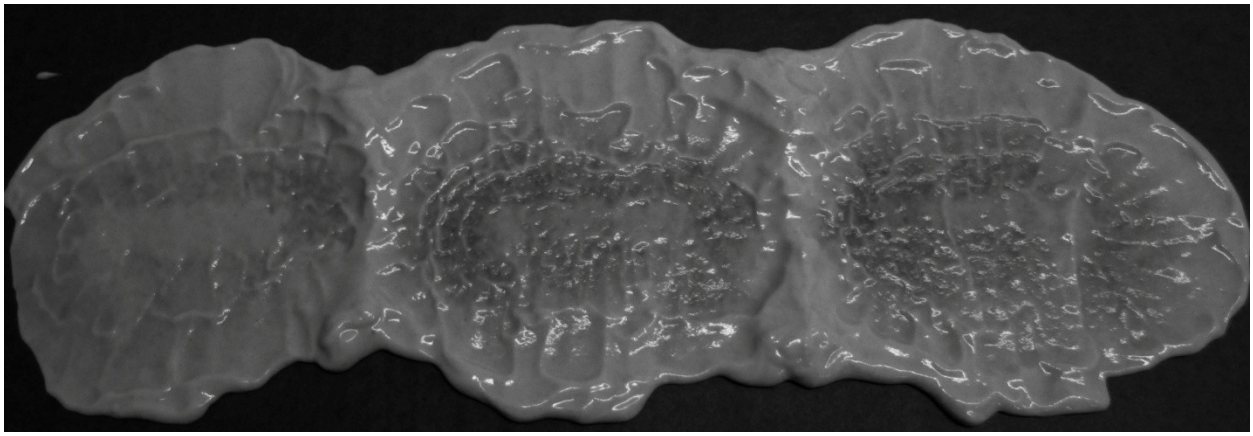
This image reveals a colorful vision of the shearing of a slightly viscous fluid. From this image, the viewer can see different layers of fluid that are formed by the impinging air jet. I like how the image is extremely colorful, bright, and catches the viewer's eyes. The image editing makes the fluid look like flowing magma, which also experiences fluid shear. What I dislike about this photograph is the lack of shadow resolution. I should have edited it in a way were the shadows of the sheared fluid stand out much more, though this may cause the image to lose its magma like quality. I also dislike how the image doesn't incorporate any visualization of the impinging air jet from the Airblade.

Josh's Image

My image was taken using a Canon PowerShot SX 200 IS. The field of view was chosen to capture the entire fluid are and show how it was being distorted by the impinging air jet. The physical size was approximately 1.3 feet by 4 inches. The camera was held four feet above the subject in order to capture it in its entirety. The focal length when the image was taken was 5 mm, with an aperture value of f/3.3 and an f-stop of f/3.4. The shutter speed was 1/15 of a

second with an ISO of 80. No flash was used. The original image was 4000 x 3000 pixels with a resolution of 180 pixels/in. The final image was cropped down to 4000 x 1374 pixels with the same resolution.

In Photoshop I initially cropped the image to just show the distorted fluid layer. I cropped out just a bunch of empty cardboard that had no effect on the image. The colors were rather uninteresting so I changed it to black and white to focus more on the physics of the image. I then used the curves tool to darken the image quite a bit in order to bring out more definition. Lastly the brightness/contrast tool was used and I set brightness to 20 and contrast to 60. This helped brighten up the image just a little bit while increasing and the contrast and definition in the image. The initial and final images are shown below for comparison.



The image displays the effects of shearing in a thin fluid layer caused by an impinging air jet. I like how the dead spots in the airflow created three separate regions and how you can tell that due to the parabolic shape of the arm the air knife on the left was farther away from the fluid surface and that is why there is less definition in that region. I think that the alterations made in Photoshop made this image much more compelling and dramatic, and that they also helped bring out a lot of the detail in the image. I had an image from a second air knife setup that used three parabolic air knives so that there were no gaps. I wanted to display that image below this one to display the differences but couldn't get them to be visually pleasing. I would love to be able to pursue my initial idea of visualizing this flow with smoke at some point as I believe it would lead to a drastically different, and much more compelling visualization.