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Team #2 Photo - MCEN 5151
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The fourth project of the Flow Visualization class was to develop for the second time an image working with a team. As in the last team assignment, the goal was to provide a more complicated flow visualization image by collaborating with team members on ideas and setup of flows, but unfortunately with severe schedule conflicts the team was not able to get a consensus. So I went along with my idea to capture an image of a Kelvin-Helmholtz as seen in Figure 1.

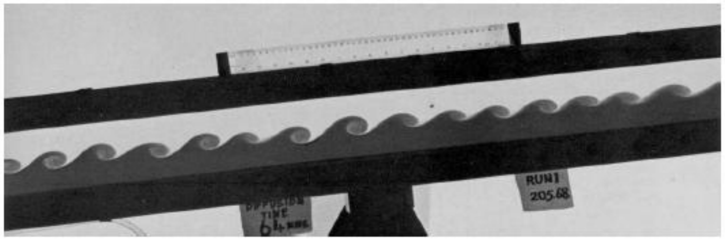

Figure 1: Kelvin-Helmholtz instability experiment[1]

The setup for the image was simple, but creating the apparatus was not. The apparatus was essentially a channel that was 36 inches long, 1.5 inches wide and 12 inches tall (Figure 2). Wood was used to build the frame, and acrylic was used on the sides to keep in the fluid. Water with green dye and vegetable oil were used as the fluids. The channel was placed on a kitchen table, and a white board was held behind it during the video recording. A fluorescent drop light provided additional lighting. At first I tried rocking the channel in order to create the stability, but it did not occur. I changed the frequency of lifting each side by roughly every two seconds to one, and that also did not produce the instabilities. Eventually I resorted to using a kitchen spatula to create movement in the top fluid to create the instability (Figure 3). Then I was able to capture the instabilities that resemble the Kelvin-Helmholtz instability. Later on I discovered that a rocking motion is not how the instability is created, but leaning it one way and holding it will create the instability.

Figure 2: Channel apparatus

The Kelvin-Helmholtz instability is instability at the interface between two horizontal parallel fluid streams with different velocities and densities.[2] It is caused by the destabilizing effect of shear, which overcomes the stabilizing effects of stratification.[2] Probably the most accessible example of Kelvin-Helmholtz instability in nature is the existence of surface gravity waves.[3] Surface tension is an important but not dominant damper on instability at the smallest scales.[3]

By disturbing the top layer, or making it move at a faster velocity than the bottom, Kelvin-Helmholtz instability was created. The specific gravity of vegetable oil is 0.92, making the oil lay on top of the green-dyed water. The estimated velocity of the oil is one foot per second since that is how fast the spatula pushed the oil, and the length scale is 3 feet since that is how far the fluid travelled. The kinematic viscosity of vegetable oil is $4.65 x 10^{-4}$ $feet^2$ per second. Plugging these values into the Reynolds equation gives the following:

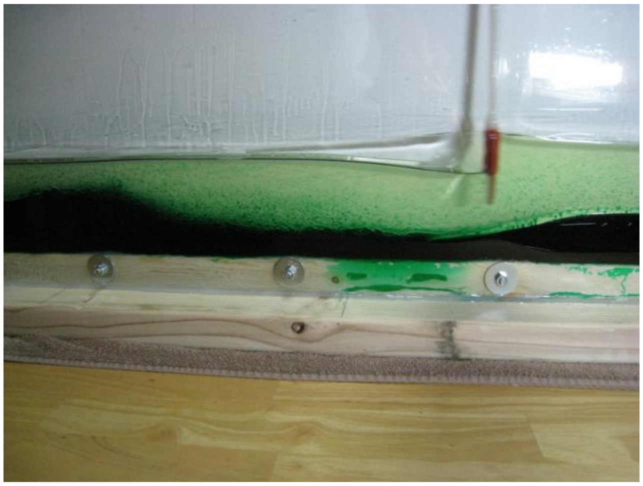

Figure 3: Spatula disturbing the upper layer of fluid

$$Re = \frac{UL}{\upsilon} = \frac{\left(1\frac{ft}{s}\right)(3\,ft)}{4.65\;x\;10^{-4}\;ft^2/s} = 6452$$

This puts the flow of oil in the laminar regime which is not surprising since it has a higher viscosity when compared to water and the velocity is not large.

The size of the field of view is approximately two feet square. The camera used to record video was a Canon *PowerShot* SD1100 IS, and the video was taken at 30 frames per second. Three videos were taken, each video shows two disturbances that create or almost create the instability. The three videos were combined and modified using Windows Live Movie Maker program. The best two out of six instabilities were kept and put together in one video. The original video resolution was 640 pixels wide and 480 pixels high, but Windows Live Movie Maker increased the resolution to 1440 pixels wide and 1080 pixels high. The colors and contrast were not changed.

Figure 4: Kelvin-Helmholtz instability in the channel

At first I did not like the initial results because I was not able to capture an image or did not see an image on the video, but when I slowed down the video, it was clear that a Kelvin-Helmholtz instability was produced (Figure 4). I did fulfill my intent by capturing a Kelvin-Helmholtz instability, but there are many improvements that can be made for a better quality video and image. First I would use a good quality high-speed camera. Secondly, I would try to use two fluids that contrast better. Thirdly, I would make the channel smaller, using thinner layers and less fluid. And lastly I would tilt the channel to roughly thirty degrees and hold it to see if instability occurs. Overall, I am pleased with the outcome.

References

[1] http://www.ifh.uni-karlsruhe.de/lehre/envflu_II/Students/ocen689ch11.pdf.

[2] Kundu, P. K, Cohen, I. M. and Dowling, D. R. Fluid Mechanics: Fifth Edition. 2012. Page 477-480.

[3] Gramer, Lew. "Kelvin-Helmholtz Instability", April 27, 2007: http://www.rsmas.miami.edu/users/isavelyev/GFD-2/KH-I.pdf.