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Group Project 3
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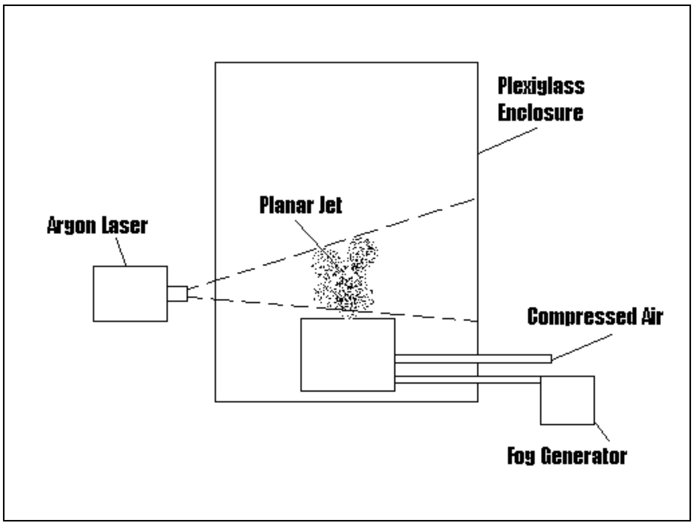
For the third group project, the planar jet was opened to groups to use, so our group decided to use it because of the possibility of capturing some images that have not been possible at other points in the course. Normally this experimental setup is used to view (and sometimes induce) oscillations and instabilities in planar jet flow. While experimenting with different flow rates, we observed some quite beautiful flows at extremely low flow rates, and I have decided to submit a series of photos (to be viewed as a video clip) from this series of photos at the low flow rate.

The flow apparatus used for this image is the planar jet in Professor Hertzberg's lab. The substance that shows up green in the image is stage fog flowing from a 2.5mm wide opening excited by an Argon Ion sheet laser beam. (The laser beam effectively sections our view of the flow at whichever point we would like along the 400 mm 'depth' of the jet). This whole setup (with the exception of the laser) sits within a large plexiglass box so that ambient air currents do not disturb the flow. See figure below for clarification.



For the given setup we can estimate Reynolds numbers using the following equation:

$$Re=U_oL/\nu$$

Where Uo is the free stream velocity emerging from the jet, L is the distance from the jet, and ν is the kinematic viscosity. The total cross sectional area of the jet is 1000 mm2 (2.5 mm wide by 400 mm long). We measured the flow rate from the jet to be 1.5 L/min, which then corresponds to a Uo of 2.5 mm/sec. The top of the flow at the end of the clip is approximately 150 mm (6 in.) from the nozzle outlet, and thus corresponds to a Reynolds number of 25. With this experimental setup, the critical Reynolds number that marks the transition from laminar to turbulent flow is far above this value and thus we have completely laminar flow. This is due in large part to the low flow velocity.

Because of the completely laminar flow, we can see the effects that the vortices (the two spiral patterns near the beginning of the clip) have on the overall movement of the flow. The plume is symmetrical, however small unpredictable differences in the vorticity between the right and left sides cause the overall flow to curl in a counterclockwise fashion. Near the end of the clip we even see a third vortex enter the flow. This new vortex is rotating in a clockwise fashion, but breaks off of the main left-side counterclockwise vortex and traverses through the path of where the plume just exited the jet, entraining later elements of the flow with it.

The visualization technique used here is a seeded flow. It is the stage fog particles that reflect the Argon laser light, allowing us to see a cross section of the flow. No flash was used in this technique because any flash would have distorted or washed out any of the information transmitted to the camera by the laser light, so even though this is not technically a fluorescence or flame type of imaging situation, it must be treated like one in order to get a good photograph. In order to accomplish this, all of the lights were turned out in the lab so that only the green laser light from the flow was visible.

This was a very tricky lighting situation to properly expose an image with the camera. We took about 250 photographs on a Friday afternoon, and about 125 of them were needed just to find adequate camera settings. The field of view seen in the images is approximately 150 mm tall by about 230 mm wide. The camera was approximately 300 mm from the flow and had a lens focal length of 55 mm. The ISO speed was set at 400 with an aperture of F/25 and a 1/20 second shutter speed. There is no real rhyme or reason for these settings, but after much of the trial and error mentioned above, they just worked so we left them alone. Every image in the clip has these same exposure and lens settings, yet we can still see a lot of overexposure in a few of the photographs. I'm not sure why this is, but I did not change the photographs at all in Photoshop because I found that every attempt I made at changing color curves, contrast, or brightness just distorted and lost information at the edges of the flow. I simply put the raw images into a video editing program and rendered a very fast slideshow (approximately ¼ second per photo) as a video. However, had I had one single image as opposed to a fast sequence of photos, I probably would have worked a lot more with the color curves, as those showed the best promise in cleaning up the images.

Overall, I liked working with the laser and planar jet a whole lot. There are so many different images that you can make with them, that we did not even skim the surface of most of these in one afternoon. These slow moving flows were amazing just to sit and watch. I was sort of disappointed at certain times that I was the guy behind the camera because the view was much more intense and detailed when viewed with the naked eye. If I were given more time to do imaging with this setup, I would like to try to image the instabilities that develop at higher flow rates. I would also be interested in making a video of the slower flow rates like the one shown here, however this requires much more setup because you need to synchronize the timing of the laser pulses with the frame-rate of your video device. Overall, it was a great experience.

References:

- www.efunda.com
- T. Peacock, E. Bradley, J Hertzberg, Y.C. Lee. Forcing a Planar Jet Flow using MEMS. *Experiments in Fluids 37 (2004)*
- en.wikipedia.org