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Flow Visualization
Group Project 3

This report outlines the failed attempts of our group to produce a valuable image for the course Flow Visualization at the University of Colorado, taught by Professors Hertzberg and Sweetman. The objective for this project was to correlate color to shear rate in the rheoscopic "Blackstock Fluid." When dealing with Blackstock fluid, if one linearly polarizes the light source and orthogonally polarizes their viewing window, the fluid will exhibit varying color based on the amount of shear it experiences. We were hoping to create highly controlled, fully developed channel flow, the characteristics of which are very well understood and documented, and apply that understanding to equate color with shear rate. Because Blackstock fluid is experimental and proprietary, the color to shear rate correlation has not been either described or studied. An accurate determination of this relationship would be extremely valuable for understanding the underlying mechanics at play in flow visualization.

In order to study this correlation, we machined a $1/8^{th}$ inch wide by $1/8^{th}$ deep channel in a plastic sheet, and using plastic tubing and syringes created a syringe pump in an instron load frame. By using the instron to compress the plunger of a syringe, an extremely precise volume driven flow rate can be established. The channel was covered on top by another sheet of plastic. The first difficulty we encountered was in sealing the machined channel sheet to the top cover sheet. Initially we expected that liberal application of silicon grease would provide an adequate seal since we were not expecting very high pressures. As it turned out, the silicon did not initially seal properly, and fluid escaped the channel. Acetone was then used to "weld" the two layers together. Acetone is effective at this, but the working time is relatively brief, so we were not able to get careful application along the whole channel before the bonding period had passed. After that, we reverted back to the silicon grease, and used a large number of clamps to create an effective seal.

The next major issue is with the plastic we used and how it affected the polarization of the light. We had acquired a large sheet of linearly polarized lighting filter. To test the effectiveness, we cut two small squares and turned them 90 degrees to each other to observe that they blocked all light. This worked, however when we performed the same test with the plastic sheet in between, light was not blocked. This really confused us as we did not know that plastic has a polarizing effect. This effect did not occur when a piece of glass was inserted between the layers. We also observed that not all camera polarizing filters work in the sense that they will block light when turned against each other. I strongly recommend the use of polarized sheet films because of the ease with which they can be indexed orthogonally to each other.

Despite many efforts to perfect lighting conditions, the flow in the channel was extremely difficult to see. In the interest of fully developed flow we wanted to have a small cross section channel so that it would not need to be as long. This small cross section presented difficulties in that bright lighting would completely wash out any detail in the flow, and low light would cause technical difficulties in exposing the photos. I think that for our setup, the thickness of the fluid was just too thin to really see good

results. In addition to these lighting difficulties, better care should be taken to ensure that the only light in the shooting area is from the polarized source. I think our working area may have been experiencing contamination from non-polarized light, ruining the characteristics of the Blackstock fluid.

While our attempts to document this flow setup were not successful, I think that we made some progress and can offer some recommendations to future groups who want to continue this work. First, the visualization will never work unless the medium of the channel does not affect the polarization of the light. Glass works, but is not reasonable to machine. There may be some plastics that work, it will simply require some research. A good option would be a long glass tube to act as the flow channel. There will need to be some experimentation with cross sectional area of the flow channel in order to have sufficient fluid thickness that the flow can be easily observed and lit without loss of detail. If machined slots are to be pursued, sealing of the channel with silicon grease worked pretty well once we realized that it needed to be clamped strongly. I would also recommend taking precautions to be absolutely sure that no outside light enters the work space, and that no light from the source leaks past the polarizing sheet unpolarized. By following these setup and experimentation recommendations, I am confident that a future group can achieve valuable results.