Manotech Lab #2

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Flow Rate Experiment:

1. Sample calculations:
   a. Experimental flow rate
   $$Q = \frac{V}{t} = \frac{5.20\ mL}{60\ s} = 0.0867\ mL/s$$
   b. Experimental pressure
   $$\Delta P = \rho g h = 0.99777\ g/mL * 980\ cm/s^2 * 52.8\ cm = 51628.61\ dyne/cm^2$$
   c. Wall shear stress based on experimental flow rate
   $$\tau = \frac{12\mu Q}{2WH^2} = \frac{12 * 0.01\ g/cm{*}s * 0.0867\ mL/s}{2 * 0.0288\ cm * (0.0254\ cm)^2} = 279.97\ dyne/cm^2$$
   d. Wall shear stress based on experimental pressure
   $$\tau = \frac{H\Delta P}{2L} = \frac{0.0254\ cm * 51628.61\ dyne/cm^2}{2 * 2.48\ cm} = 264.39\ dyne/cm^2$$
   e. Pressure based on experimental flow rate
   $$\Delta P = \frac{12\mu L Q}{WH^3} = \frac{12 * 0.01\ g/cm{*}s * 2.48\ cm * 0.0867\ mL/s}{0.0288\ cm * (0.0254\ cm)^3} = 54671.20\ dyne/cm^2$$
   f. Flow rate based on experimental pressure
   $$Q = \frac{WH^3\Delta P}{12\mu L} = \frac{0.0288\ cm * (0.0254\ cm)^3 * 51628.61\ dyne/cm^2}{12 * 0.01\ g/cm{*}s * 2.48\ cm} = 0.0819\ mL/s$$

2. Insert a scatter plot of experimental flow rate vs. water column height below (Plot 1):

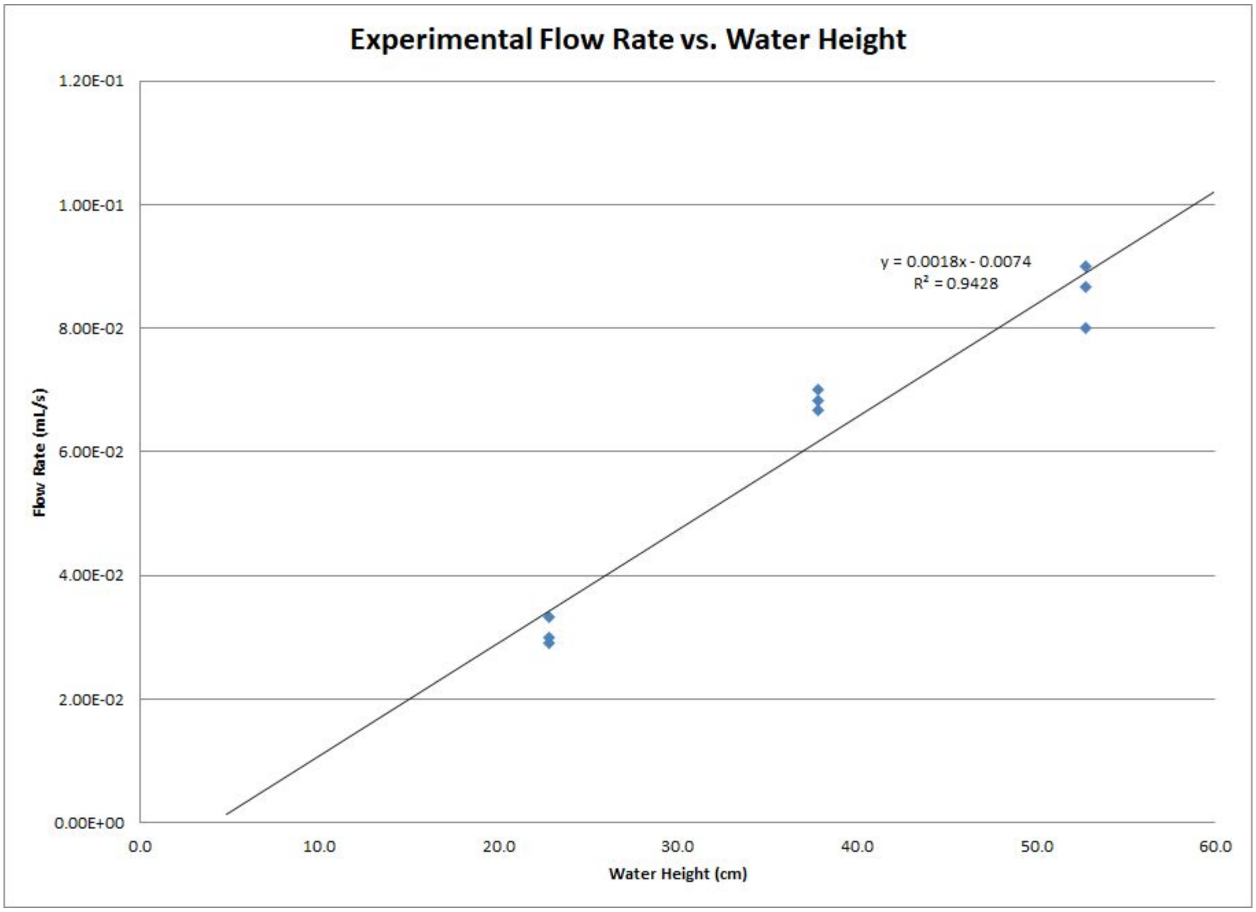

Figure 1: Effect of Water Column Height on Flow Rate.

Briefly describe the relationship between experimental flow rate and water column height:

As the water height of water increases, so does its flow rate. This is due to the acting force of gravity, where more elevated water columns apply more pressure on the system, increasing the flow rate of the water through the channel.

3. Insert a scatter plot of theoretical pressure (from your program using experimental flow rate) vs. water column height below (Plot 2):

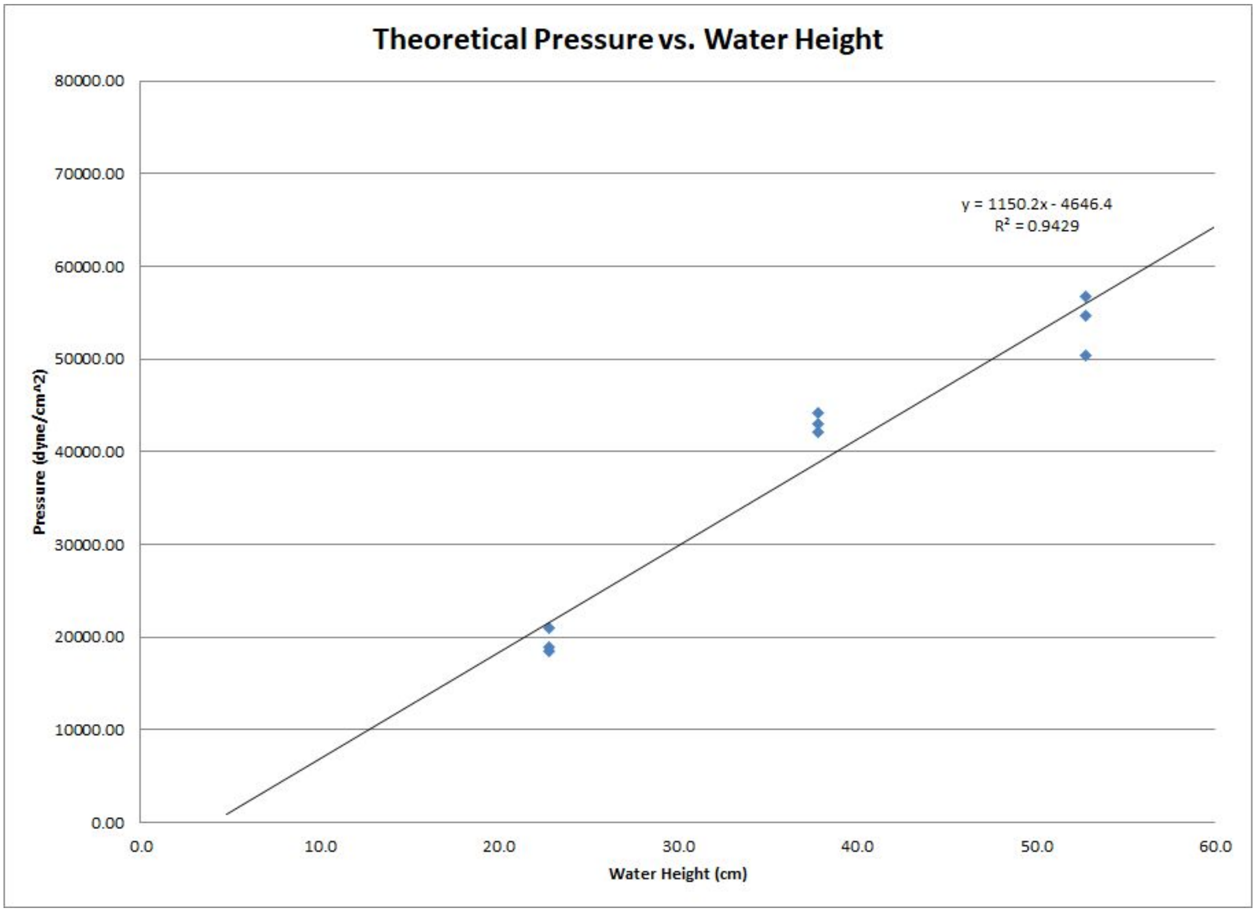

Figure 2: Effect of Water Height on Pressure.

Briefly describe the relationship between theoretical pressure and water column height:

As the height of the water increases, so does the pressure that it applies on the channel. Similar to flow rate, this can be explained by the force of gravity. As water column height increases, the weight of water pushing through the channel increases, which increases pressure.

4. Insert a scatter plot with both experimental flow rate vs. experimental pressure and theoretical flow rate (from your program using experimental pressure) vs. experimental pressure below (Plot 3):

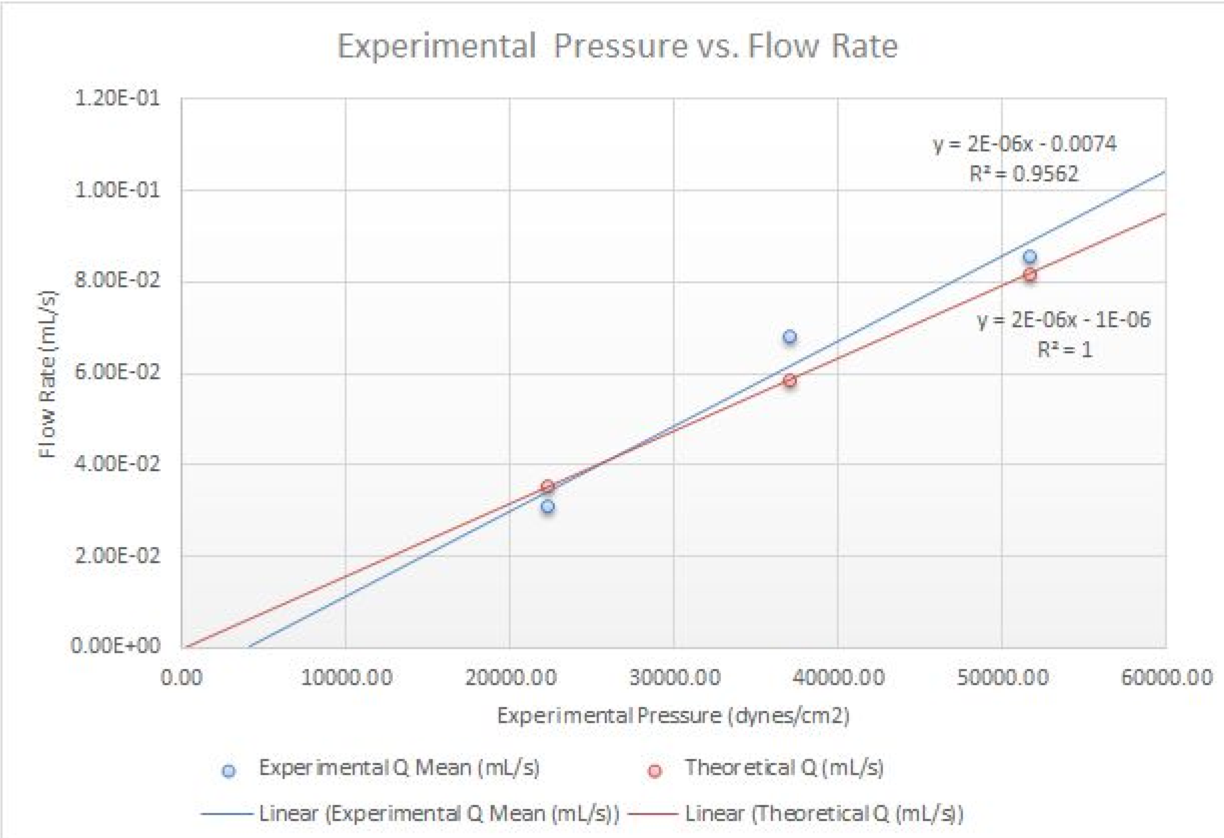

Figure 3: Scatter Plot of Flow Rate vs. Pressure.

Discuss reasons why experimental flow rate differs from theoretical flow rate. Consider the following aspects of our testing:

- Based on the assumptions of the fluid mechanics program, it should accurately describe the flow parameters of the standard chip.
- What assumptions were necessary to calculate the flow rate using your program? How good or bad are these assumptions when you consider the experiment?
- Were there any sources of error within the experiment that could account for differences in the theoretical and experimental flow rate?
- How could you improve upon either the experiment or program to address these differences? Is it feasible to adjust the assumptions of your program?

During the experiment the tips of the tubes inserted into the channel were not completely perpendicular. The inlet and outlet being at angles may have affected the fluid flow. This could be easily fixed to minimize this error by holding the inlet and outlet tips perpendicular to the chip. The fluid mechanics program also assumed the channel was perfectly rectangular which experimentally is impossible. The program also assumes that there is no fluid velocity in the x direction which may not be true. It is not feasible to adjust the assumptions made in the program because in order for it to become more accurate, the number of calculations and experimental data points needed would increase and make the calculations much more complex. It is also not possible for it to ever be completely accurate with the program because of errors during the experimental process.

Sensitivity Analysis:

5. Insert screen shots of your cut plots showing velocity contours below:

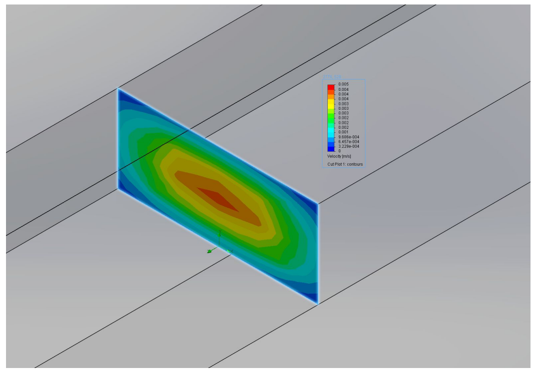

Figure 4: Velocity Cut Plot of Regular Height Channel

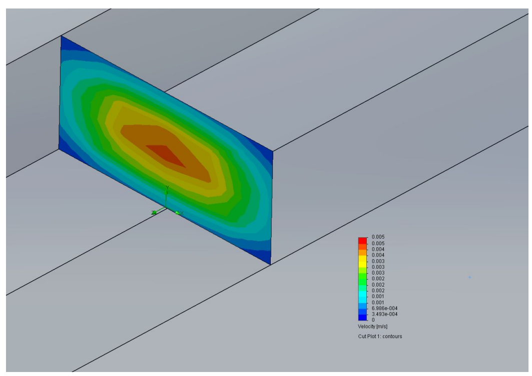

Figure 5: Velocity Cut Plot of +5% Channel Height

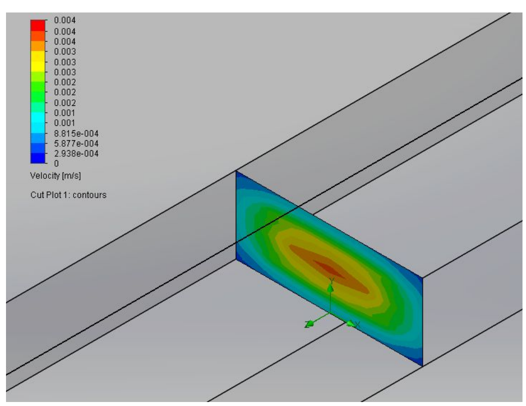

Figure 6: Velocity Cut Plot of -5% Channel Height

6. Insert a scatter plot of average and maximum velocity vs. channel height below:

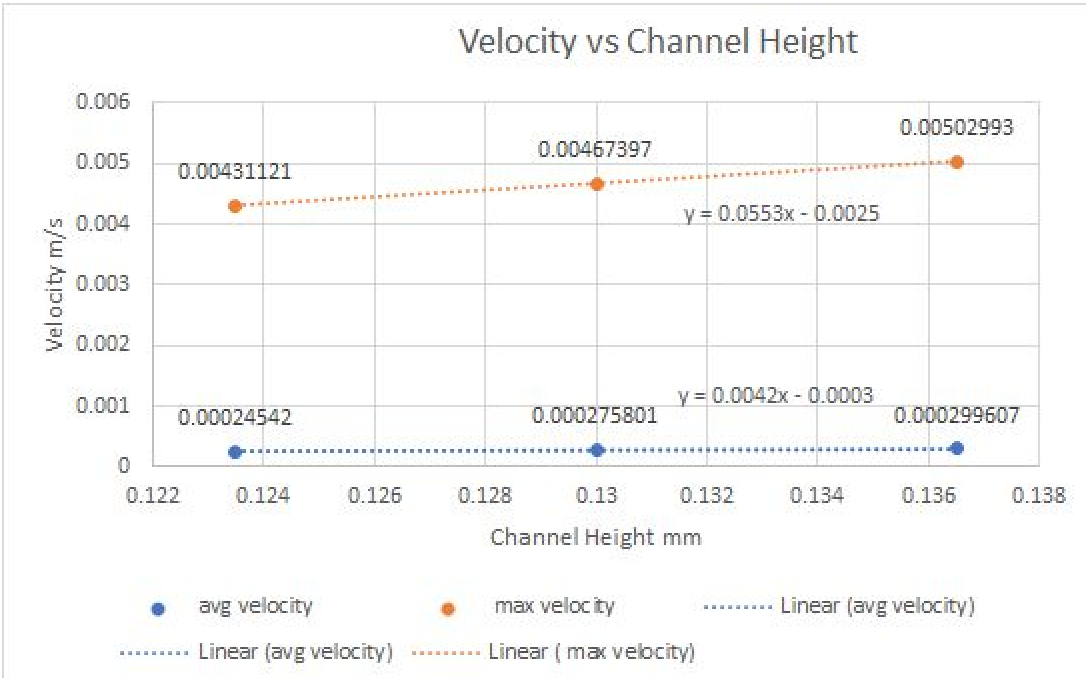

Figure 7: Scatter plot of Maximum Velocity vs. Channel Height

What trends do you see regarding the effect of channel height on velocity in the channel? Consider both the velocity contours and the channel velocities.

As the channel height increases the fluid velocity also increases. The maximum increases at a faster rate than the average shear stress, shown above by its larger slope of trendline.

7. Insert screen shots of your surface plots showing shear stress profile below:

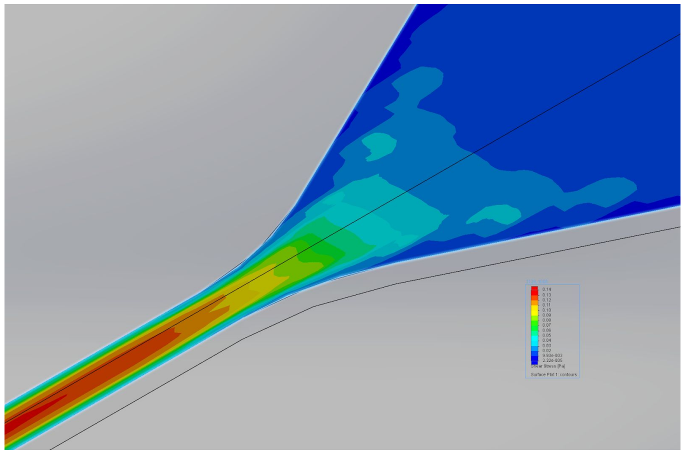

Figure 8: Shear Stress Surface Plot of Regular Channel Height

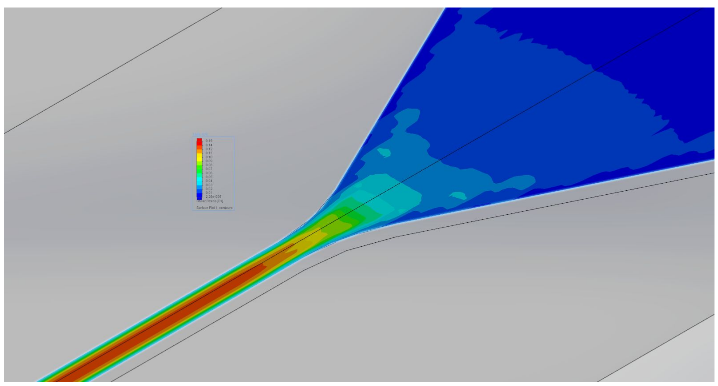

Figure 9: Shear Stress Surface Plot of Channel Height +5%

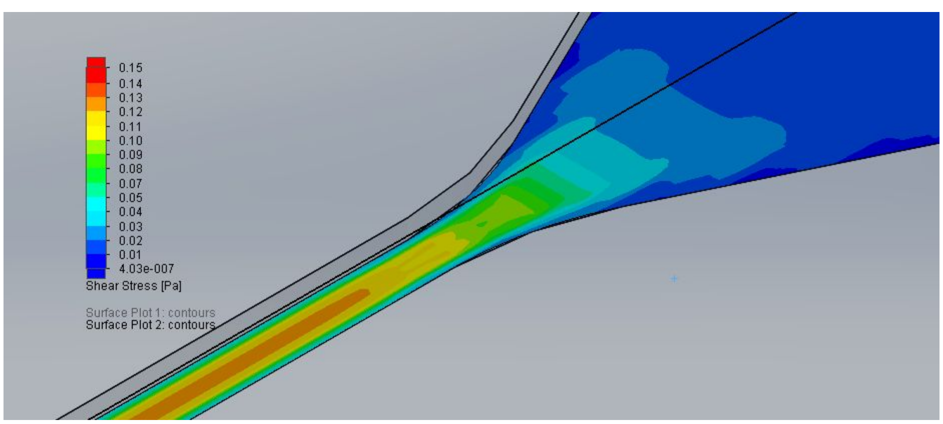

Figure 10: Shear Stress Surface Plot of -5% Channel Height

8. Insert a scatter plot of average and maximum shear stress vs. channel height below:

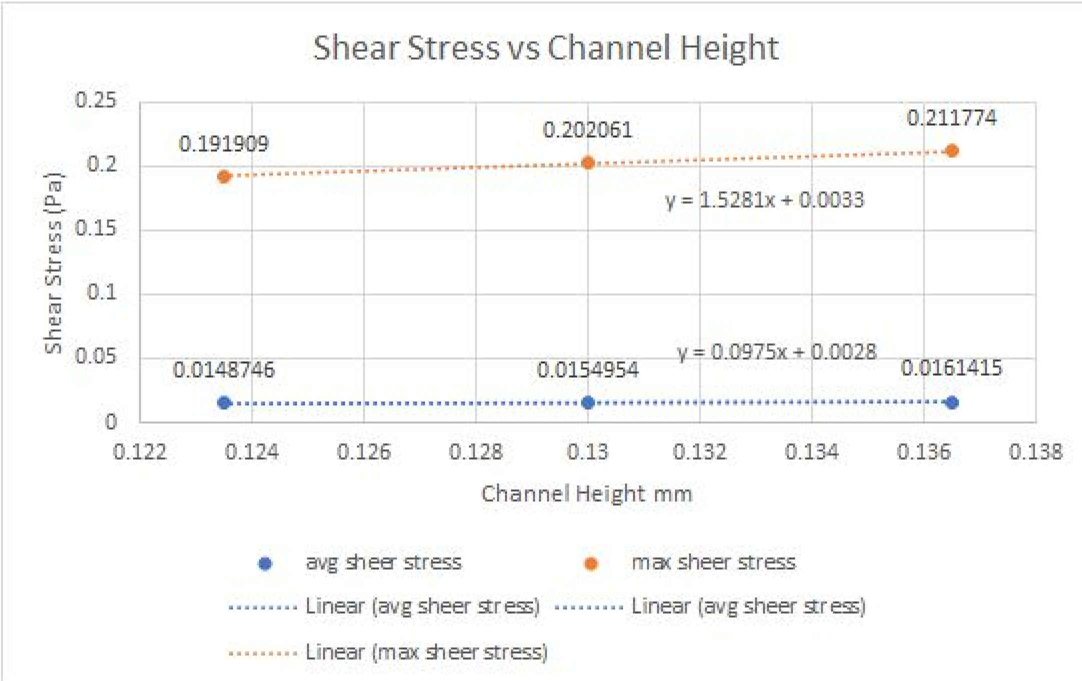

Figure 11: Scatter Plot of Shear Stress vs. Channel Height

What trends do you see regarding the effect of channel height on shear stress in the channel? Consider both the shear surface plots and the channel shear stress values.

The shear stress in the channel increases as the height of the channel increases. The maximum shear stress increased at a faster rate as a function of channel height compared to the average shear stress which increased very little.

9. Will the results of your sensitivity analysis affect your chip design or experimental procedure? Why or why not? If so, how will it affect your design? Use quantitative data to justify your decision.

Increasing channel height appeared to increase fluid velocity and shear stress. This is shown by the positive trendline slope on both velocity and shear stress vs channel height scatter plots. Varying channel height has an effect on fluid flow and could be a possible variable tested.

10. Below is a screen shot of a shear stress surface plot:

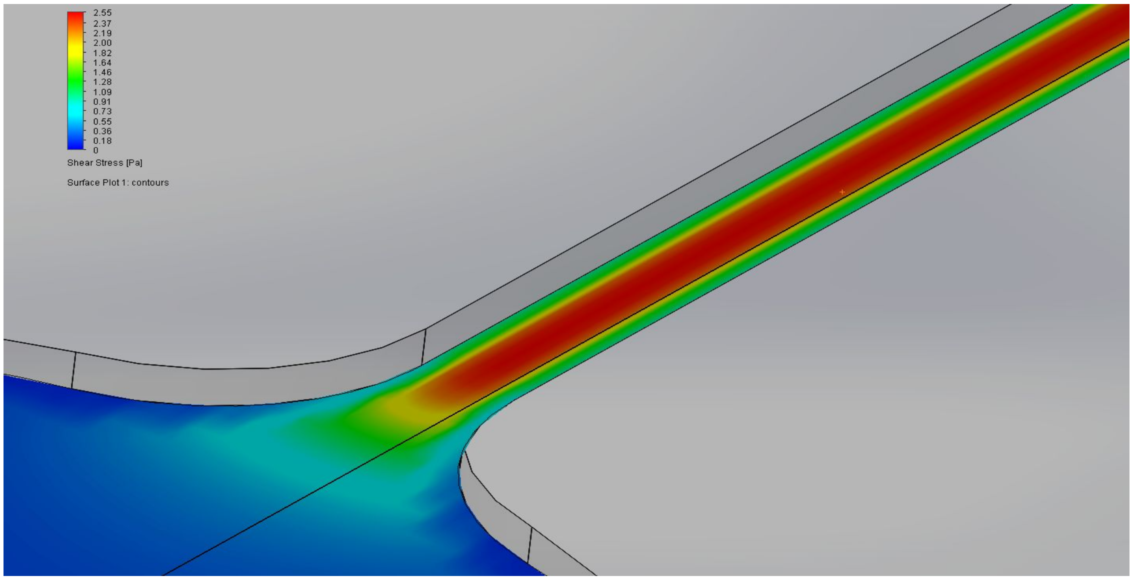

Figure 12: Shear stress surface plot.

Based on the assumptions of our fluid mechanics worksheets, the bottom of the channel should have a uniform shear stress across the width of the channel. It is apparent from this surface plot that this is not the case. Using the assumptions present in our shear stress derivation and in the SolidWorks flow simulation, explain why the shear stress is not uniform across the channel. (Hint: What did we assume regarding the x-dimension of our channel?)

When completing our fluid mechanics worksheets, we assumed the velocity in the x direction to be zero. In the surface plot above, shear stress is not uniform across the channel because Solidworks does not assume the fluid velocity in the x direction (across the width of the channel) to be zero. This causes a varying sheet stress due to different flow velocities.