Rapid Prototyping of Co-Flow Microfluidic Devices for Red Blood Cell Aggregation

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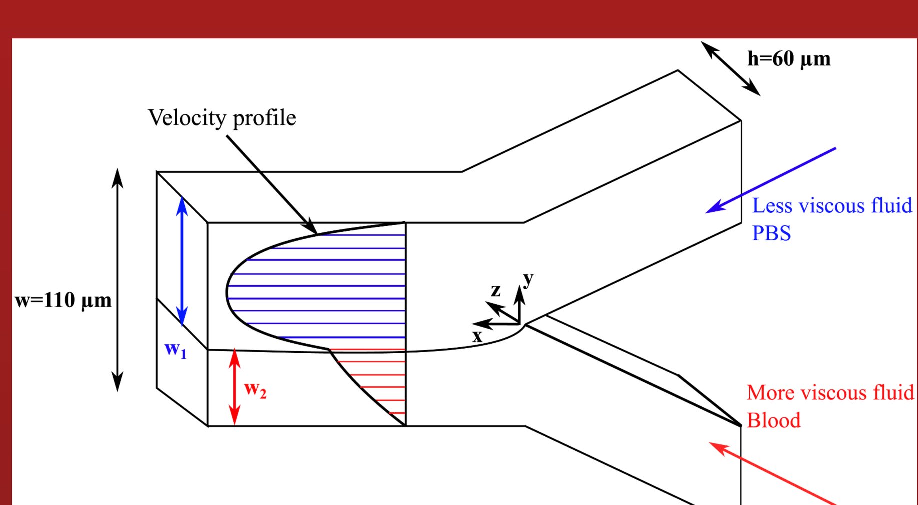
Overview

- Design, optimize, prototype microfluidic device to investigate red blood cell (RBC) aggregation under controlled shear rate.
- Test geometries and flowrate ratios with CFD.
    - ➢ Linear velocity profile for blood.
- Add Luer lock compatible inlets/outlets in CAD.
- Prototype with resin 3D printing.

Background

- RBC aggregation: formation of stacks of RBCs

- Studies have shown RBC aggregation can indicate abnormal physiological conditions [2] [3].
- Shear rate is a factor that affects the aggregability of RBC [1].
- Co-Flow microfluidic devices apply shear to blood using a less viscous fluid.



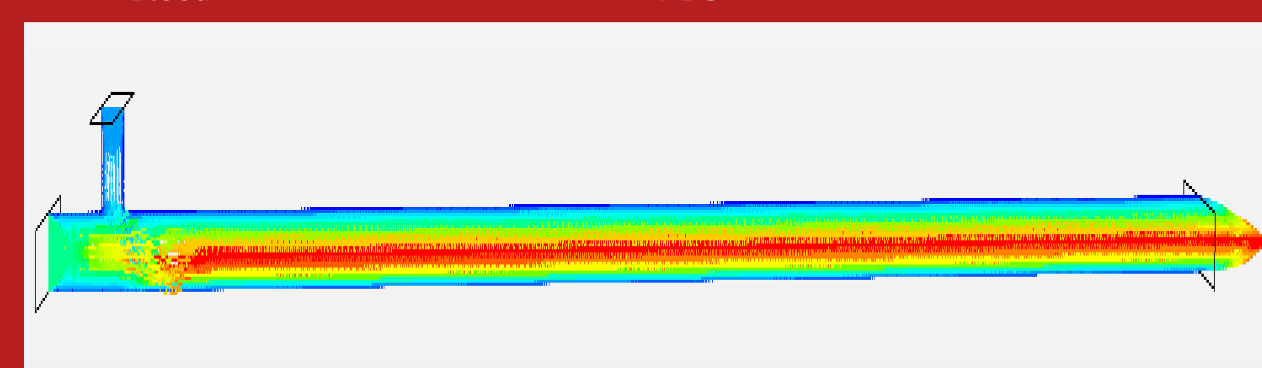
- Previous microfluidic devices use Y-channel geom.

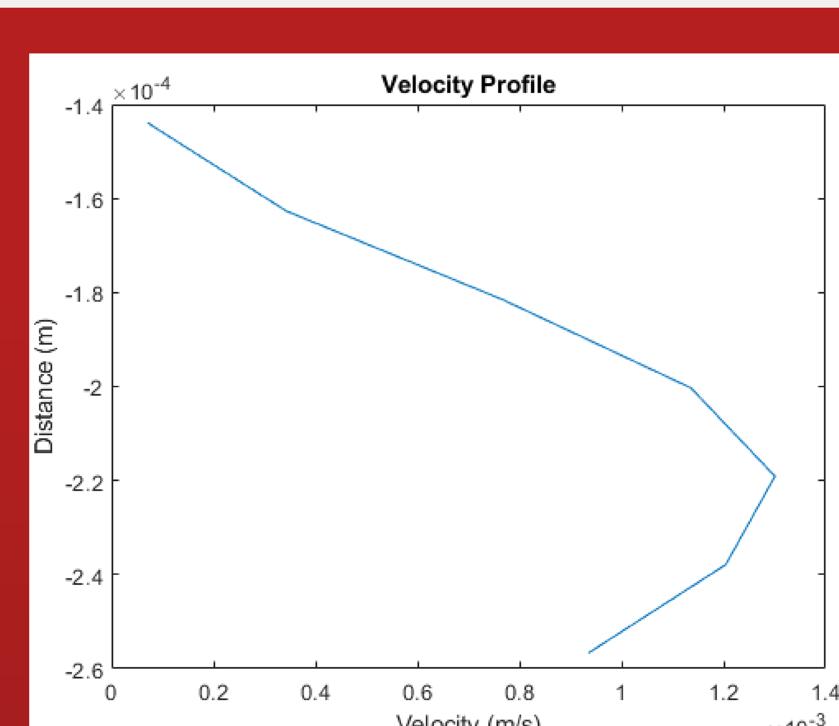
Y-Channel Microfluidic Device [4]

Methodology

CFD:

- Eulerian multiphase model: volume of fluid
- Laminar and Steady Flow.
- Flow rate ratio of 8:1 of PBS to blood.
- Q_{Blood} = 5.5575E-8 m^3/s, Q_{PBS} = 4.446E-7 m^3/s.

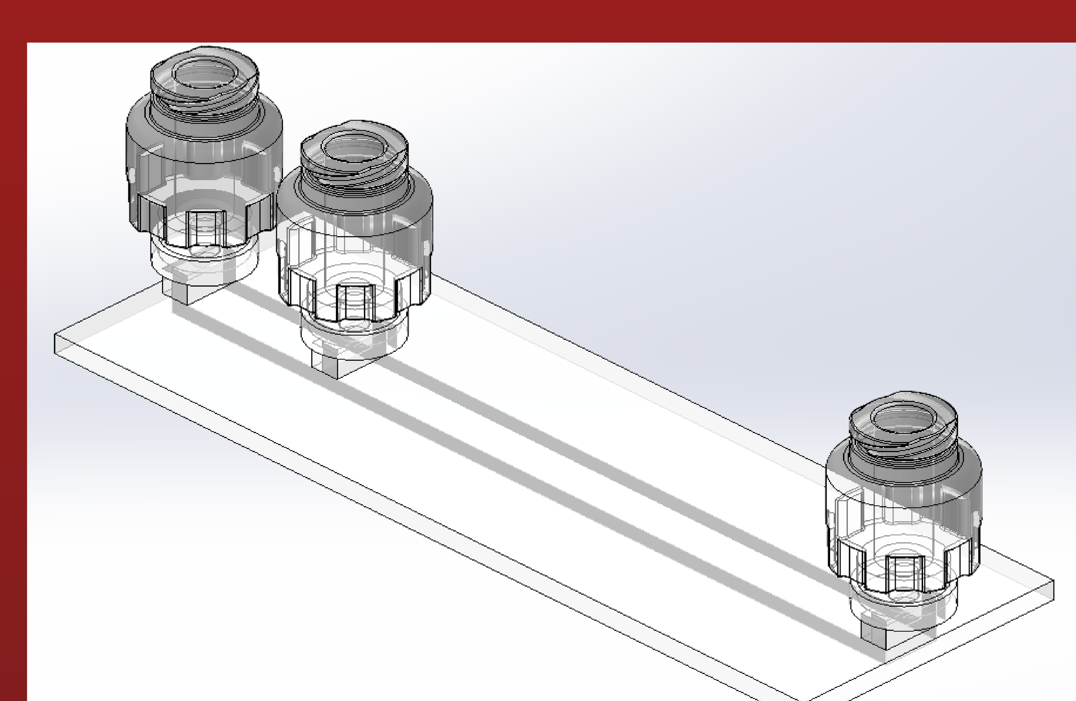




Velocity Profile in Microfluidic Device

Prototyping:

- Microfluidic device designed in SOLIDWORKS with Leur lock inlets/outlets.
- Resin 3D printed using Elegoo Mars 2.



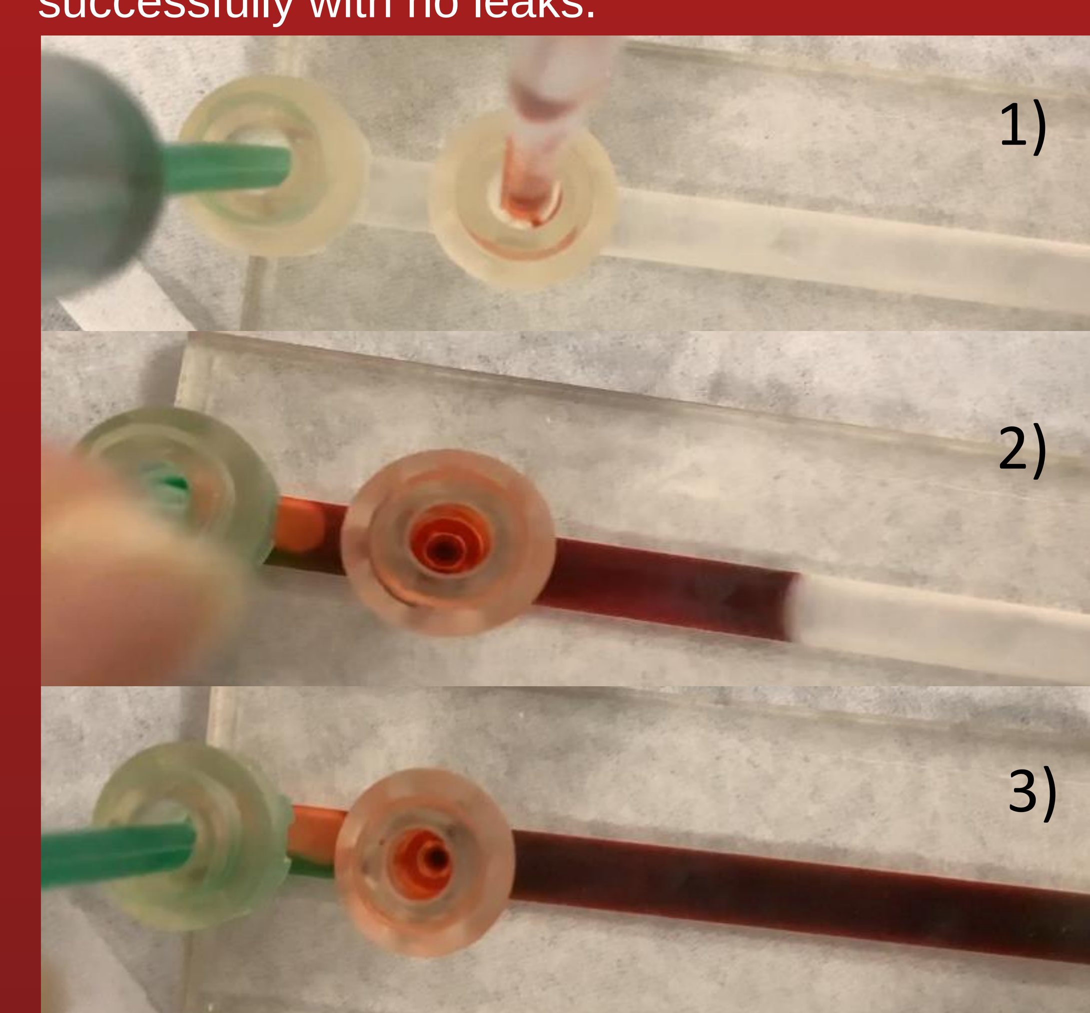
CAD Design of Microfluidic Device

Results

- Initially, the entire microchannel was resin 3D printed.
- Issues: the bottom was opaque and susceptible to warping.
- New "Hybrid" design -> 3D print the top of the microchannel onto a glass (microscope) slide.
    - 75 mm x 25 mm
- Improves optical clarity from the bottom and prevents warping.

Prototyped Hybrid Microfluidic Device

- Prototyped hybrid microfluidic device functioned successfully with no leaks.



Flow Test of Hybrid Microfluidic Device in Stages (1,2,3)

Conclusion

- The prototyping of hybrid microfluidic device was successful.
- The hybrid microfluidic device possess greater optical clarity and durability than initial prototype.
- The flow test of hybrid microfluidic device was successful.
- Next step is to perform PIV to verify CFD trial.
- This will determine if device will be effective as co-flow microfluidic device.
- Design will be developed further to incorporate an ultrasonic sensor to characterize RBC aggregates.
- Further testing will be conducted to determine long term durability.

References

[1] R. Mehri, C. Mavriplis, and M. Fenech, PLoS One, vol. 13, no. 7, p. e0199911, Jul. 2018.

[2] R. Ben Ami et al., Am. J. Physiol. - Hear. Circ. Physiol., vol. 280, no. 5, 49-5, 2001.

[3] J. Tripette et al.,,"Haematologica, vol. 94, no. 8, pp. 1060–1065, Aug 2009.

[4] Armstrong, Curtis James Karns. "Red Blood Cell Aggregation Characterization." University of Ottawa Thesis, 2020.