Blood Cell Adhesion on Silicone Polymeric Heart Valves

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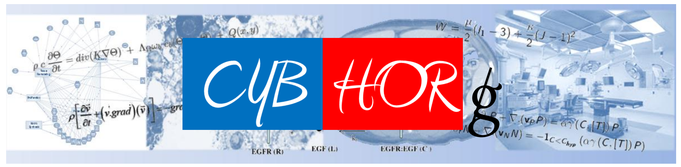
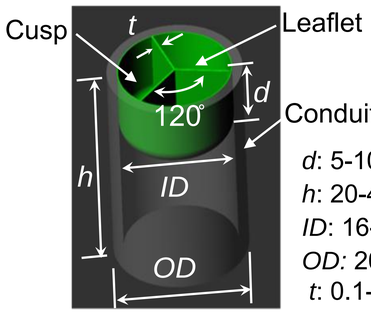


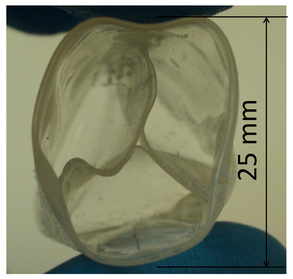
Abstract. The goal of this project is to develop an artificial heart valve that reduces the shortcomings of current bioprosthetic and mechanical valves, specifically, to minimize blood cell adhesion while maximizing durability. Avoiding blood cell adhesion is key to preventing platelet activation and subsequent thrombogenetic effects while an increase in durability will allow for fewer surgeries throughout the life of the patient. To achieve these effects, a single polymer structure made of a silicone elastomer was chosen for the trileaflet valve design. Encouraging results regarding blood cell adhesion have been achieved by controlling the surface textures of the valves via a Magnetic Abrasive Finishing (MAF) process. However, further experimental and computational work is necessary to optimize the valve design.

Introduction

The aim of this project is to develop an artificial heart valve from a single polymer structure in a way that reduces blood cell adhesion on the valve. The silicone valve surface textures are determined by what they are cured in contact with, e.g., the mold surface or air. The tubular brass molds are polished using a Magnetic Abrasive Finishing (MAF) process. Blood cell adhesion tests were done on leaflets with varying surface textures to determine the optimum surface qualities. The silicone tubes are then used to form valve prototypes, Figure 1.



(a) Valve Schematic



(b) Valve Prototype

Figure 1 Formed Valve

Leaflet Surface Fabrication

MAF finishes a mold surface by the relative motion between the mold surface and abrasive pushed by the magnetic particles. In the case of Figure. 2, the mold rotates and the abrasive translates in the mold axis direction.

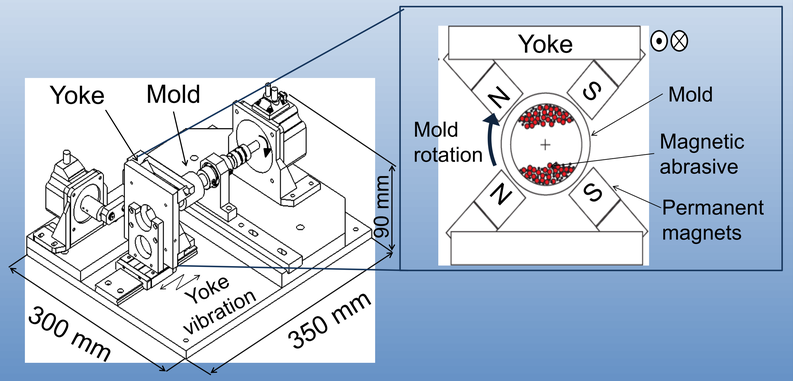
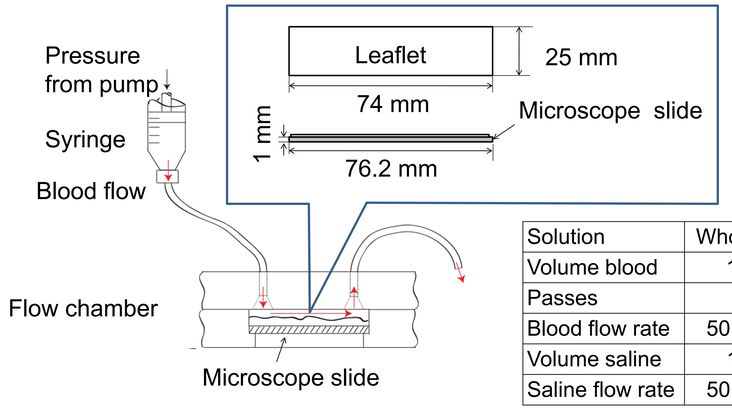


Figure 2 Finishing Machine

Blood Cell Adhesion Tests

Leaflets were flushed with whole human blood followed by phosphate buffered saline using the testing apparatus seen in Figure 3. They were flushed through the flow chamber over each of the samples at 50 mL·hr^{-1}, at a shear rate of 220 s^{-1}. The leaflet surfaces were viewed using light microscopy after being flushed.



Solution	Whole blood
Volume blood	15 mL
Passes	1
Blood flow rate	50 mL·hr^{-1}
Volume saline	15 mL
Saline flow rate	50 mL·hr^{-1}

Figure 3 Experimental Setup and Conditions

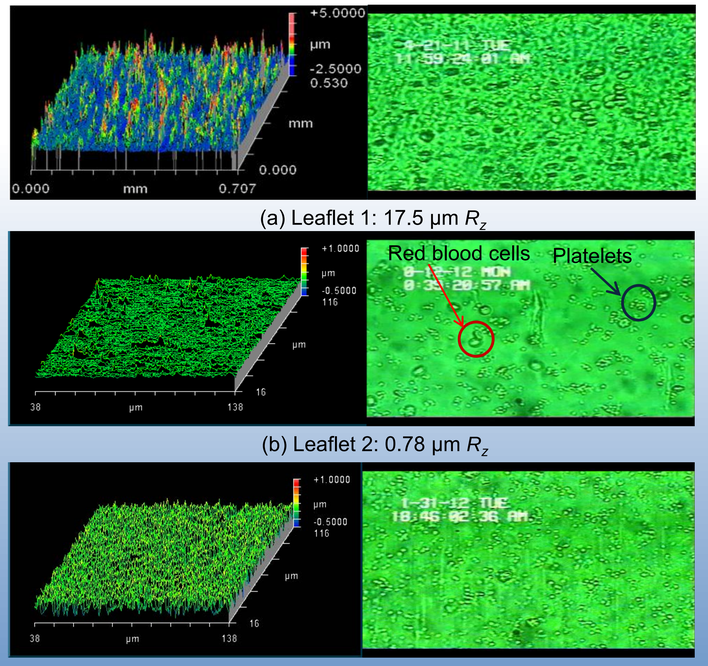
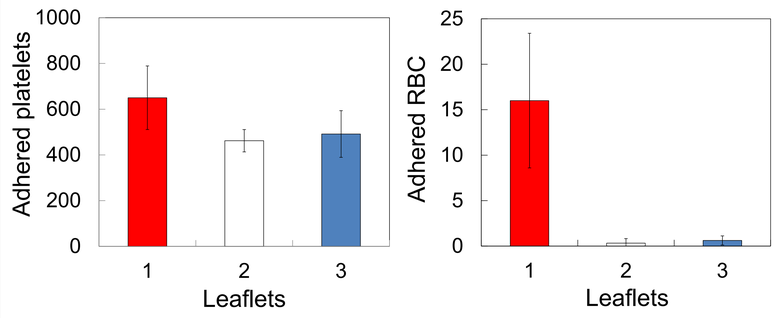


Figure 4 Leaflet Surface Profiles and Cell Adhesion Images



(a) Platelets adhered to leaflets (b) Red blood cells adhered to leaflets

1 = Leaflet cured in contact with Mold 1 (2.59 μm R_z, 0.34 μm R_a)
2 = Leaflet cured in contact with Mold 2 (0.79 μm R_z, 0.06 μm R_a)
3 = Leaflet cured in contact with air

Figure 5 Cell Adhesion Results

Blood cell adhesion was quantified by counting the number of adhered blood cells and normalizing by the sample surface area. Figure 4 shows leaflet surface profiles and still images of leaflets with blood cells during the tests. While Figure. 4(a) and (b) are the mold-replicated surfaces, 4(c) is the surface cured in contact with air. The results using the three leaflets are shown in Figure. 5.

Conclusions

The blood cell adhesion is reduced by smoothing the leaflet surface, and the mold surface fabrication is a key to controlling the effects. Future work will include continued refining of mold surfaces and valve design to further minimize blood cell adhesion. Computational simulations and improved manufacturing techniques will also be explored to increase repeatability and efficiency.

Acknowledgement

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References

Boggs T., Yamaguchi H., Tran-Son-Tay R., DeGroff C., Al-Mousily F.: Blood Cell Adhesion on a Polymeric Heart Valve Leaflet Processed using Magnetic Abrasive Finishing, Proceedings of ASME 2011 6th Frontiers in Biomedical Device Conference & Exhibition, BioMed2011.