# Mechanical Heart Valve

Project By: Theresa-Lynne Danielle Filio,Vasudha Kalia, Taimoor Khan, Peter Morreale

## Introduction

### Problem Statement

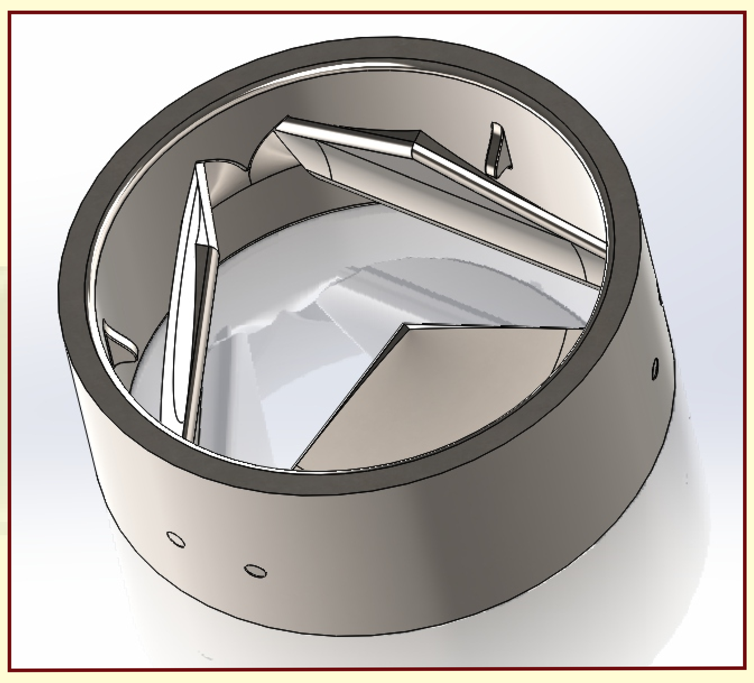
- The four valves of the heart are integral to controlling the uni-directional flow of blood through the body.
- A defect in one of these valves can result in diseases such as stenosis of the valvular opening, a prolapse or regurgitation of blood which can result in cardiac distress.
- Valvular heart disease accounts for about 10-20% of cardiac surgical procedures usually resulting in valve replacement.

### Objective

The goal of this project was to design, model and experimentally test a mechanical heart valve that serves as a successful alternative to existing mechanical valve designs. The final deliverable was to provide a prototype printed in 316L medical grade stainless steel.

## Design

- The design consists of a cylindrical housing, three leaflets, and three pins to form a pivot point.
- The leaflets were designed to concentrate flow along the edges in order to move the leaflets to the open and closed positions.
- The housing contains grooves for the leaflets to rest in when in the open position and stopping wedges in the closed position which both act to control the range of motion.
- Edges were rounded to smooth flow over the surfaces minimizing shear forces which could damage blood cells.

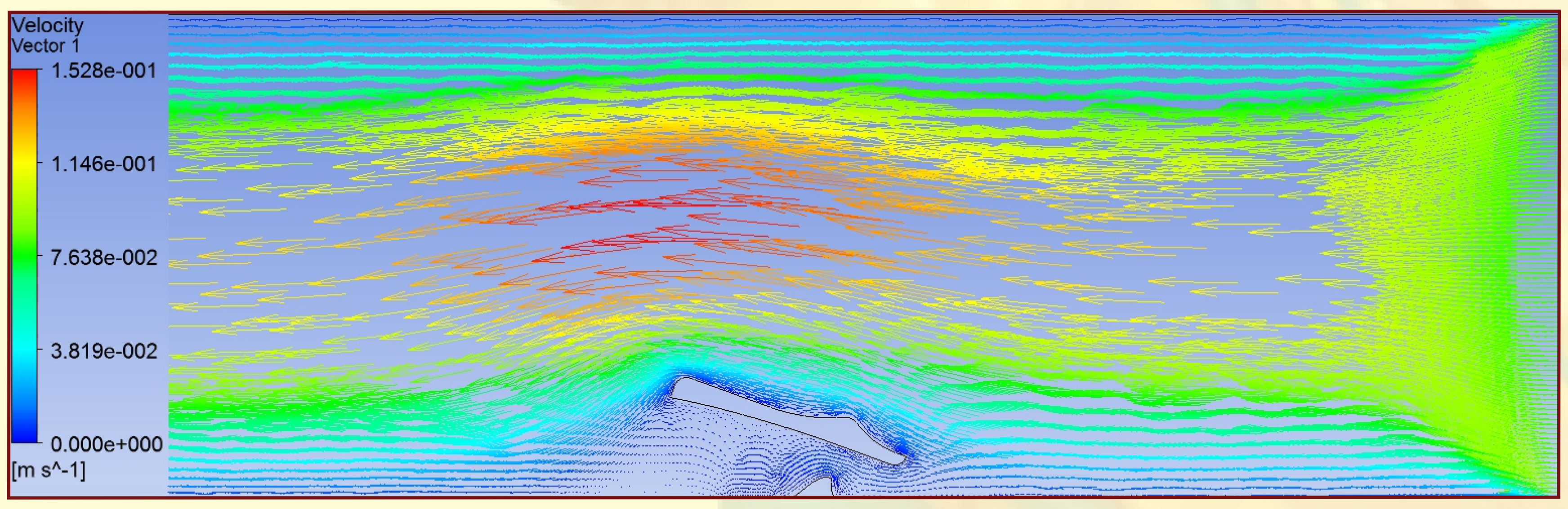


SolidWorks Model of Tri-Leaflet Valve

## Design Evaluation

### Computational Fluid Dynamic (CFD) Model

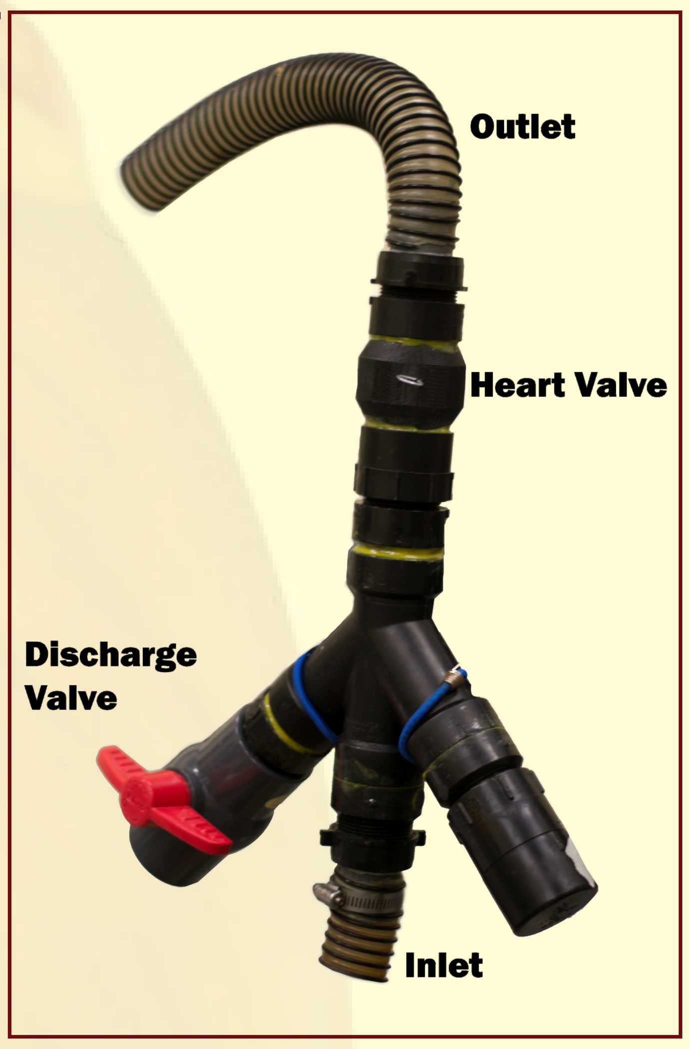
- A 2-D CFD analysis was performed on the valve cross section focusing on fluid flow around one leaflet.
- The simulation was evaluated using a standard k-omega model and consisted of 16,611 computational nodes.
- Fluid properties of blood including density, viscosity, and a physiological inlet velocity of 0.018m/s was calculated for the model.
- The maximum flow velocity around one leaflet was determined to be 0.15m/s, which is expected to be less than a 3-D model.
- The maximum flow velocity is comparable to a 2-D analysis performed on existing mono-leaflet and bi-leaflet designs.




CFD Analysis of Tri-leaflet Design

### Heart and Lung Simulator Testing

- An ex Vivo heart and lung simulator was used to simulate the physiological conditions of the heart.
- The system created a closed loop, pulsatile, vascular circulation system to replicate ventricular contractions.
- An upscaled 3-D model was printed in ABS plastic and was connected to standard pipe fittings.
- An AC synchronous motor was used to pump water through the system at a rate of 50L/min.
- A Stepper motor and pulse valve were used to replicate a pulse.
- An outflow valve was used to manipulate backflow pressure.
- Pressure required to open the valve was calculated by measuring the water column height above the valve.
- An endoscope was used to monitor flow behaviour and valve functionality under different conditions.
- The valve was tested up to a systolic pressure of 94 mmHg and diastolic pressure of 50mmHg.




Experimental Apparatus

## Conclusions and Recommendations

Through the use of the heart and lung simulator, the designed mechanical heart valve withstood approximate physiological pressures. The flow velocities observed in the CFD model were consistent with existing designs. It is recommended that future cyclic loading tests be conducted to determine the longevity of the device. Experimental testing with fluids similar to blood composition should also be used to analyze the biocompatibility of the 316L stainless steel. Its is also recommended to increase the systolic pressure in the experimental setup to achieve more accurate physiological conditions.

School of Engineering

Acknowledgments: Dr. John Runciman Ph.D., P.Eng. (Faculty advisor)
Dr.(?)Bruce Guest [place holder title], Erika Fiedler,
Dr. Jonathan VanderSteen, Ph.D., P.Eng.

The BetterPlanet Project

University of Guelph

Changing Lives Improving Life