Artificial Cardiovascular and Hemodynamics Experiment (ACHE)

TEXAS A&M UNIVERSITY Engineering

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TEXAS A&M UNIVERSITY ROBOTICS TEAM & LEADERSHIP EXPERIENCE

Intro & Problem Definition

Heart Failure affects over 25 million people worldwide and brings nearly a million new cases each year [1]. While assisting devices such as Left Ventricle Assisting Devices (LVADs) currently provide support, the massive prevalence of heart failure and lack of cure often leads to far too many biventricular failure cases. As transplant options are limited, Total Artificial Hearts (TAH) offer a promise to the future of treatment.

Usage in Industry

While still emerging, various TAH designs have shown success worldwide. Two models are currently approved for human trials in the United States:

BiVacor:

Pros:
- Single moving part and compact design
- Reduced hemolysis compared to prev designs

Cons:
- Continuous flow vs physiological pulsatility [2]
- Thrombogenic risk requires aggressive anticoagulation

SynCardia Total Artificial Heart:

Pros:
- Pulsatile flow maintains arterial compliance and organ perfusion
- Variable cardiac output responsive to patient

Cons:
- External pneumatic driver weighs 13.5 lbs
- Percutaneous drivelines increase infection risk

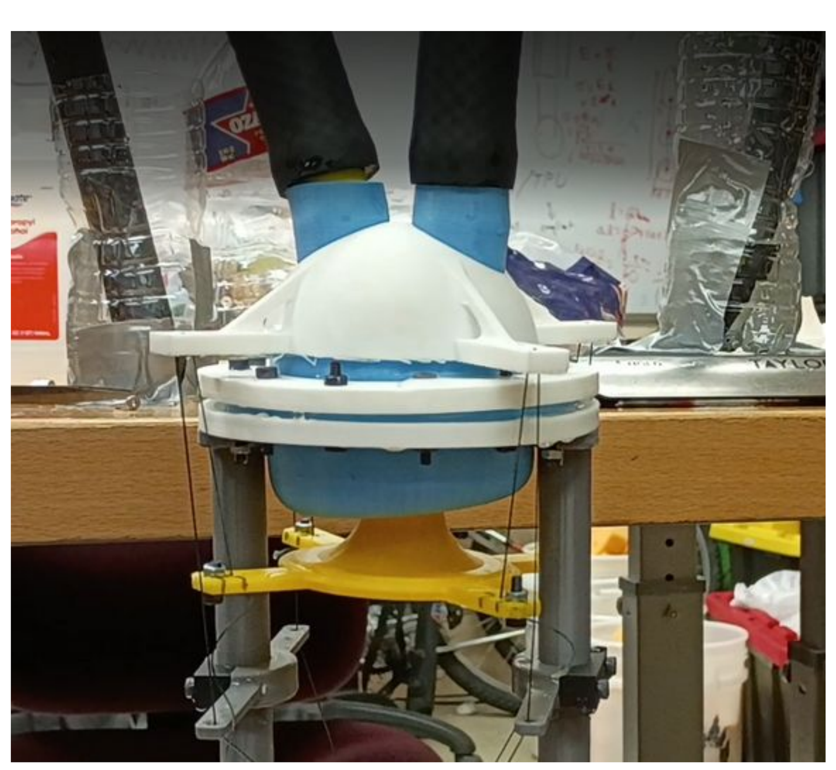

Figure 1. Ventricle chamber assembly and circulatory loop

Mission Statement

Our mission is to engineer a TAH that replicates the human heart's pumping mechanism through controlled contraction and relaxation. By integrating fluid simulation and a dual-ventricle prototype, we aim to explore key principles of cardiovascular biomechanics, validate our design against current TAH benchmarks, and enhance our understanding of biomedical device development.

Mechanical

This semester we:
- Iterated through design elements of the tension driven system
- Added a planetary gearbox to the output shaft of the stepper motor
- Redesiged the actuator bottom plate to increase stroke volume.

Using the improved tension design, we were able to connect a check valve and tube to the input and output vessels and get baseline flow. From experimentation, as a baseline we achieved 0.5 L/min at approximately 30 bpm.

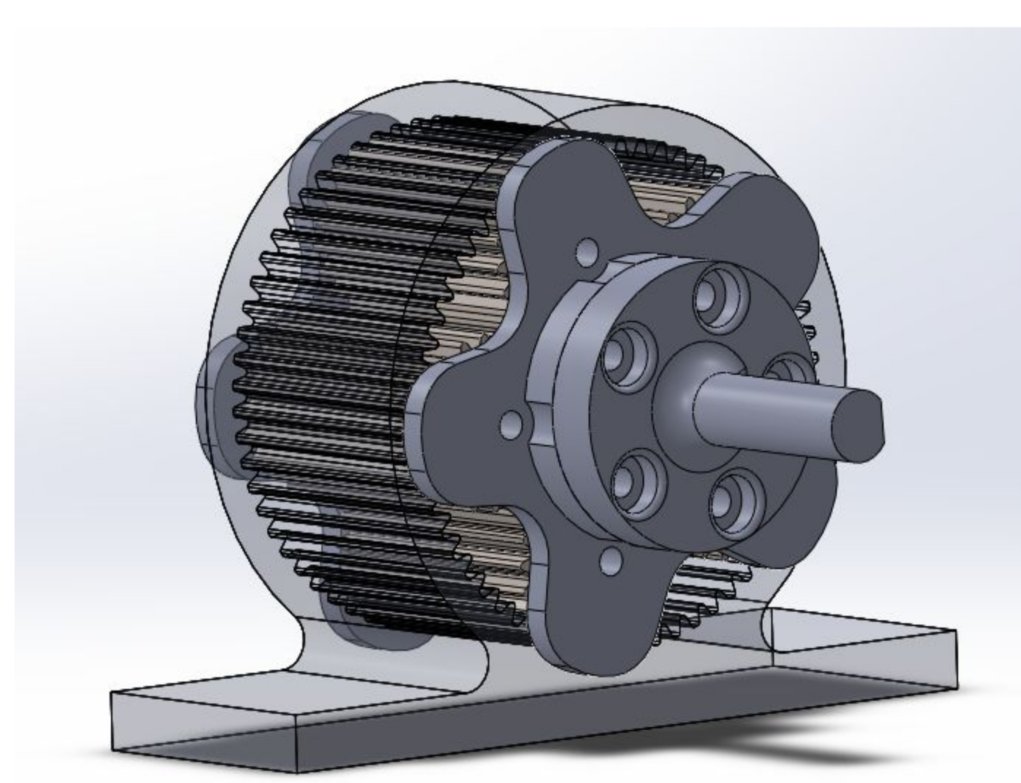

Figure 2. Planetary Gearbox

Additionally, we started research on different actuation methods, including magnetic levitation and electrohydraulics.

Electrical

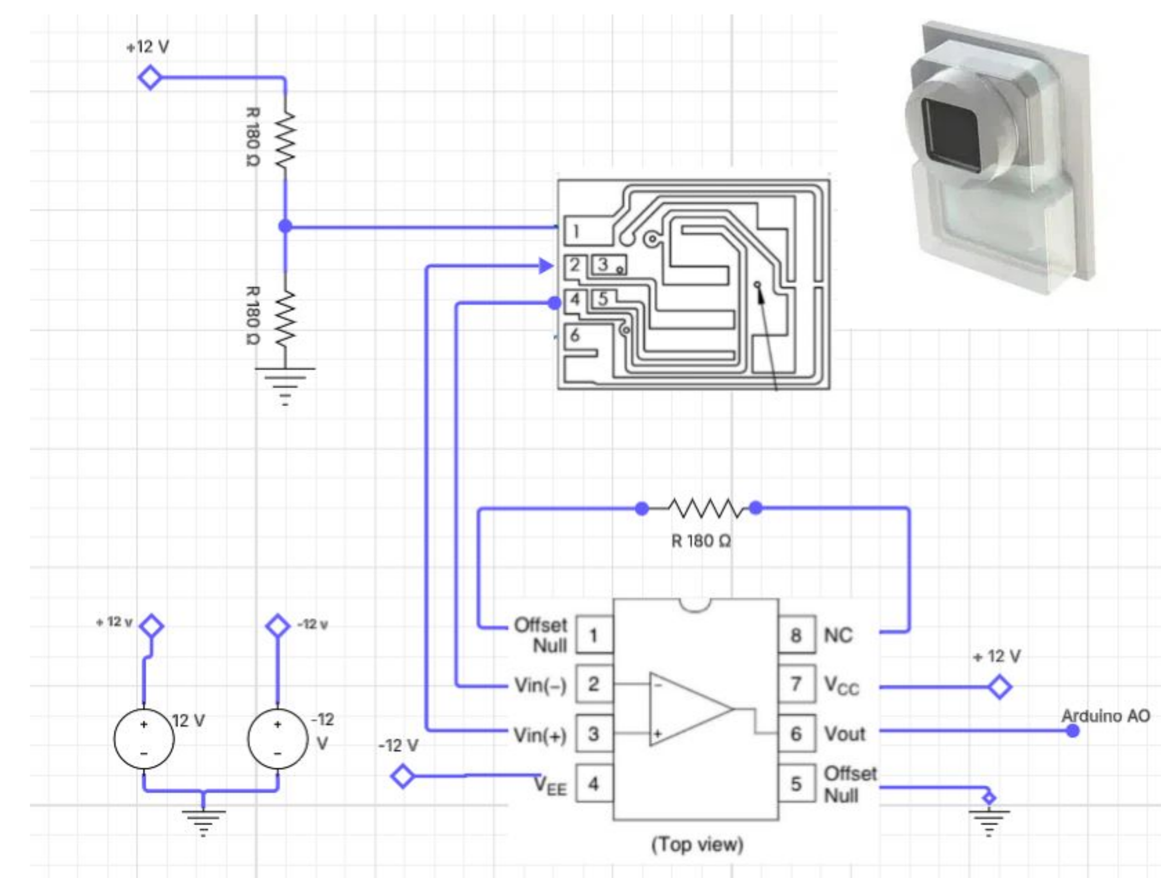

Figure 3. Schematic for Pressure Sensor Circuit

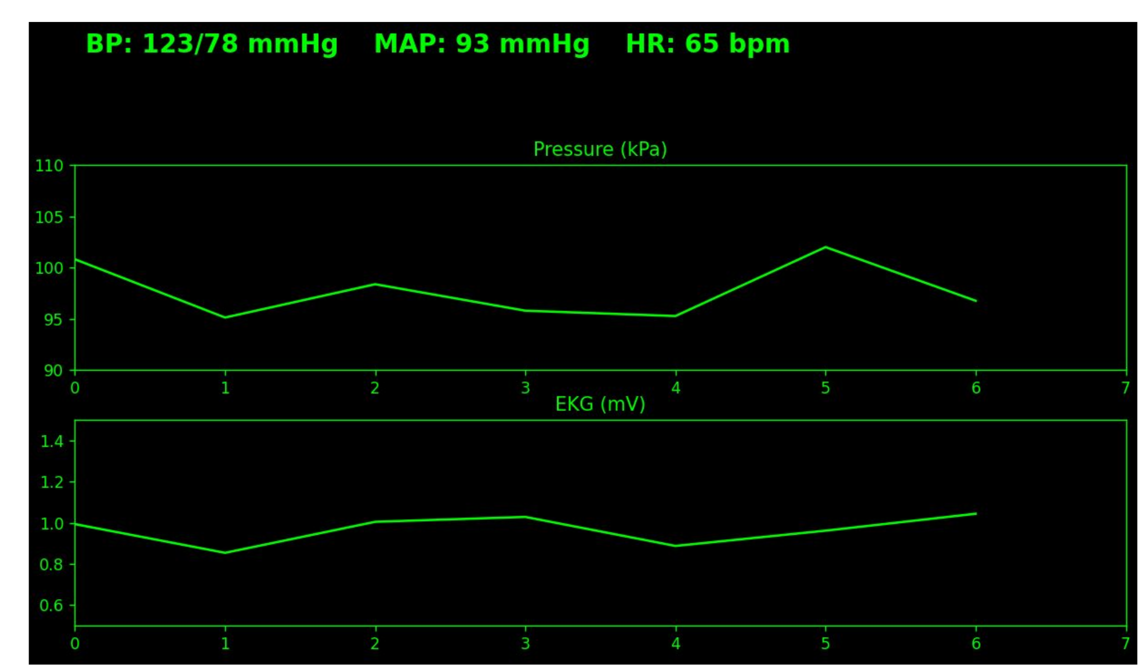

Figure 4. Randomized data to demonstrate GUI

We plan to use the output of the Pressure Sensor to plot the Diastolic and Systolic readings which can be used to calculate a mean arterial pressure (MAP).

$$\text{MAP} = \text{Diastolic BP} + \frac{1}{3}(\text{Systolic BP} - \text{Diastolic BP})$$

Simulation

This semester we utilized ANSYS Fluent to simulate our TAH design at various different static times for optimization and ulltilized a dynamic mesh to simulate a check valve.

We will move forward to implement sliding meshes and and more accurate boundary conditions within our simulation to better reflect conditions when used *in vivo*.

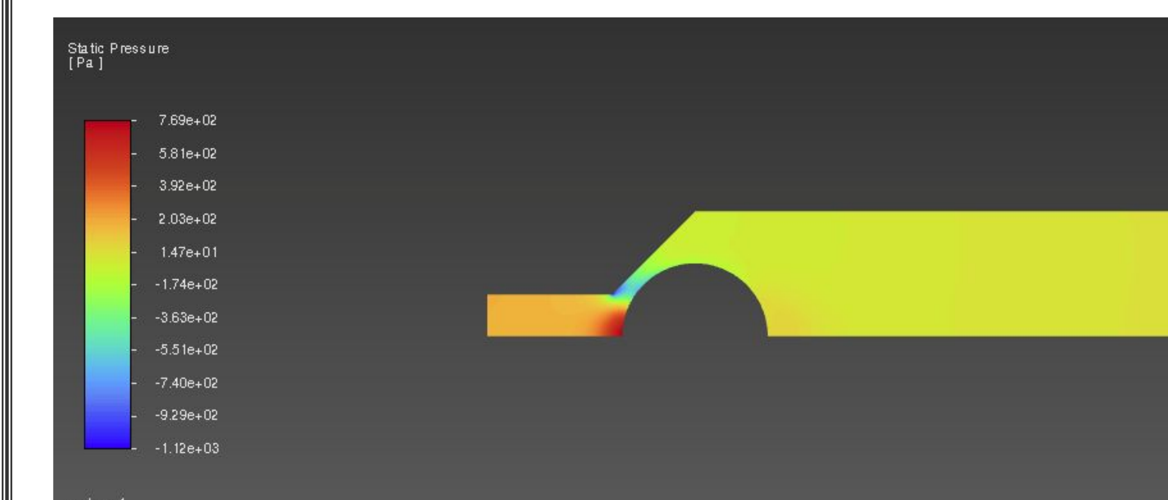

Figure 3. Schematic for Pressure Sensor Circuit

Figure 3. shows a simulation of the pressure during check valve operation. The full simulation is dynamic and calculates the changing pressures throughout flow as the valve opens and closes.

Next Steps

Mechanical
- Design hydraulic device to compare performance
- Test TPU shell vs silicone shell

Electrical
- Design and print Custom Printed Circuit Board
- Connect Pressure sensor for initial readings
- Handle motor control for appropriate BPM and flow rate

Fluid
- Use results to optimize valve and chamber designs
- Continue to model flow during different static steps of the pumping cycle
- Explore dynamic Meshing and Windkessel boundary conditions In ANSYS

Sources

[1] Savarese G, Lund LH. Global Public Health Burden of Heart Failure. Card Fail Rev. 2017 Apr;3(1):7-11. doi: 10.15420/cfr.2016:25:2. PMID: 28785469; PMCID: PMC5494150.

[2] Nader Moazami, Walter P. Dembitsky, Robert Adamson, et al.Does pulsatility matter in the era of continuous-flow blood pumps?,The Journal of Heart and Lung Transplantation, https://doi.org/10.1016/j.healun.2014.09.012.