NFPA Fluid Power Vehicle Challenge

NFPA Education and Technology Foundation

FINAL PRESENTATION
NORTHERN ILLINOIS UNIVERSITY
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04/16/2021

OUTLINE

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VI. Electronics/Sensors
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IX. Results
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TEAM INTRODUCTION

VEHICLE FRAME TEAM

Thomas Stewart

Pawel Jakubczyk

Joshua Rogers

VEHICLE HYDRAULIC/PNEUMATIC TEAM

Jason Fidder

Grant Heckel

Trey Fry

DESIGN OBJECTIVES

- Vehicle supported by a highly rigid and stable frame, that is resistant to the environment/corrosion.
- Highly ergonomic design for comfort and ease of control for the user.
- Components should be mounted properly, maintaining vehicle integrity and safety.

DESIGN OBJECTIVES

- Hydraulic system having simple controls without sacrificing functionality.
- Consider and design around rider safety and component serviceability.
- Keep the circuit simple, allowing for easier mounting and less confusion.

ETHICS

- Past designs for the FPVC should be used as inspiration, not used as own project, as ABET Code of Ethics States:

"Engineers uphold and advance the integrity, honor and dignity of the engineering profession by being honest and impartial, and serving with fidelity the public, their employers and clients."

- Safety of rider, and surrounding persons must be a top priority in order to create an ethical design. Humans must interact with the design, and will be near the vehicle constantly. It is important that the frame is rigid enough to support given loads, and components are mounted/fastened properly to avoid failure.

ETHICS

- Materials used in the construction of the frame should not harm the environment.
- All fittings, hosing, and other hydraulic components should be away from the rider and moving parts, and shielding present if possible.
- All electrical components should have waterproof housings, and any wires should be kept away from moving parts, and properly shielded.

FRAME DESIGN SELECTION

Design Considerations	Weighting	Bicycle	Recumbent Trike	4 - Wheel Vehicle
Safety	.30	1 - (.30)	2 - (.60)	3 - (.90)
Efficiency	.30	1 - (.30)	3 - (.90)	2 - (.60)
Manufacturing	.15	3 - (.45)	2 - (.30)	1 - (.15)
Stability	.10	1 - (.10)	2 - (.20)	3 - (.30)
Cost	.10	3 - (.30)	2 - (.20)	1 - (.10)
Weight	.10	3 - (.30)	2 - (.20)	1 - (.10)
Unweighted Total	**N/A**	**12**	**13**	**11**
Weighted Total	**1.00**	**1.75**	**2.4**	**2.15**

The items for each design are ranked on their capabilities in the respective design aspect categories. Each category contains a weighting that represents the priority of objectives with the project. Three points means it is the best in the category, and 1 point means it is the worst. The options are totaled to achieve an all-around dominant design.

FRAME MATERIAL SELECTION

Material Analysis

- Table 20.1 shows 5 materials that cycle frames can be made from.

- Carbon Fiber has been chosen for the frame material based on the density and tensile strength.

- Carbon Fiber has less mass per unit of volume. Using carbon fiber for the frame will make the frame lightweight. The FPVC competition has a weight restriction for the vehicle up to 210 lbs.

- Carbon Fiber has a high tensile strength, which is the maximum amount of tensile stress a specimen can experience before fracture. The frame needs to be strong to support the weight of all the components and the rider.

Table 20.1 Density (ρ), Strength (τ_f), the Performance Index (P) for Five Engineering Materials

Material	ρ (Mg/m^3)	τ_f (MPa)	$\tau_f^{2/3}/\rho = P$ [$(MPa)^{2/3}m^3/Mg$]
Carbon fiber-reinforced composite (0.65 fiber fraction)[a]	1.5	1140	72.8
Glass fiber-reinforced composite (0.65 fiber fraction)[a]	2.0	1060	52.0
Aluminum alloy (2024-T6)	2.8	300	16.0
Titanium alloy (Ti-6Al-4V)	4.4	525	14.8
4340 Steel (oil-quenched and tempered)	7.8	780	10.9

[a] The fibers in these composites are continuous, aligned, and wound in a helical fashion at a 45° angle relative to the shaft axis.

FRAME MATERIAL SELECTION

Material Analysis

- Rock West Composites has been chosen as the distributor for the carbon fiber tubing desired to build the frame.
- Rock West Composites offers bolted joints for easy connectivity of the carbon fiber tubing.
- Standard Modulus (SM) Carbon Fiber is the kind of Carbon Fiber being used for the Frame.

TECHNICAL DATA SHEET
No. CFA-005

TORAYCA®

T700S DATA SHEET

Highest strength, standard modulus fiber available with excellent processing characteristics for filament winding and prepreg. This never twisted fiber is used in high tensile applications like pressure vessels, recreational, and industrial.

FIBER PROPERTIES

		English	Metric	Test Method
Tensile Strength		711 ksi	4,900 MPa	TY-030B-01
Tensile Modulus		33.4 Msi	230 GPa	TY-030B-01
Strain		2.1 %	2.1 %	TY-030B-01
Density		0.065 lbs/in³	1.80 g/cm³	TY-030B-02
Filament Diameter		2.8E-04 in.	7 μm	
Yield	6K	3,724 ft/lbs	400 g/1000m	TY-030B-03
	12K	1,862 ft/lbs	800 g/1000m	TY-030B-03
	24K	903 ft/lbs	1,650 g/1000m	TY-030B-03
Sizing Type & Amount	50C	1.0 %		TY-030B-05
	60E	0.3 %		TY-030B-05
	FOE	0.7 %		TY-030B-05
Twist		Never twisted		

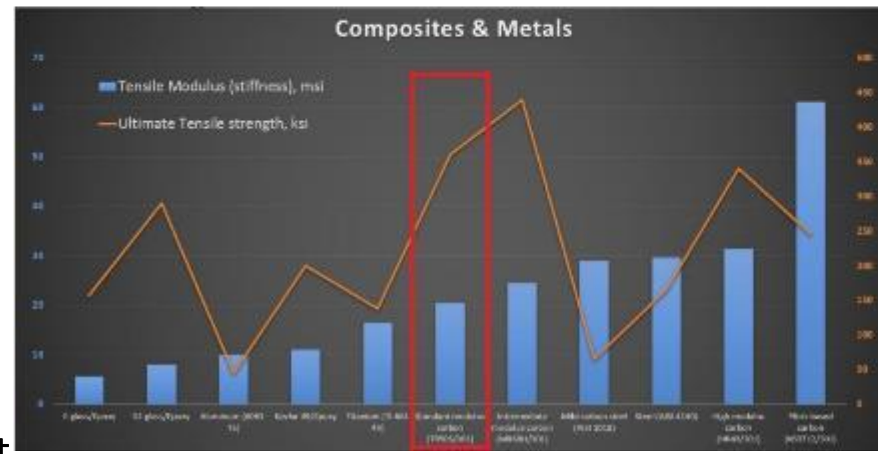
FUNCTIONAL PROPERTIES

CTE	-0.38 α·10⁻⁶/°C
Specific Heat	0.18 Cal/g·°C
Thermal Conductivity	0.0224 Cal/cm·s·°C
Electric Resistivity	1.6 x 10⁻³ Ω·cm

FRAME MATERIAL SELECTION

Standard Modulus Carbon Fiber

- Used in bike frames, sports equipment, general-purpose tubing
- Most common carbon fiber found in industry
- High Ultimate Tensile Strength
- Low Density

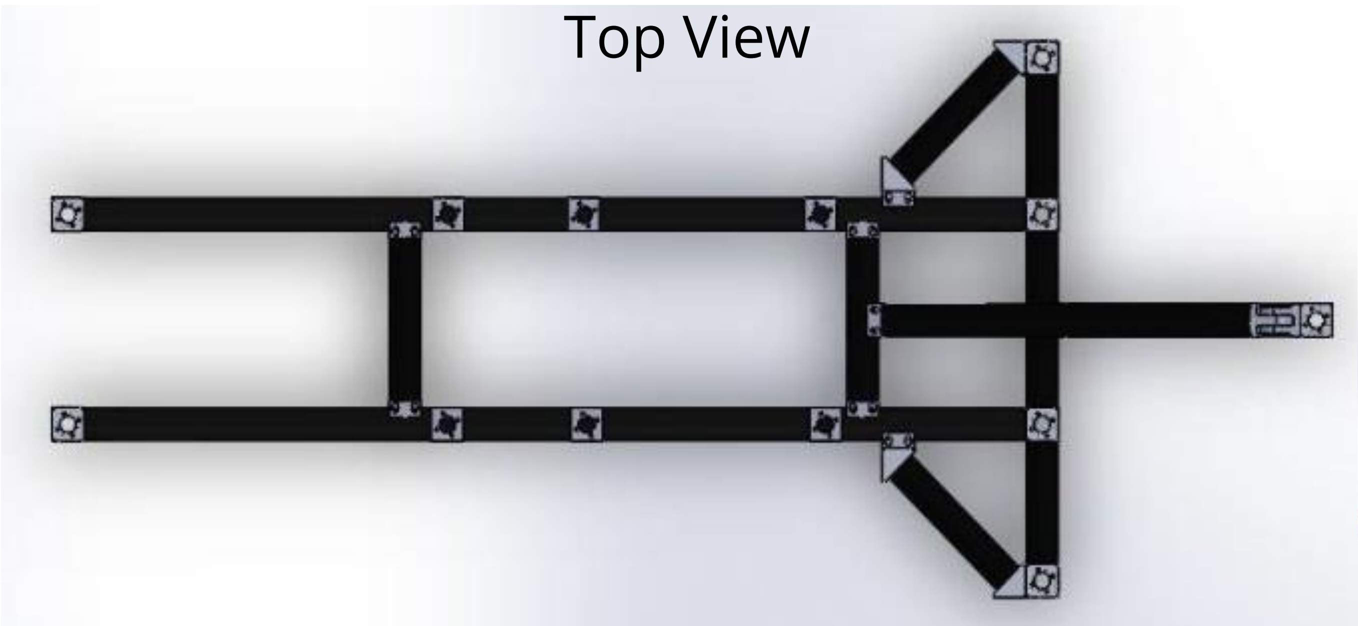


CARBONnect Connectors

- Manufactured from 6061-T6 Aluminum
- Used in Structural applications like aircraft, boats, etc.
- Most common material for bike frames.
- 20-42 ksi tensile strength

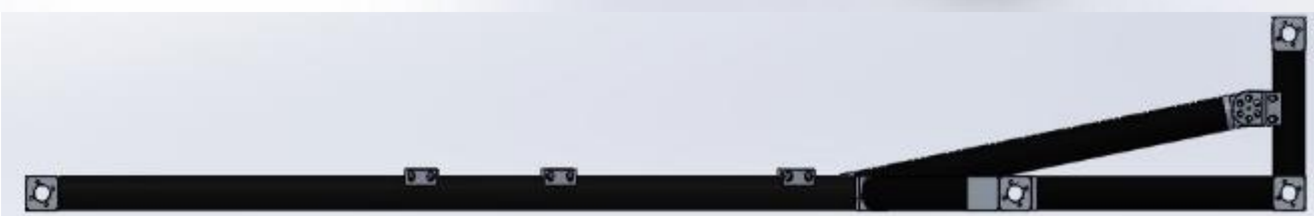
RECUMBENT TRIKE FRAME

Recumbent frame CAD model of one of the Concept Frames using Rockwest Composites tubing and CARBONnect connectors.



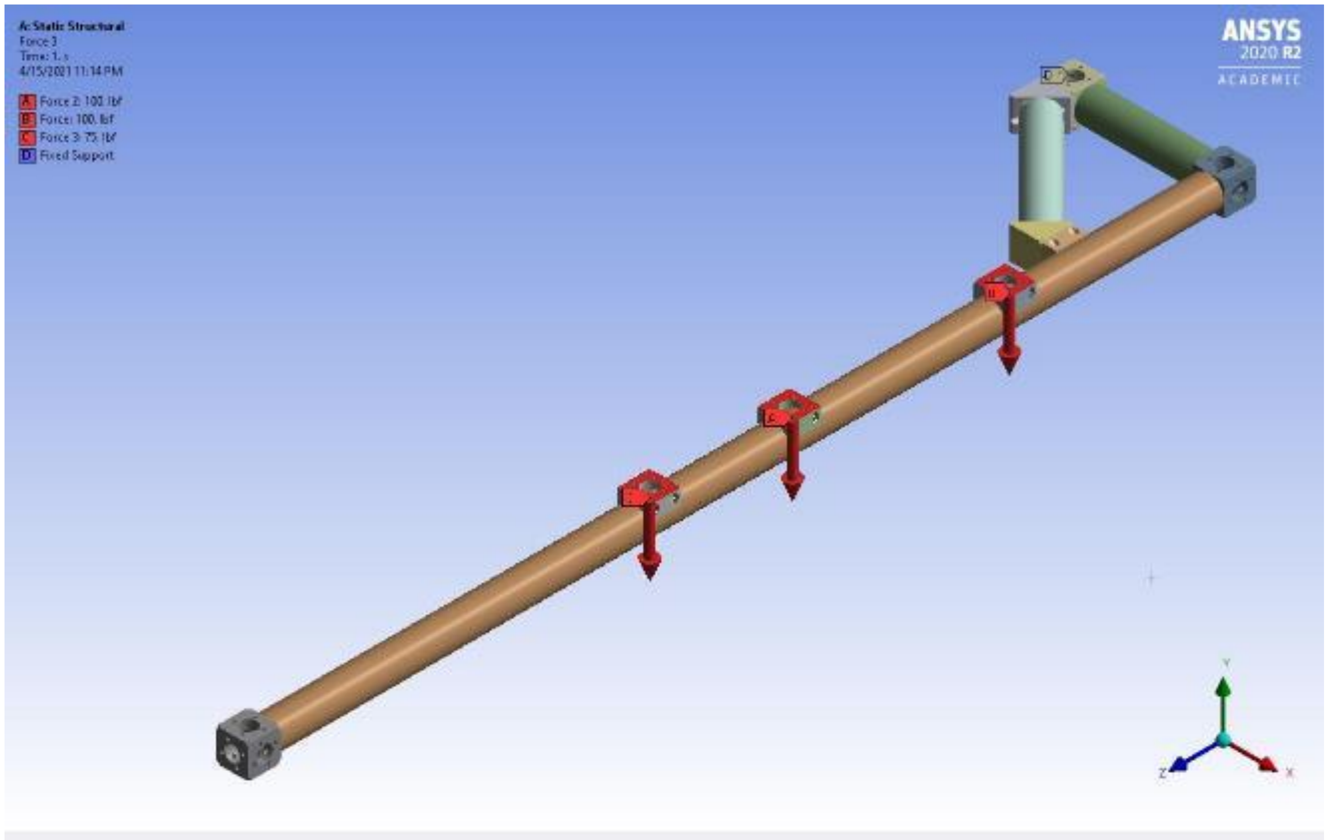
Top View

Isometric View



Right View

FINITE ELEMENT ANALYSIS



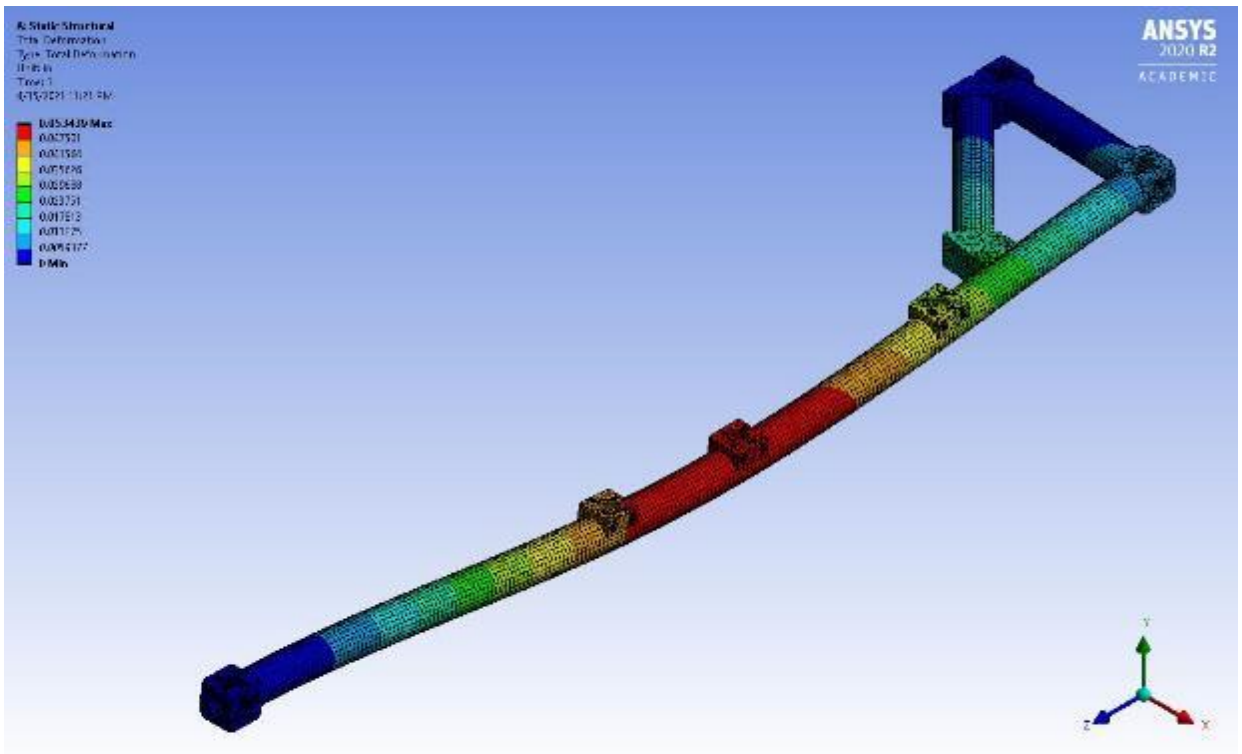
Loading conditions on Ansys concept frame model (loading condition were excessive)

FINITE ELEMENT ANALYSIS

NFPA Fluid Power Vehicle Challenge

Maximum Total Deformation

0.053439in (1.357351mm)

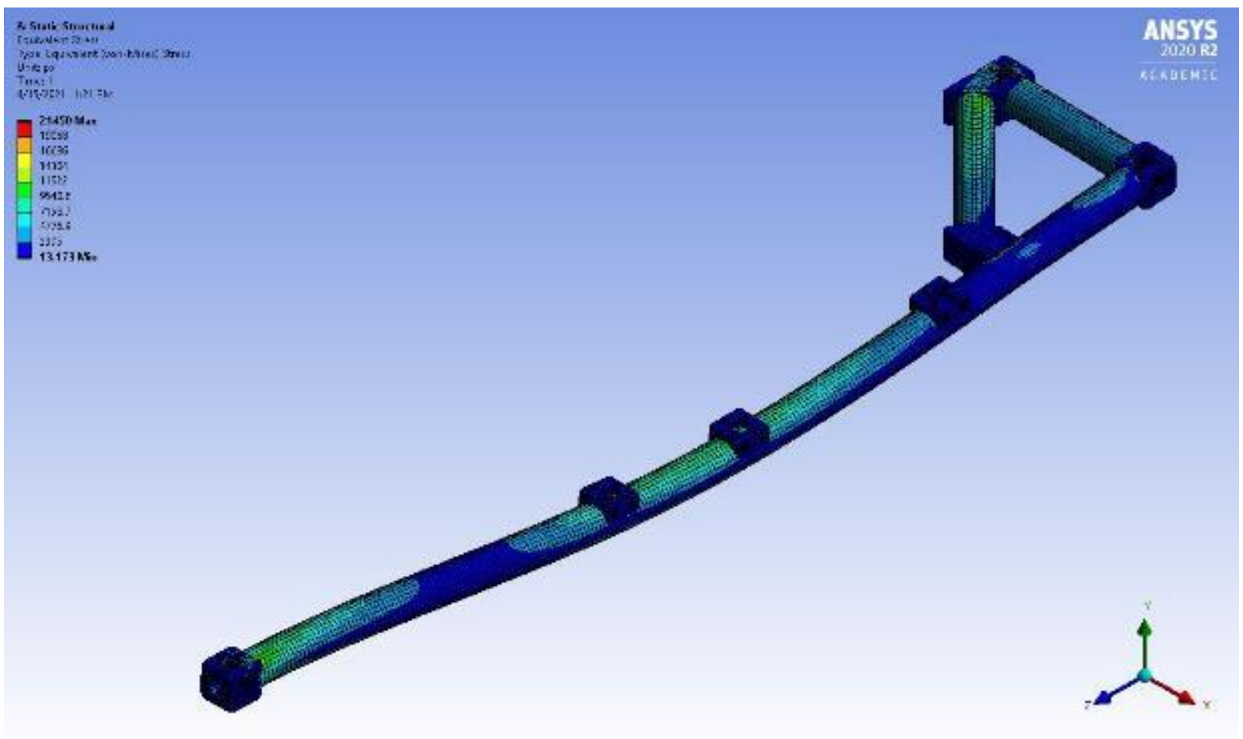


Total Deformation contour plot in Ansys of concept frame model.

FINITE ELEMENT ANALYSIS

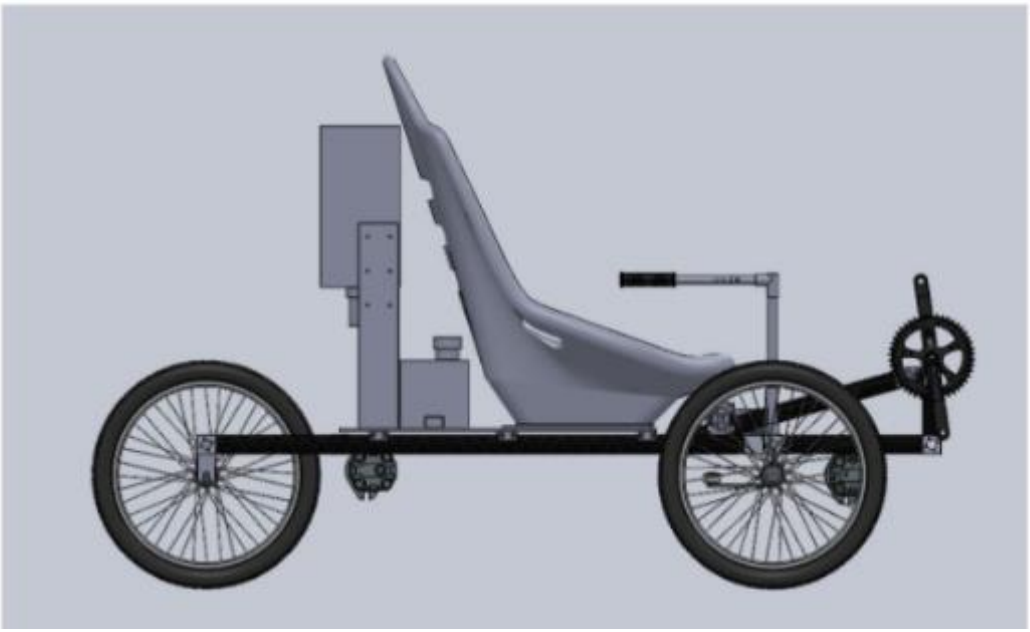
Maximum Equivalent Stresses (Von-Mises)

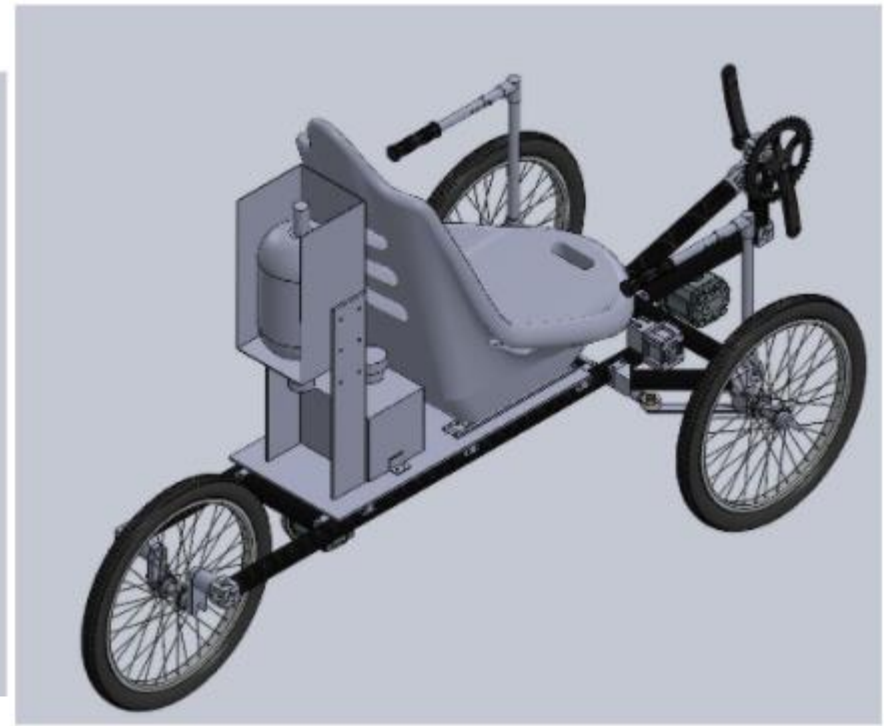
21450 psi (147.89 MPa)



Equivalent Stress (Von-Mises) contour plot in Ansys of concept frame model.

CAD MODEL





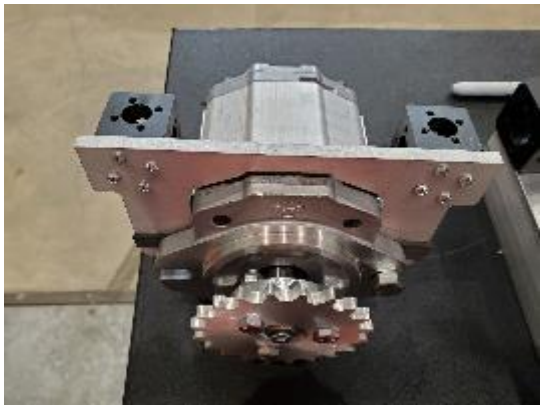
ACTUAL MODEL

Constructed Frame

ACTUAL MODEL

ACTUAL MODEL

Various Components



Motor mount

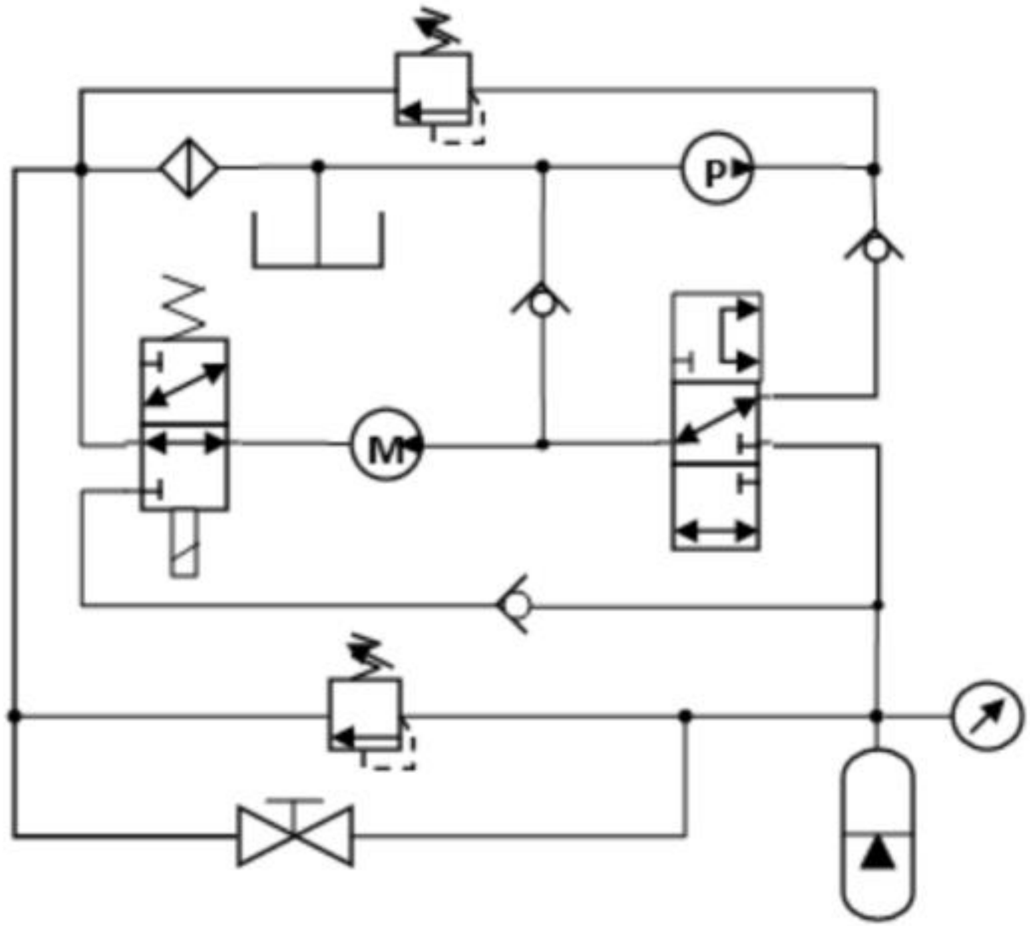
Steering stops

Steering assembly

Rear axle mounts and spacers

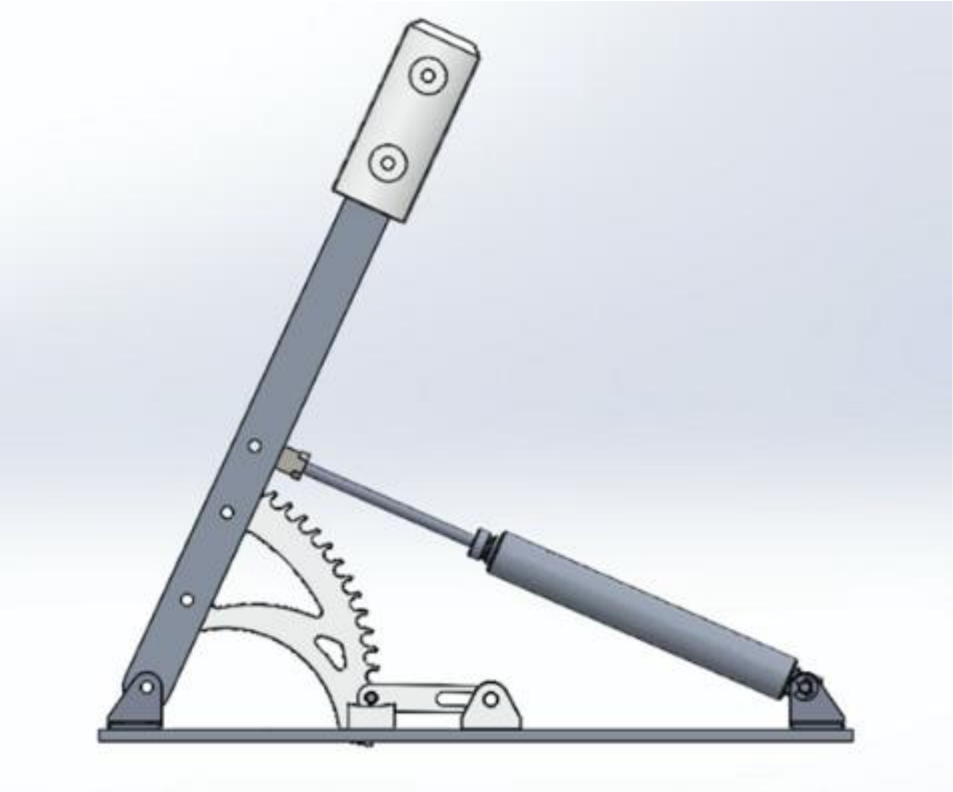
Steering block/spindle

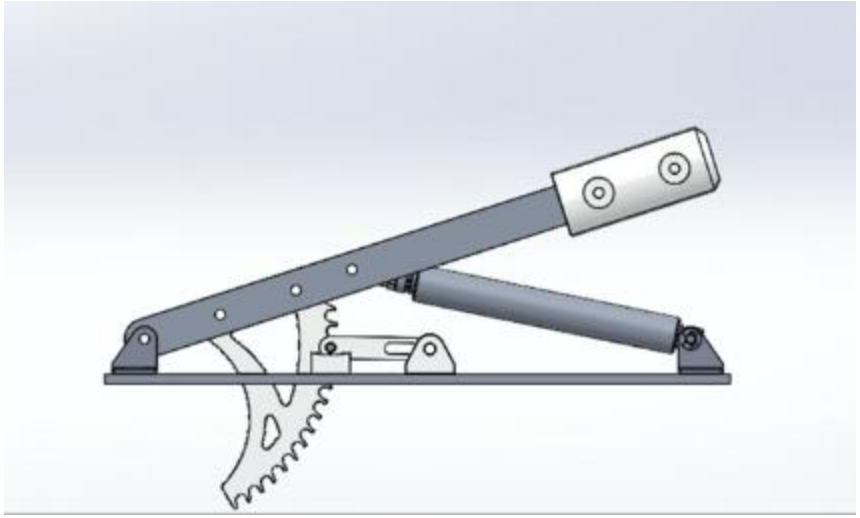
HYDRAULIC CIRCUIT



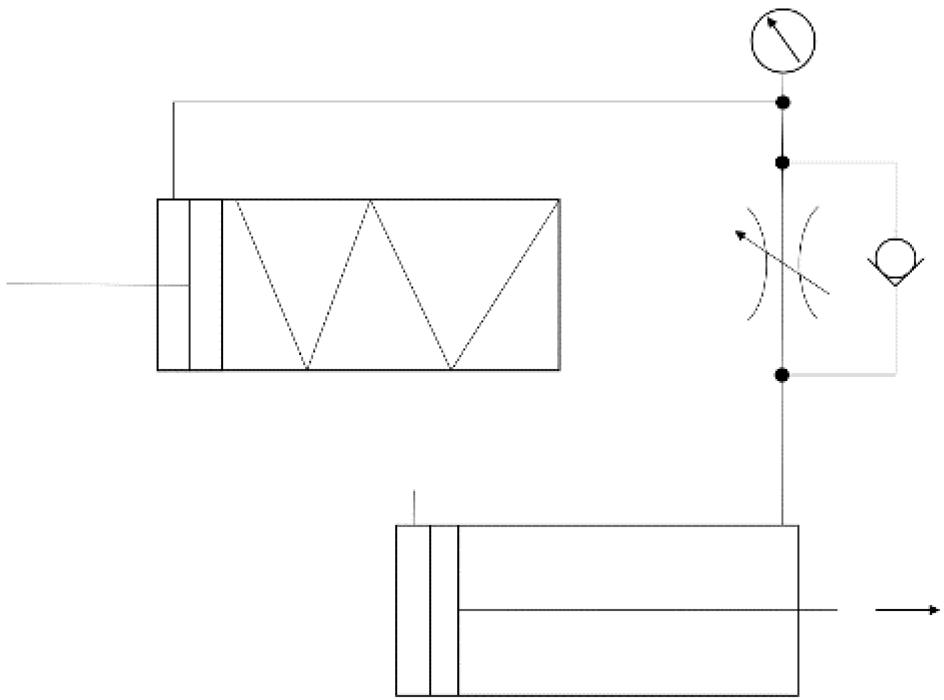
Hydraulics

Pneumatic Parking Brake





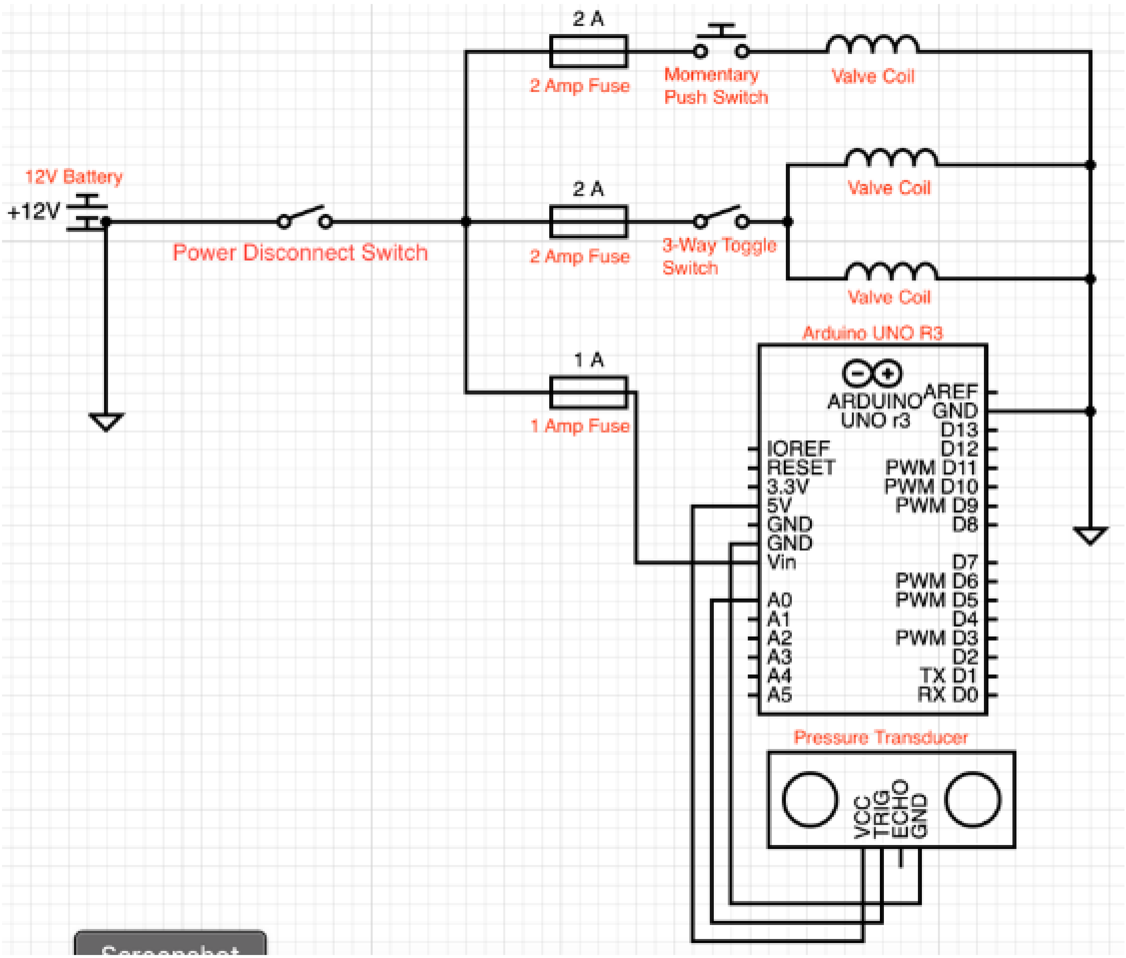
PNEUMATIC CIRCUIT



Electronics

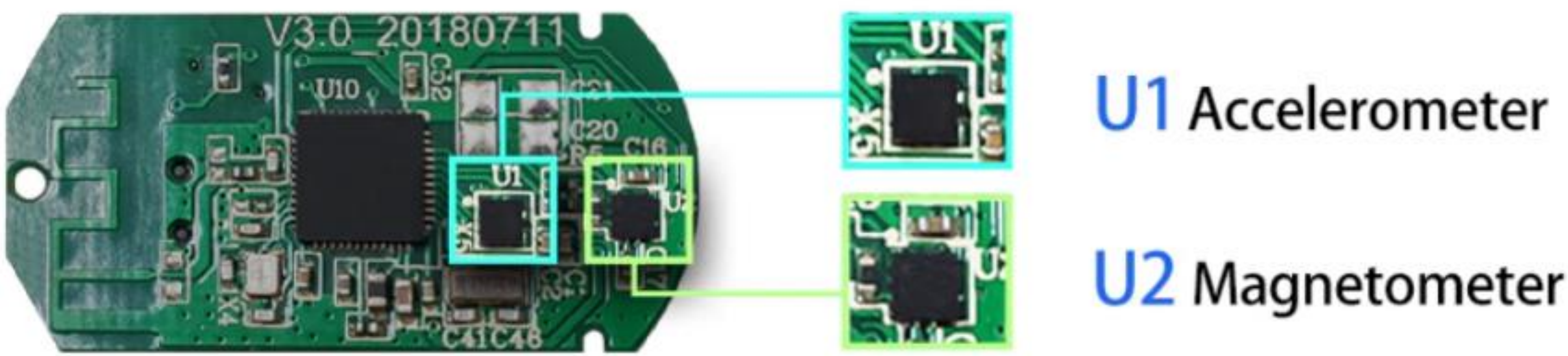
- Valves actuated by solenoid coils controlled by switches
- Arduino Uno R3 used for accumulator charge monitoring

Electronics



PRE-ENGINEERED SENSORS

CYCPLUS ®
SPEED AND CADENCE SENSORS



COST ESTIMATE & BUDGET

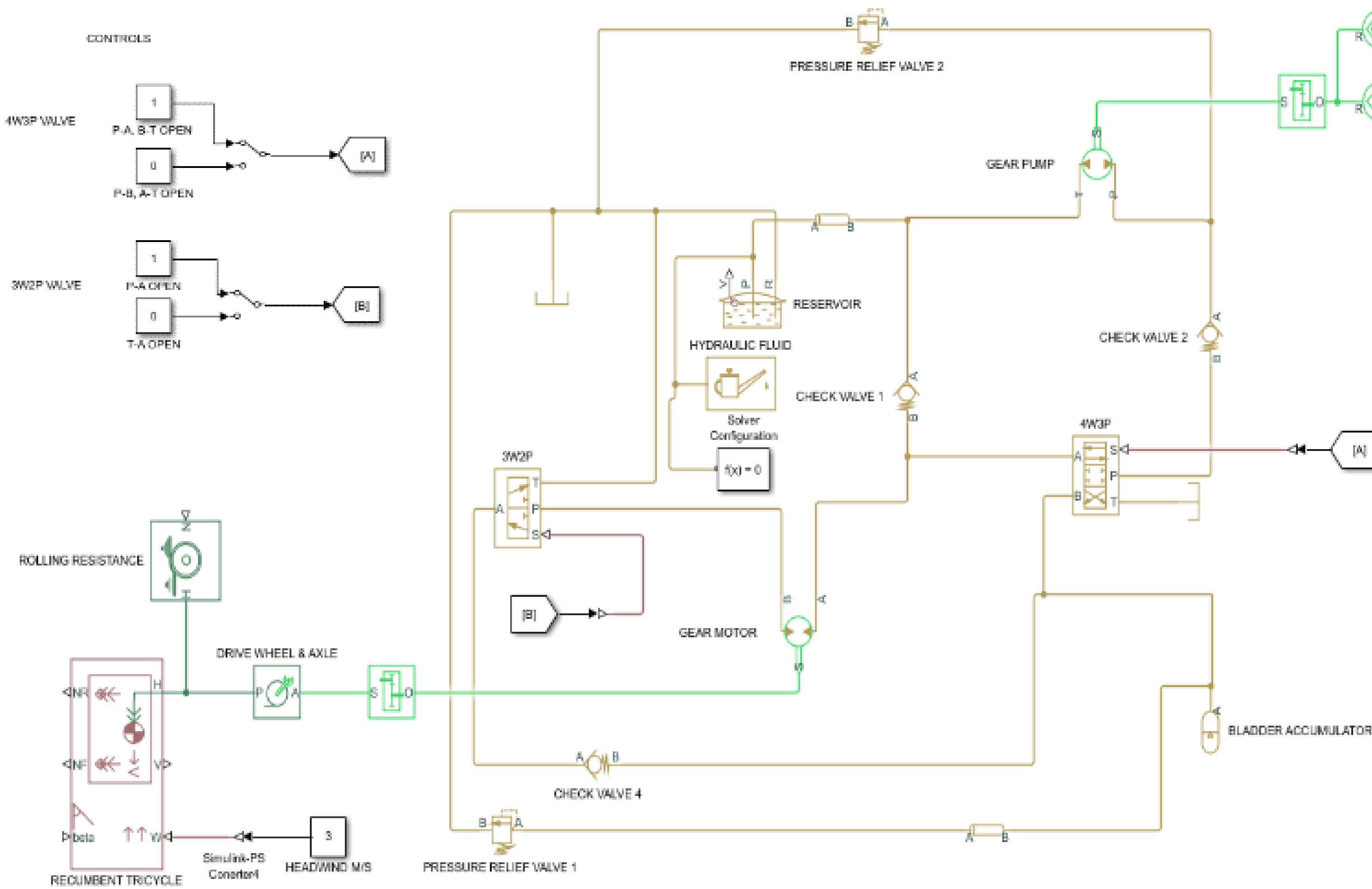
FRAME TEAM BUDGET

#	Money Source	Donation Value	Remaining
1	NFPA	$ 2,500.00	$ -
2	NIU	$ 1,000.00	$ -

HYDRAULIC/PNEUMATIC TEAM BUDGET

#	Money Source	Donation Value	Remaining
1	SunSource	$ 1,000.00	$ -
2	NFPA	$ 2,500.00	$ -
3	NIU	$ 1,000.00	$ 786.41
4	Eaton/Danfoss	$ 3,000.00	$ 1,959.00
5	Norgren	$ 500.00	$ 406.90

SIMULATION (SIMULINK ®)



<u>Human Motion Inputs:</u>
Cadence = 90 rpm
Pedal Torque = 40Nm (29.5ft-lbs)

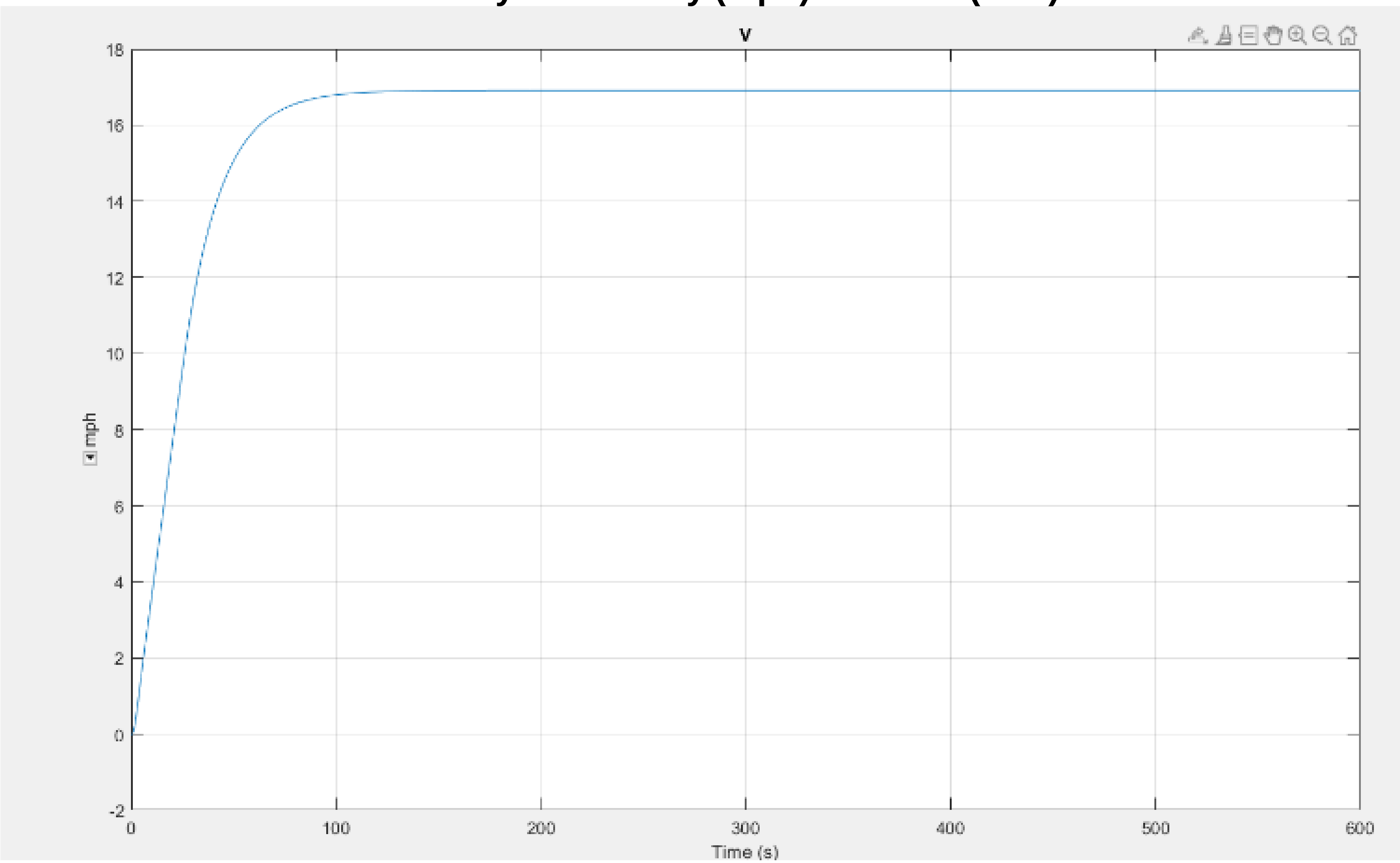
<u>Gear Inputs:</u>
Front Gear Ratio: 1.285
Back Gear Ratio: 1.25

<u>Hydraulic Inputs:</u>
Part Data Sheets

<u>Recumbent Trike Inputs:</u>
Headwind = 3 m/s (6.7mph)
Drag Coefficient= 0.9
Mass = 182kg (400lbs)
Rolling Resistance Coefficient = 0.003
Slope = Neglected

SIMULATION RESULTS

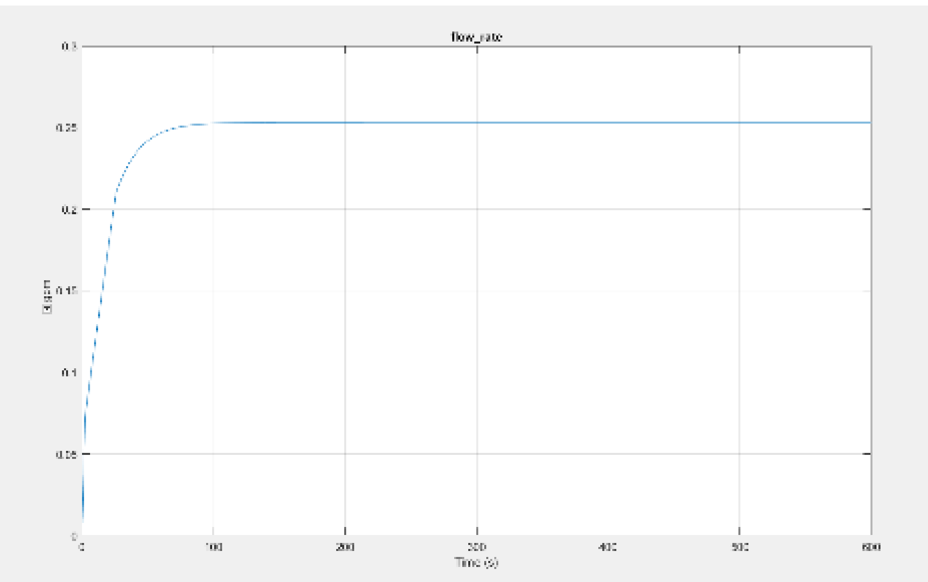
Tricycle Velocity (mph) vs. Time (sec.)



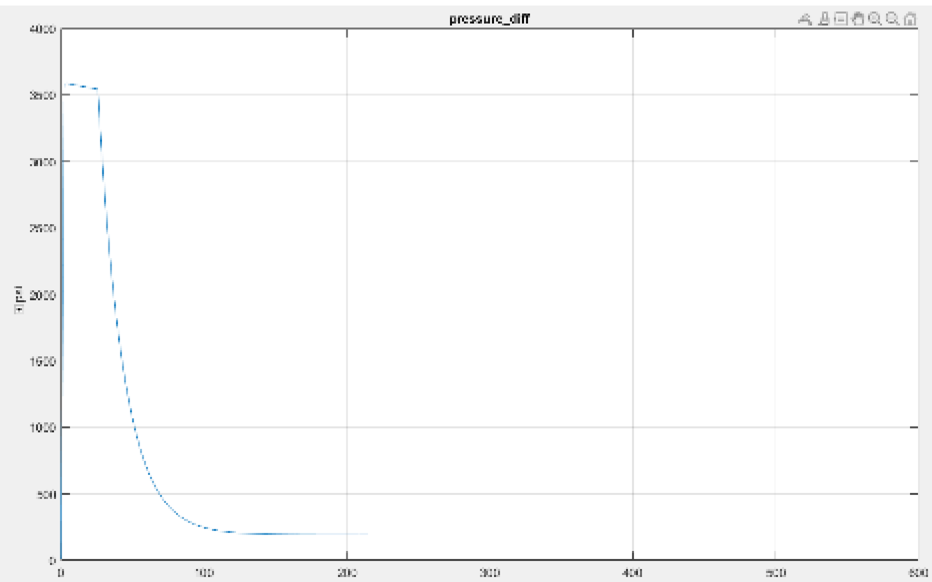
SIMULATED STEADY-STATE VELOCITY = ~17MPH

SIMULATION RESULTS

Motor Flow Rate (gpm) vs. Time (sec.)



Motor Pressure (psi) vs. Time (sec.)



RESULTS

- Leaks in fittings (not completely sealed)
- Chain repeatedly came undone (sprocket too thin for motor, pump-required torque with current setup too high)
- Fluid not reaching motor in direct drive (Likely the direction of flow through the 4w3p switch)

CONCLUSIONS

- Utilize time management more efficiently
- Order extra parts that are inexpensive and you know extra may be needed
- Things don’t always work out as planned/expected
- Engineering for perfection, is not the perfect practice
- Nobody likes COVID

SPECIAL THANKS TO:

NFPA Fluid Power Vehicle Challenge

Danfoss

EATON

BIMBA

Parker

Lubrizol

SUNSOURCE

IFP

CATERPILLAR

NORGREN

NORTHERN ILLINOIS UNIVERSITY
College of Engineering and Engineering Technology
Northern Illinois University

NIU
Northern Illinois University
Machine Shop

NATIONAL FLUID POWER ASSOCIATION
NFPA

NIU

QUESTIONS?

NFPA Fluid Power VEHICLE Challenge

NIU