NFPA Fluid Power Vehicle Challenge

NFPA
Education and Technology Foundation

FINAL PRESENTATION
Kennesaw State University
Jared Ripoli
April 11, 2019

Photo of Vehicle

Team Introductions

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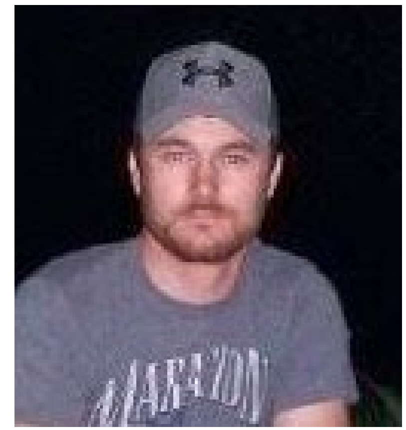

Paola Kimbell

Ashtah Das

Outline

- Problem Statement
- Midway Review Summary
    - Design Objectives
    - Vehicle Design
    - Fluid Power Circuit Design
    - Hardware Selection
    - Results and Analyses
- Vehicle Construction
- Vehicle Testing
- Lessons Learned

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Problem Statement

Design a vehicle that can store and release hydraulic energy while also being able to incorporate regenerative braking.
Design must satisfy the design constraints.
Also, the bike prototype must endure a Sprint Race, Efficiency Race and Endurance Race.

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Midway Review Summary

Design Objectives

- Build the most effective hydraulic circuit
- Safe
- Include regenerative braking
- Low cost/within budget
- Reliable for all 3 races
- Easily portable

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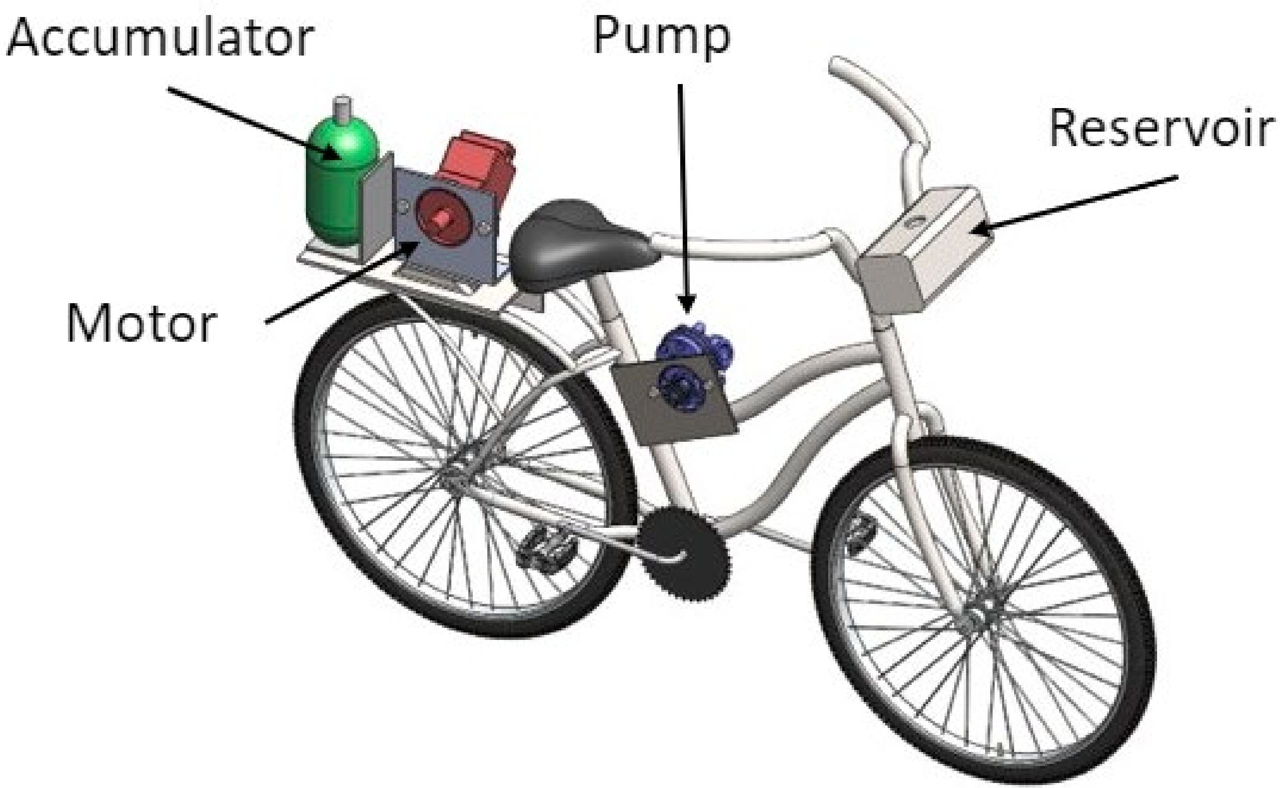
Vehicle Design

- Chose to modify a current bicycle instead of building a new
- This allows for costs savings
- Chose a beach bicycle because of the rear bike rack, and the ability to mount a front basket, both of which will come in handy for retrofitting the bike with hydraulics

Vehicle Design

- Replace the wood in the bike rack with a steel base, this steel base will have a slotted flange plate on the top, allowing the motor to be mounted.
- For the pump, a custom cut piece of plate steel was welded to the bicycle's upper and lower frame. This allows to mount the pump where it will not collide with a rider's legs.

Vehicle Design



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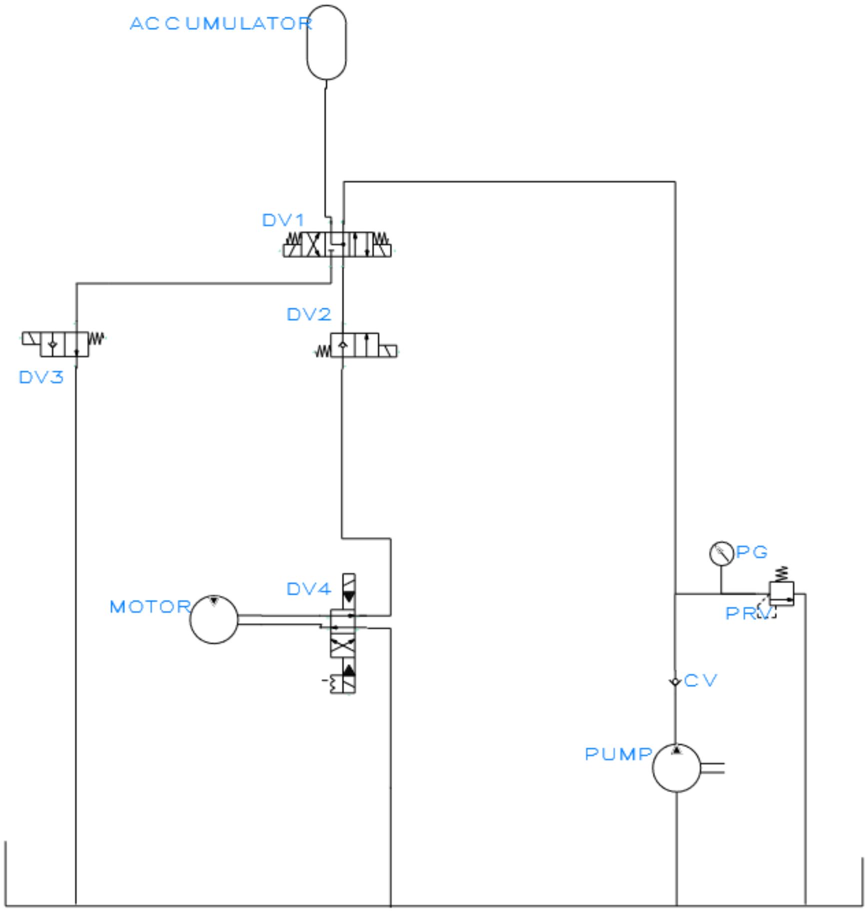
Fluid Power Circuit Design

- Accumulator
- Reservoir
- Pump
- Motor
- CV – Check Valve
- DV1- Directional Valve 1
- DV2- Directional Valve 2
- DV3- Directional Valve 3
- DV4- Directional Valve 4
- PRV- Pressure Valve



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Hardware Selection

- Piston Motor, MA 10

CHARACTERISTICS OF THE MA SERIES MOTORS (SAE)

Motor model	Displacement		Continuous max. speed (1)	Intermittent max. speed (1)	Max. flow absorbed		Torque		Torque at 350 bar (5100 psi)		Theoretical maximal power at 5800 psi 400 bar		Max. allowable pressure continuous / peak		Weight (kg)	
	cu.in/rev	cc/rev	rpm	rpm	gpm	l/mn	lbf.ft/psi	N.m/bar	lbf ft	N.m	HP	kW	psi	bar	lbs	Kg
MA 10	0.62	10.2	8000	8800	21.6	82	0.0082	0.16	42	57	72.9	54.4	5800 / 6525	400 / 450	14.3	6.[illegible]

- Accumulator, 1 quart, SAE -12 port

- Gear Pump, 0.58 CID, Keyed Shaft .625", CW rotation

- Custom made steel reservoir

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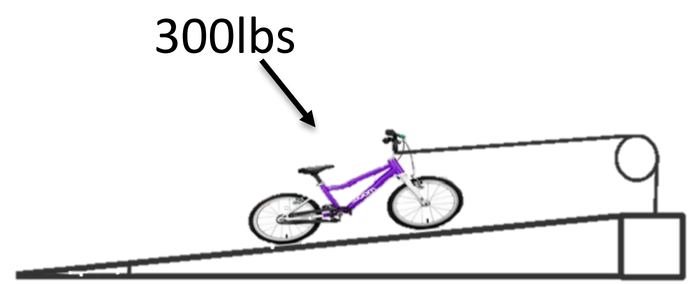
Results and Analyses

1. $Incline = -tan^{-1}(grade)$
   - ❑ $2.862° = -tan^{-1}(.05)$
2. $Weight\ of\ Bike\ + Weight\ of\ Rider = Total\ Weight$
   - ❑ $180lbs + 120lbs = 300lbs$
3. $Uphill\ Pull = -sin(incline) * Total\ Weight$
   - ❑ $14.98lbs\ = -sin(2.862) * 300$
4. $Rolling\ Resistance\ Pull = -cos(incline) * Total\ Weight * Roll\ Resist\ of\ Materials$
   - ❑ $1.2lbs\ pull = -cos(2.862) * 300 * .004$
5. $Max\ Pull = Uphill\ Pull + Rolling\ Resistance\ Pull$
   - ❑ $16.2lbs\ pull =\ 14.98lbs + 1.2lbs$
6. $Torque = Radius * Max\ Pull$
   - ❑ $202.5in * lbs =\ 12.5" * 16.2lbs$
7. $Torque = MotorCIR * \frac{PSI}{2\pi} \rightarrow$

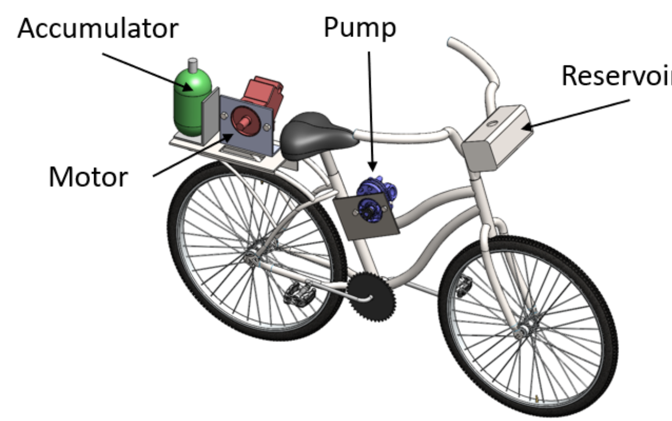
   $MotorCIR = Torque * \frac{2\pi}{PSI}$
   - ❑ $202.5in * lbs =\ 12.5" * 16.2lbs$

Free Body Diagram



Results and Analyses

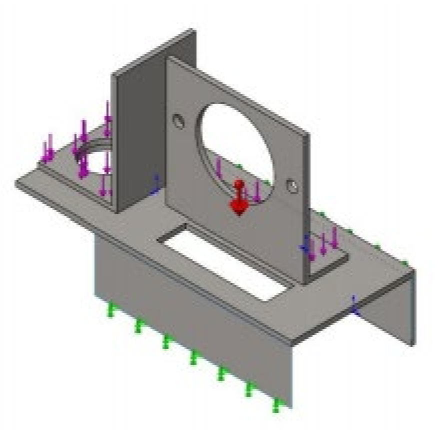
8. $Motor\ Size = \frac{Motor\ CIR}{Motor\ Efficiancy}$
   - $0.564\ CIR = \frac{508\ CIR}{0.9}$
9. $Wheel\ RPM = \frac{336*(desired\ mph)}{Diameter\ of\ wheel(in)}$
   - $201.6\ RPM = \frac{336*15\ mph}{25"}$
10. $Pump\ RPM = Pedaling\ RPM * Gear\ ratio$
    - $240RPM = 60RPM * \frac{4}{1}$
11. $Pump\ CIR = \frac{Motor\ Size*231}{Pump\ RPM}$
    - $0.543CIR = \frac{0.564*231}{240}$
12. $Pump\ Size = \frac{Pump\ CIR}{Pump\ Efficiancy}$
    - $0.603\ CIR = \frac{0.543}{0.9}$
13. $GPM\ Required = \frac{Motor\ Size*Wheel\ RPM}{231}$
    - $0.492\ GPM = \frac{0.564*201.6}{231}$
14. $Max\ Velocity = \frac{0.32*GPM}{Hose\ Area} \rightarrow Hose\ Area = \frac{0.32*GPM}{Max\ Velocity}$
    - $0.00787in^2 = \frac{0.32*0.492}{\frac{20\ ft}{s}}$
15. $Hose\ Diameter = Hose\ area^{0.5}$
    - $0.0887\ in = (0.00787)^{0.5}$

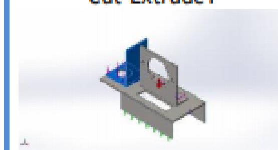


Results and Analyses

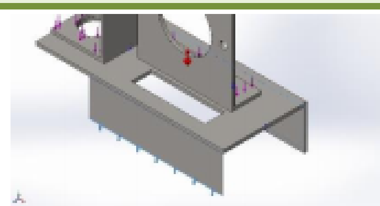
- Total Weight: 300lbs
- Uphill Pull: 14.98lbs
- Rolling Resistance Pull: 1.2lbs
- Max Pull: 16.2lbs
- Torque: 202.5in*lbs
- MotorCIR: 0.508CIR
- Motor Size: 0.564CIR
- Wheel RPM: 201.6RPM
- Pump RPM: 240RPM
- Pump CIR: 0.543CIR
- Pump Size: 0.603CIR
- GPM Required: 0.492GPM
- Hose Diameter: 0.0887in

Results and Analyses



Solid Bodies		
Document Name and Reference	Treated As	Volumetric Properties
Cut-Extrude1 	Solid Body	Mass:1.11918 kg Volume:0.000143485 m^3 Density:7800 kg/m^3 Weight:10.968 N
Cut-Extrude4 	Solid Body	Mass:3.07823 kg Volume:0.000394645 m^3 Density:7800 kg/m^3 Weight:30.1667 N

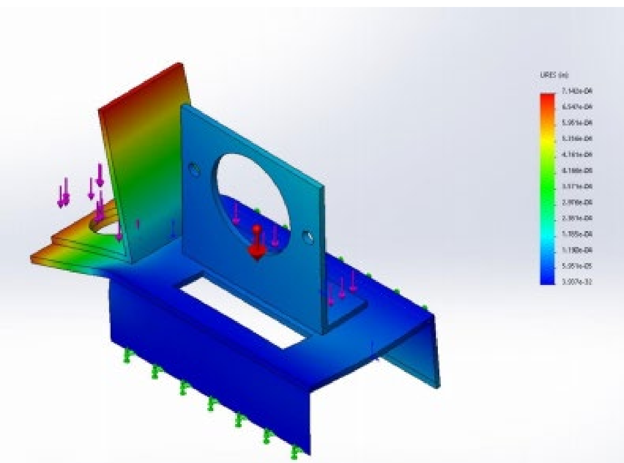
Loads and Fixtures

Fixture name	Fixture Image	Fixture Details
Fixed-1		Entities: 2 edge(s) Type: Fixed Geometry

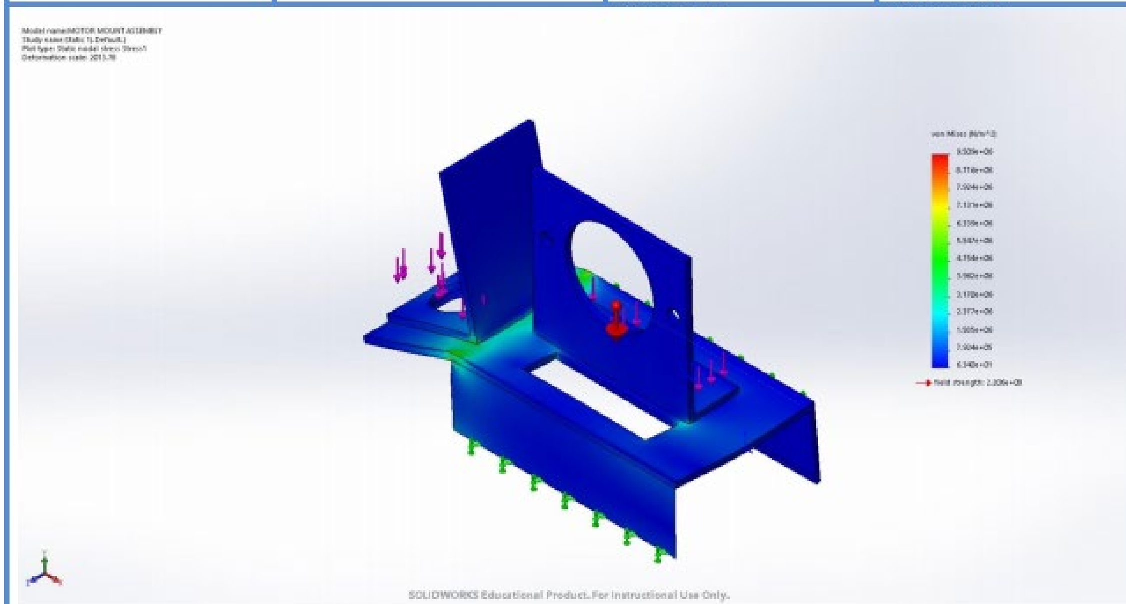
Resultant Forces

Components	X	Y	Z	Resultant
Reaction force(N)	-0.108724	191.487	0.0043906	191.487
Reaction Moment(N.m)	-0.511723	0.00124655	0.000723609	0.511725

Results and Analyses



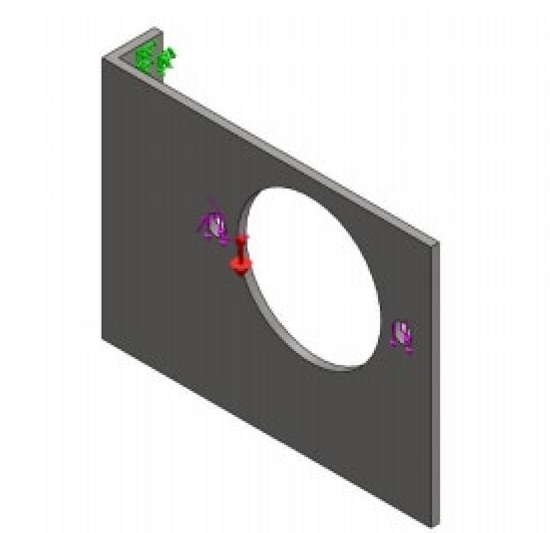
Name	Type	Min	Max
Stress1	VON: von Mises Stress	6.340e+01 N/m^2 Node: 2993	9.509e+06 N/m^2 Node: 29566

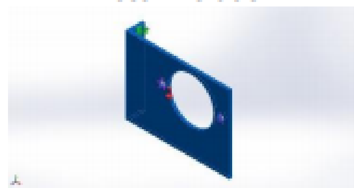


MOTOR MOUNT ASSEMBLY-Static 1-Stress-Stress1

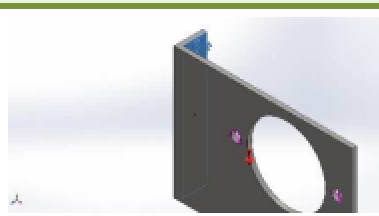
Name	Type	Min	Max
Displacement1	URES: Resultant Displacement	0.000e+00 in Node: 16253	7.142e-04 in Node: 12

Results and Analyses



Solid Bodies		
Document Name and Reference	**Treated As**	**Volumetric Properties**
Boss-Extrude4 	Solid Body	**Mass:0.906301 kg Volume:0.000116192 m^3 Density:7800 kg/m^3 Weight:8.88175 N**

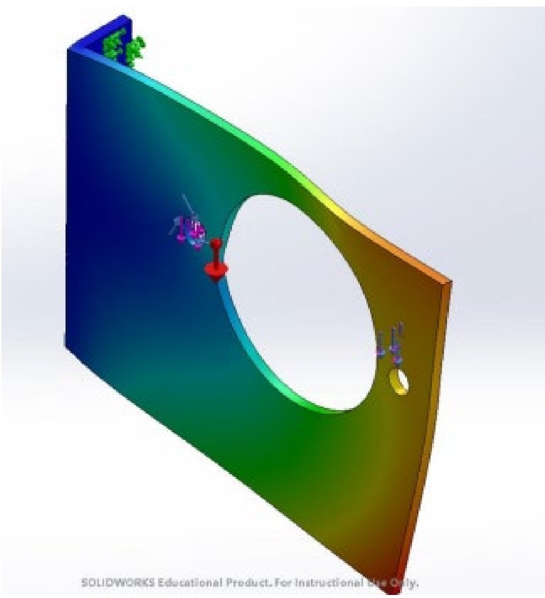
Loads and Fixtures

Fixture name	Fixture Image	Fixture Details
Fixed-1		**Entities:** 1 face(s) **Type:** Fixed Geometry

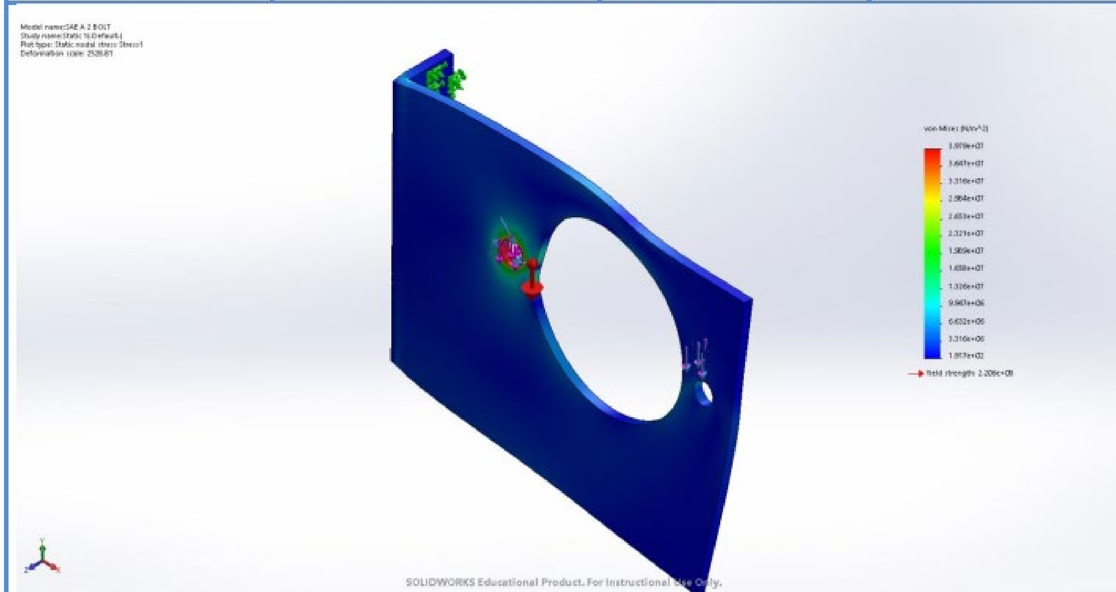
Resultant Forces

Components	X	Y	Z	Resultant
Reaction force(N)	-0.113288	246.121	-0.0876284	246.122
Reaction Moment(N.m)	0	0	0	0

Results and Analyses



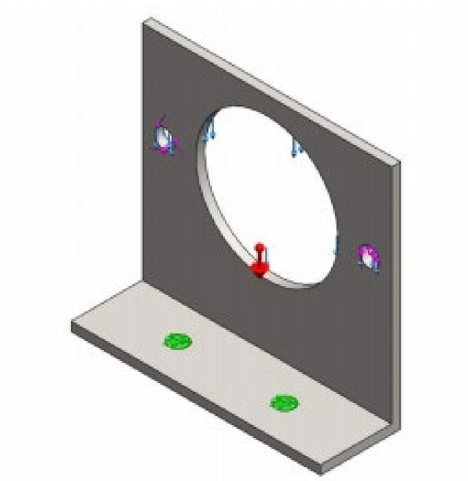
Name	Type	Min	Max
Stress1	VON: von Mises Stress	1.917e+02 N/m^2 Node: 83005	3.979e+07 N/m^2 Node: 272

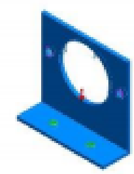


SAE A 2 BOLT-Static 1-Stress-Stress1

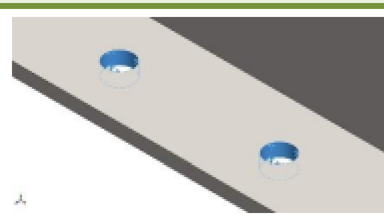
Name	Type	Min	Max
Displacement1	URES: Resultant Displacement	0.000e+00 in Node: 3	3.426e-04 in Node: 5

Results and Analyses



Solid Bodies		
Document Name and Reference	Treated As	Volumetric Properties
Cut-Extrude1 	Solid Body	Mass:1.47122 kg Volume:0.000188619 m^3 Density:7800 kg/m^3 Weight:14.418 N

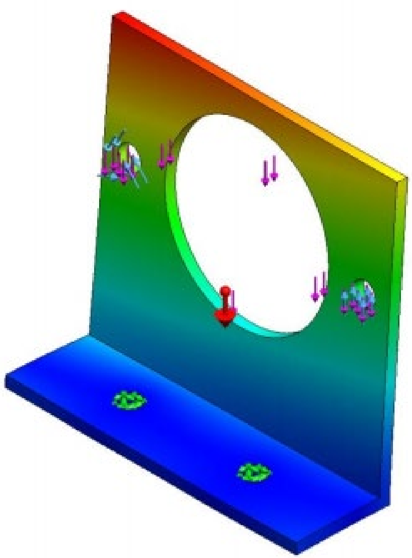
Loads and Fixtures

Fixture name	Fixture Image	Fixture Details
Fixed-1		Entities: 2 face(s) Type: Fixed Geometry

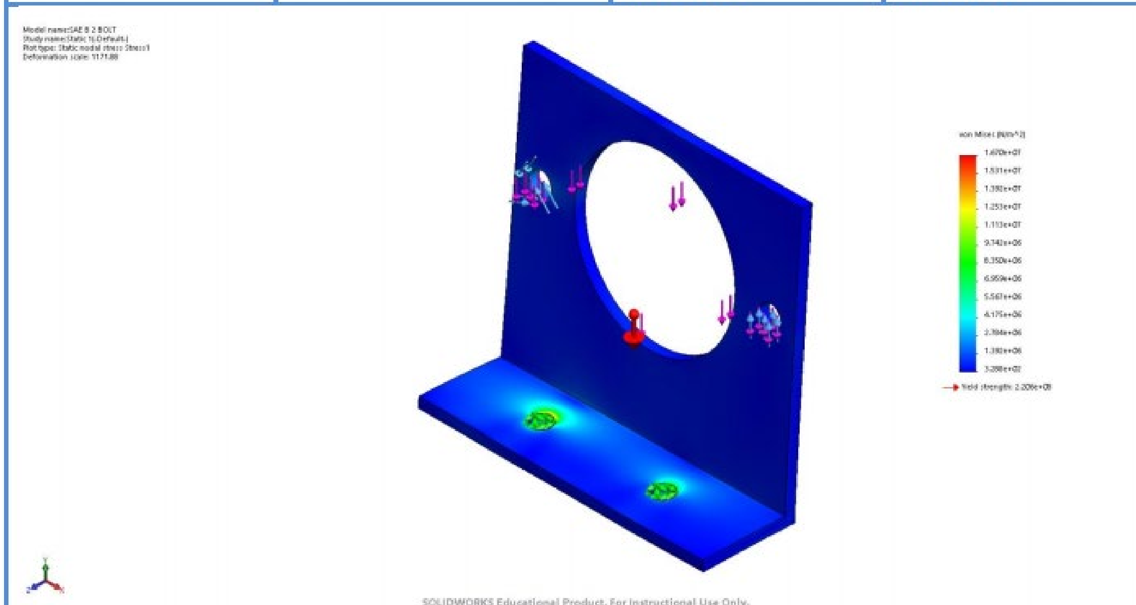
Resultant Forces

Components	X	Y	Z	Resultant
Reaction force(N)	0.00250059	160.654	0.00701411	160.654
Reaction Moment(N.m)	0	0	0	0

Results and Analyses



Name	Type	Min	Max
Stress1	VON: von Mises Stress	3.288e+02 N/m^2 Node: 18033	1.670e+07 N/m^2 Node: 19094



SAE B 2 BOLT-Static 1-Stress-Stress1

Name	Type	Min	Max
Displacement1	URES: Resultant Displacement	0.000e+00 in Node: 1035	6.207e-04 in Node: 4

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Vehicle Construction

NFPA Fluid Power Vehicle Challenge

Welded the mount to the back rack which had a slot for the accumulator. Also welded a bracket for the motor.

Welded the pump mount to the frame

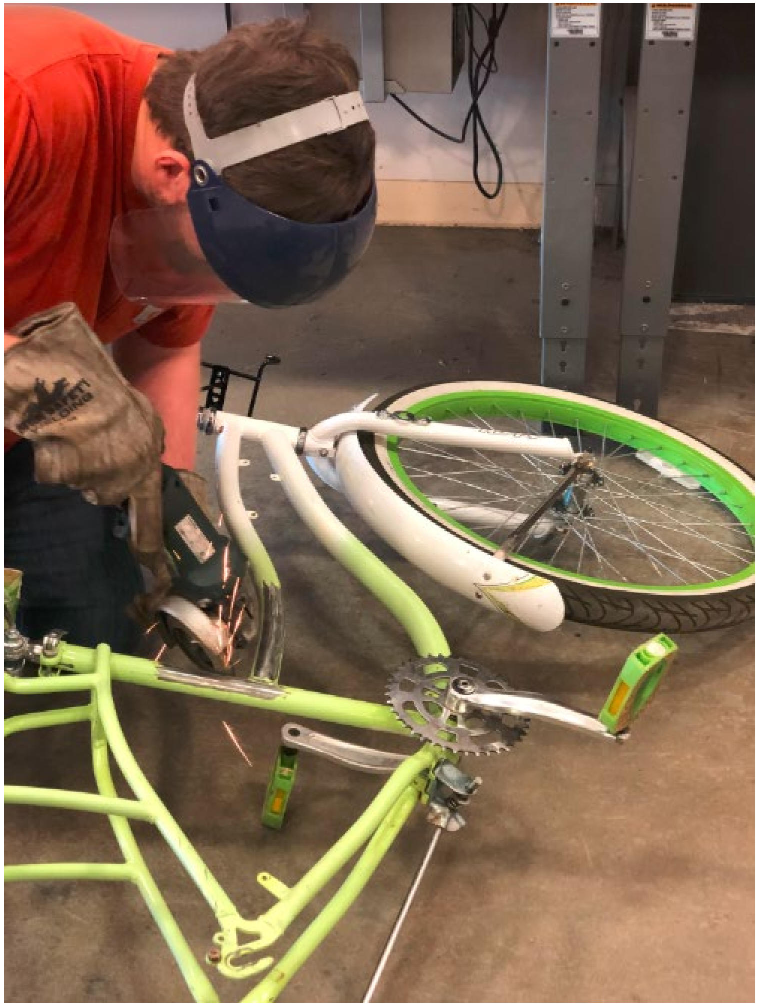
Vehicle Construction

Valves were attached to hoses and zip tied to the frame

Reservoir was placed in the basket

Training wheels were added to maintain balance

Vehicle Construction



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Vehicle Testing

- Vehicle testing
  - Was performed and improvements were made based on results such as:
    - Training wheel selection to account for better balance
    - Mounting of the motor
    - Welding vs not welding changes
    - Axle changes
    - Gear vs. Piston Motor
    - Change hose lengths to account for turns
    - Electrical circuit rearrangements to the frame
    - Selection of rider

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Lessons Learned

- Begin manufacturing and testing earlier
- Always have a backup plan
- Include time in your schedule for last minute issues
- Distribute weight more evenly
- Do research on the different types of bicycles and pick accordingly
- Be more flexible about using the budget