NFPA Fluid Power Vehicle Challenge: *Purdue Hydro-Cruiser*

PURDUE UNIVERSITY

Agricultural & Biological ENGINEERING

CENTER FOR COMPACT AND EFFICIENT FLUID POWER
A National Science Foundation Engineering Research Center

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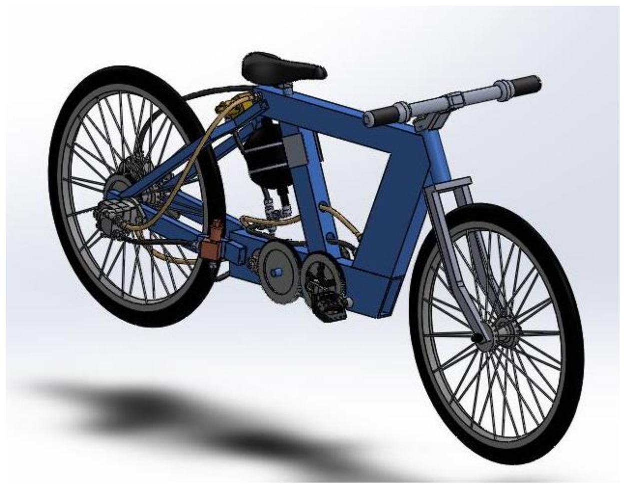
Vision and Ideas

This vehicle was designed to meet two objectives: to compete the NFPA Fluid Power Vehicle challenge and to be a competitive addition to the off road vehicle marketplace.

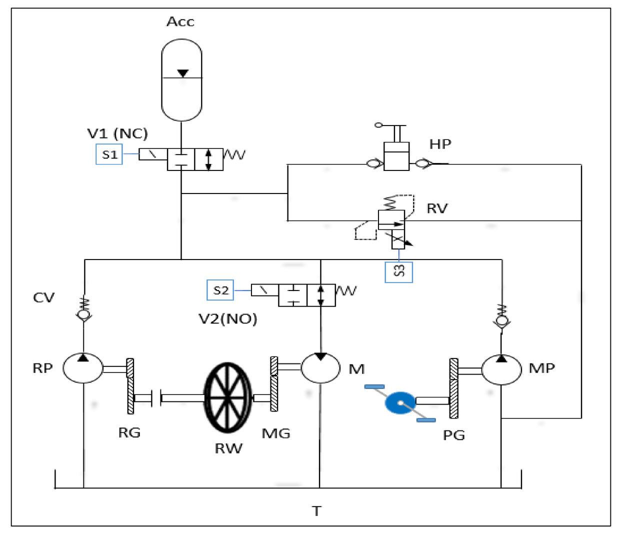


Vehicle performance
- Maximum Speed – 5.82 m/s
- Boosting Distance – 244 m

Key Features
- Light Weight – 128.5 kg
- Internal Oil Reservoir
- Aluminum-Carbon Fiber Accumulator
- Energy Storage and Regeneration System
- Electronic control System

Hydraulic System Design

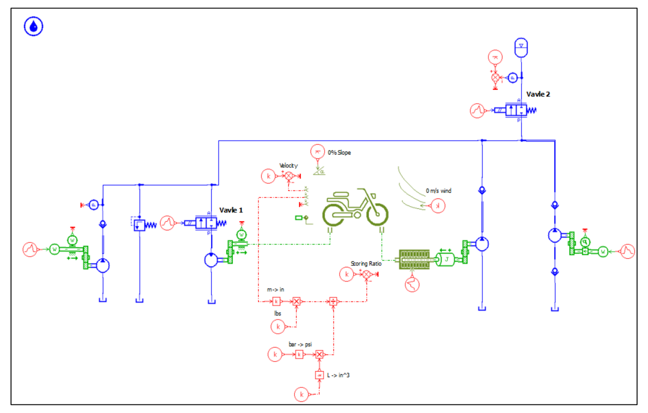
Hydraulic Circuit Layout
- A hydraulic circuit layout was developed to describe the working principle of the hydraulic system.



Layout of Hydraulic Circuit

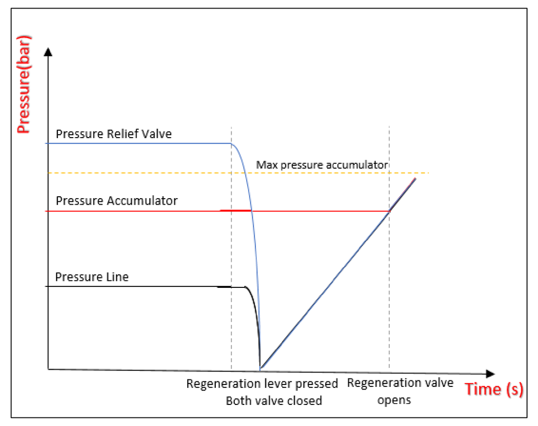
Four Operation Modes
- Pedaling Mode
- Charging Mode
- Boost Mode
- Regeneration Mode

AMESim Simulation
- Numerical Optimization
- AMESim Simulation Models

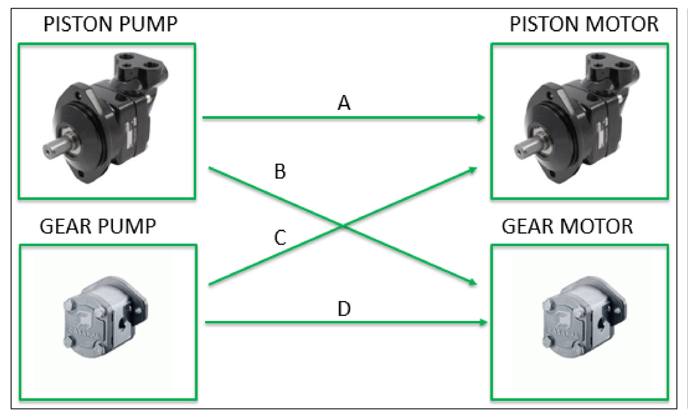


AMESim simulation circuit layout

- Controlled regeneration

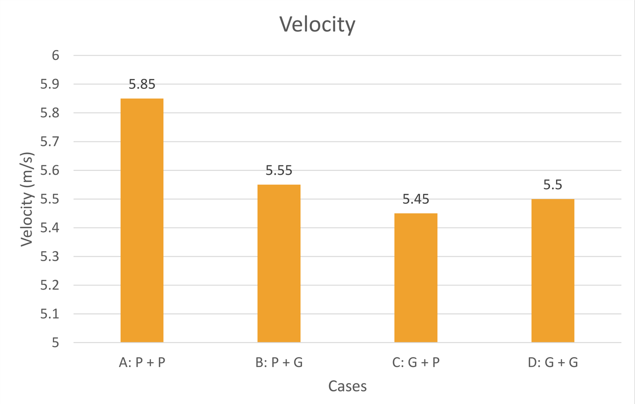


Components Selection
- The components of the hydraulic system are selected base on the simulation results comparing the performances of piston vs. gear pumps and motors.



4 Combination cases compared

Scoring ratio between 4 cases



Linear velocity between 4 cases

Selected Component	Noted Feature
Parker F11 Pump	4.9 cc/rev
Parker F11 Motor	4.9 cc/rev
Steelhead Composites Accumulator	2.00 L
Approximate Pre-Charge Gas Pressure in Accumulator	25 bar
Front Gear Ratio	120/19
Rear Gear Ratio	100/17
Performance in the Boost Mode	
Max Speed	5.42 m/s
Efficiency Function Value	59.81%
Projected Distance Traveled	244.01 m

Performance in Pedaling Mode	Noted Feature
Power Generated	170 W
Torque Input	27 N*m
Pump Shaft Speed	388 rpm
Projected Bike Speed	5.82 m/s
Main Line Pressure	49.68 bar
Main Line Flowrate	1.82 L/min
Pump Volumetric Efficiency	94.50%
Pump Mechanical Efficiency	92.50%
Motor Volumetric Efficiency	95.95%
Motor Mechanical Efficiency	93.10%
Hydraulic Transmission Efficiency	79.24%

Hydraulic components selection and corresponding performance

Cost Analysis

- Prototype Vehicle

Subsystem	Cost [$]
Frame	297.27
Gear Boxes	384.18
Bicycle Parts	238.54
Hydraulic Circuit	790.00
Pumps & Motors	4035.65
Electronic Circuit	730.52
Sensors	355.20
Donated Parts	4951.20
Total	7911.27

Cost Analysis without Donation from Sponsors

Total cost with donations: $2960.07
Total cost without donations: $7911.27

- Mass Production

Basic Model	
Shimano Alfine 8 Speed Gear System	$ 328.92

Simple Model	
Shimano Alfine 8 Speed Gear System	$ 328.92
Electronic Control System	$ 730.52
Total	$ 1,059.44

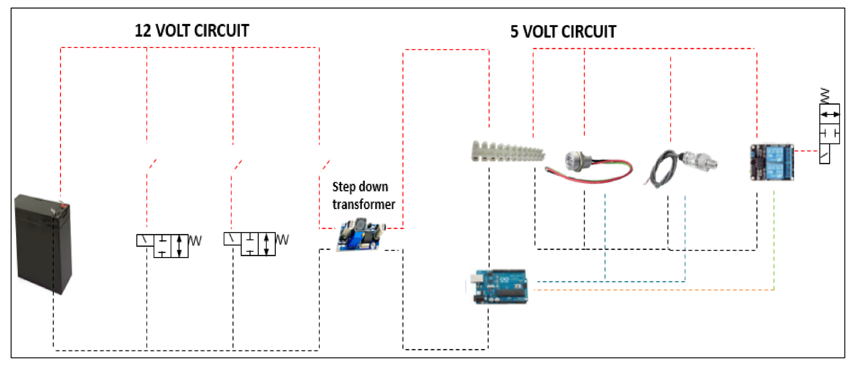
Premium Model	
Shimano Alfine 8 Speed Gear System	$ 328.92
Electronic Control System	$ 730.52
Energy Storage System	$ 245.68
Total	$ 1,305.12

Luxury Model	
Shimano Alfine 8 Speed Gear System	$ 328.92
Electronic Control System	$ 730.52
Energy Storage System	$ 245.68
Regeneration System	$ 530.25
Total	$ 1,835.37

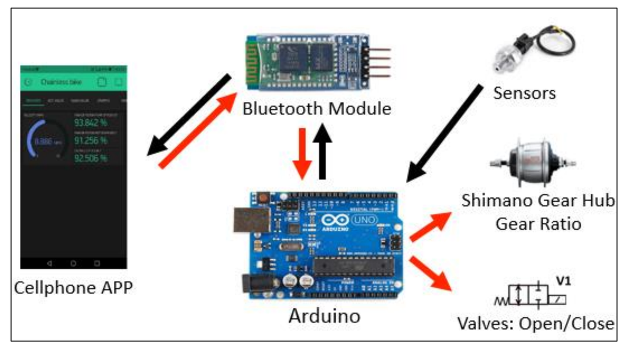
Platinum Model	
Shimano Alfine 8 Speed Gear System	$ 328.92
Electronic Control System	$ 730.52
Energy Storage System	$ 245.68
Regeneration System	$ 530.25
Custom Paint Job	$ 100.00
Total	$ 1,935.37

Electronic Control System

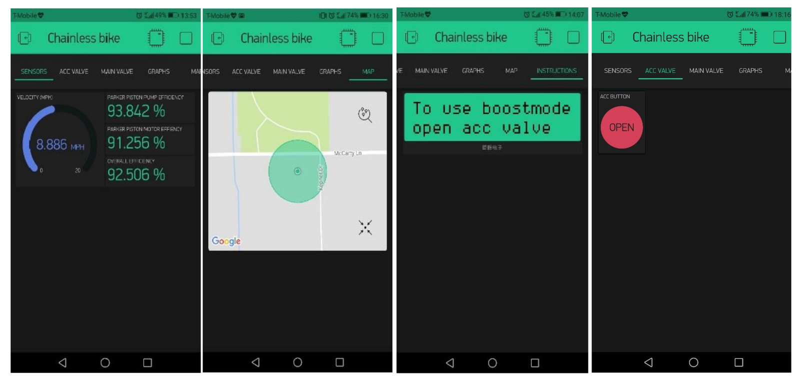
- Arduino control
- Bluetooth connection
- Phone App interface
  - Vehicle data monitoring
  - Localization
  - Gear shifting
  - Valve control



Electric circuit



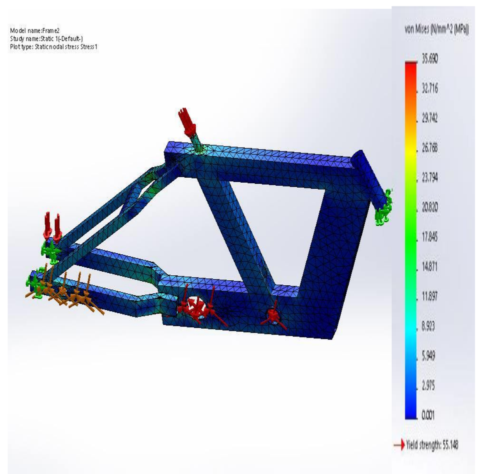
General connection between devices



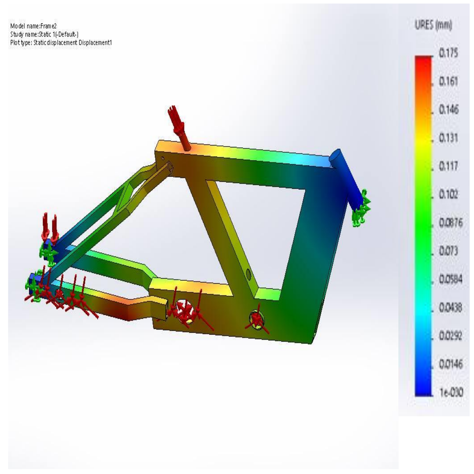
Phone app homepage

Mechanical System Design

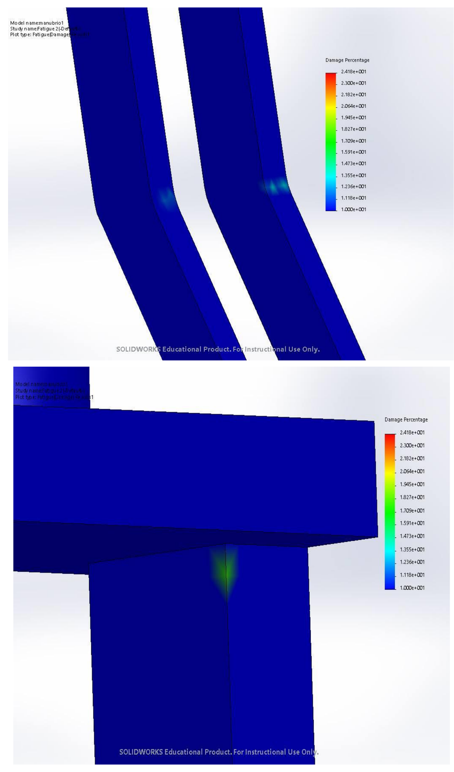
Frame FEA
- Yield Stress 55 MPa (Al 6061 weld)
- Max. Deformation 0.2 mm
- Safety factor 1.6



Static stress analysis

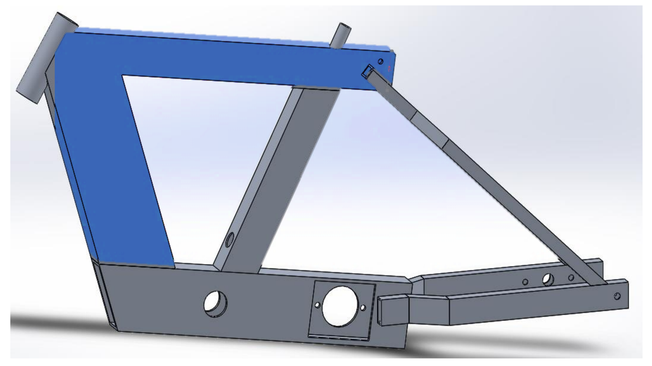


Displacement analysis



Fatigue analysis

Frame Features
- Original design
- Internal oil reservoir
- Triangular structures
- Made of aluminum



Frame with internal oil reservoir

Lessons Learned / Conclusion

- The FPVC provides college students a chance to go deeper in fluid power. After this challenge, we gained experience both in theoretical knowledge and industrial designs
- Our aim to design a product that could be successful in the free market is achieved. We believe the Hydro-Cruiser is optimally designed weight, speed, and efficiency

Sponsors
Danfoss Power Solutions
Parker Hannifin
Sun Source
Eaton Corporation
Lube-Tech
Steelhead Composites
MiSUMi
Casappa
Arduino
HydraForce

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