NFPA Fluid Power Vehicle Challenge

NFPA Education and Technology Foundation

Final Presentation
Northern Illinois University
Ghazi Malkawi
04/21/2022

Meet the Team

Every team member is a senior graduating with their B.S. in Mechanical Engineering in May of 2022. We are using the Fluid Power Vehicle Challenge as our Capstone Project and building off of the last year team's design.

Aleksa Gligorevic - Hydraulics & Electronics

Keegan Clark - Hydraulics & Frame

Chris Monmany - Electronics & Pneumatics

Eric Moriarty - Frame & Hydraulics

Ghazi Malkawi - Advisor

Edgar Torres - Industry Mentor (Bucher Hydraulics)

Pictured from Left to right: Aleksa, Eric, Chris, Keegan

Problem Statement/Objectives

- **Refine and improve last year's design**

biggest Initial Issues

- Hydraulics
  - Previous Hydraulic Circuit was put together with minimal hoses and lots of fittings, which made the system very rigid and prone to leaks.
  - Teflon Tape was used between all the fittings which could have gotten into the system and caused clogging/inefficiencies.
- Frame
  - Chain would slide off of sprocket after about one rotation
  - Because the hydraulics would have to be totally redesigned, we knew we would need a new design on the back of the bike to mount all of our components

- Electronics
  - Wiring was disconnected from the arduino, and when connected based on the given circuit, the system still did not power on.
- Pneumatics
  - Parking brake was not functional and was missing components.

Summary of Midway Review

- Vehicle Frame
    - Reuse the vehicle frame constructed by last team.
    - Initial idea: mount components lower on frame to lower center of gravity
    - We wanted to mount accumulator on its side but we would lose 50-60% of its efficiency.
- Hydraulics
    - Redesigned and includes a manifold to centralize all valves and connections.
    - Hydraulic Braking by turning a manual pressure relief valve.

- Pneumatics
    - Designed an optional air brake system for disc brakes on the rear driving wheel.

Summary of Midway Review

- Initial Sizing Calculations for Pump & Motor
  - Goal speed: 20 mph
  - With initial parameters
    - Required uphill torque: 236 lb/in.
    - Flow rate of 0.3 GPM in direct drive.

- Decided on a gear ratio of 2:1 to meet desired output
  - Change the gears on pump/motor and the sprockets on the pedal and rear wheel.

- Pneumatics
  - 1-1/16” Power Factor would offer enough to pull our brake cable and activate the brake.

Inputs:	
Velocity of Oil for ANSI (ft/sec)	20
Grade (%)	5
Rolling Resistance (concrete)	0.002
Load (lbs)	350
Diameter of Wheel (in)	26
Desired mph	20
Operating PSI	1000

Motor CIR	
(T*6.28)/PSI =	1.483994

Pump CIR	
(GPM*231)/RPM =	3.297765

Calculations for Sizing Air Cylinder

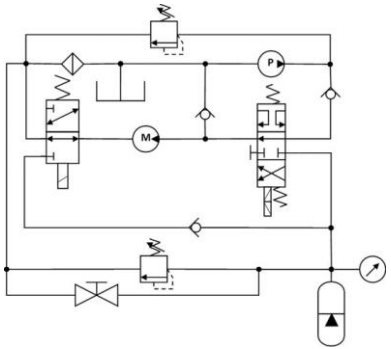
$$F = Operating\ Air\ Pressure * Cylinder\ Piston\ Area$$
$$Extension\ Force = PSI * (Bore\ Area^2 * 0.7854)\ in^2$$
$$Extension\ Force = 100\ PSI * (1.0625^2 * 0.7854)\ in^2$$
$$Extension\ Force = 88.6\ lbs$$

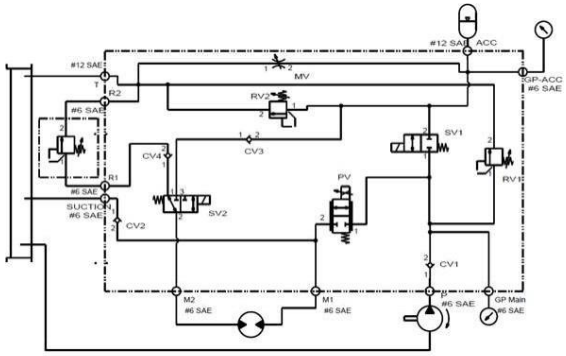
$$Retraction\ Force = PSI * ((Bore\ Area^2 - Rod\ Area^2) * 0.7854)\ in^2$$
$$Retraction\ Force = 100\ PSI * ((1.0625^2 - 0.31^2) * 0.7854)\ in^2$$
$$Retraction\ Force = 81.11\ lbs$$

Design Objectives

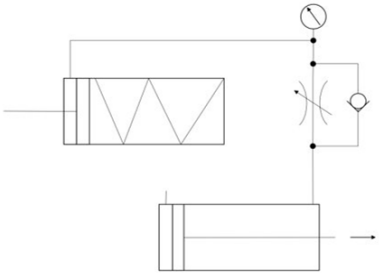
- Improve on the last year's design by making the vehicle faster, improve efficiency, and improve ergonomics.
- Redesign and optimize last team's hydraulic and pneumatic circuits.

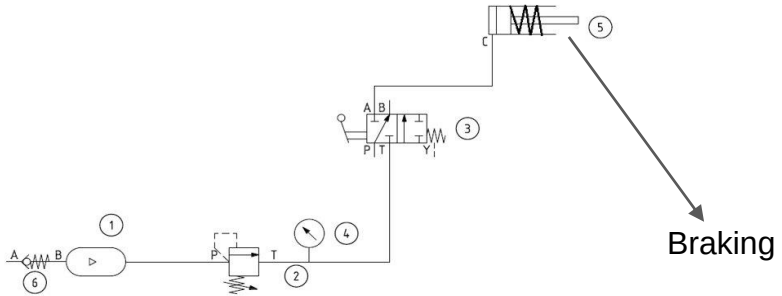
Hydraulic Circuit



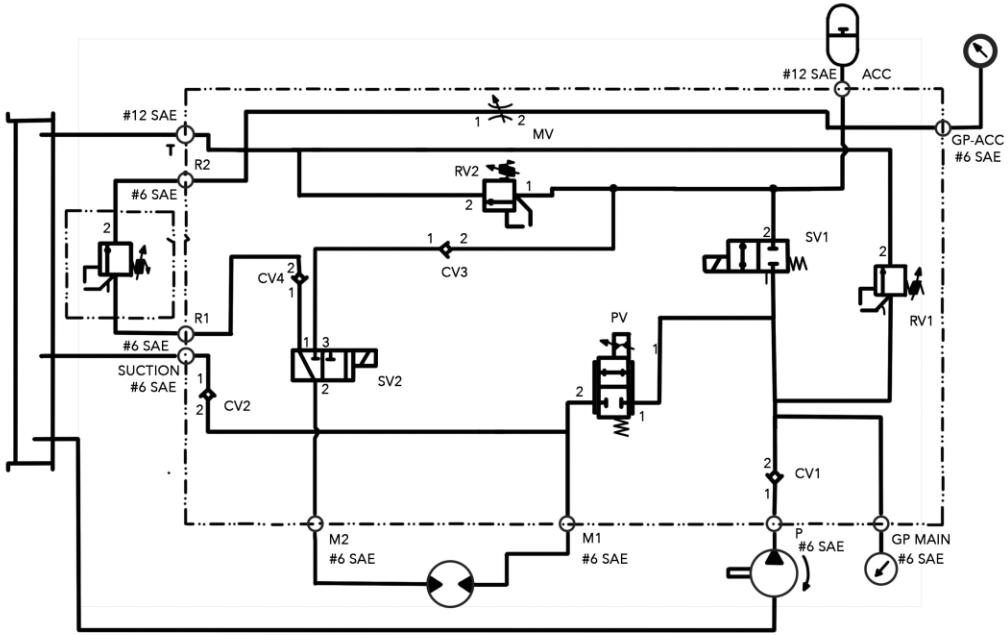


Pneumatic Circuit

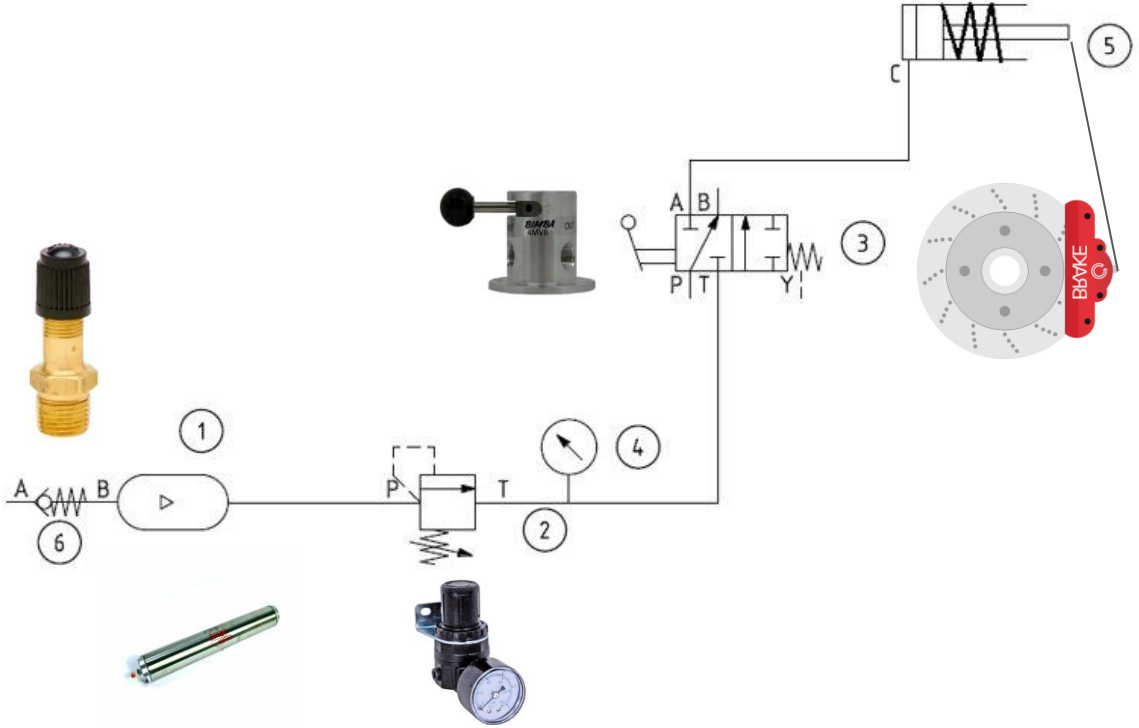




Hydraulic Circuit

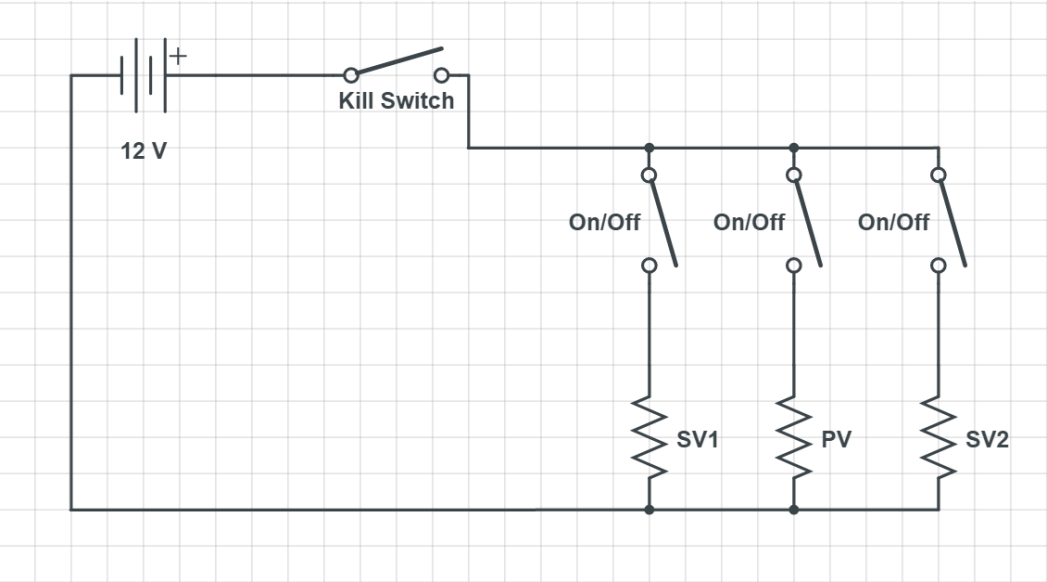


Pneumatic Circuit



- Replaced old parking brake with a manually actuated hand brake.
- Simple and much more accessible
- Previous design's lever for parking brake was out of reach of the rider.

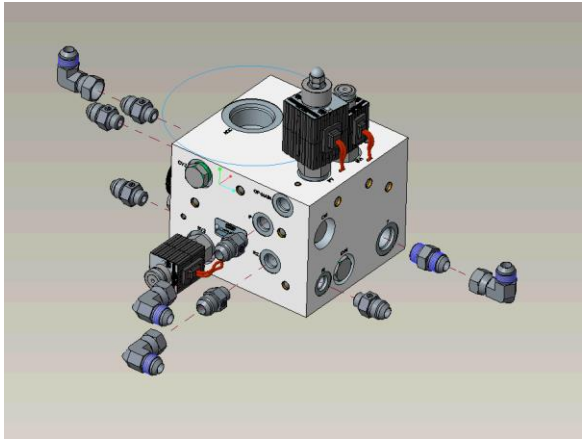
Electrical Circuit



- 12V, 7 Ah SLA Battery
- 4 On/Off Toggle Switches
- Solenoid switches wired in parallel
- Wire connections centralized onto power terminal block w/ 18 AWG wire.

Selection of Hardware-Hydraulics

- Danfoss Gear Pump .659 CID, .625" CW Rotation
- Danfoss Gear Motor .513 CID .625", Birotational
- Accumulator- 1 Gallon SAE-20 Port
- Manifold and Multiple Valves Provided by Bucher Hydraulics
- Assorted AN & SAE Fittings and Hose Assemblies



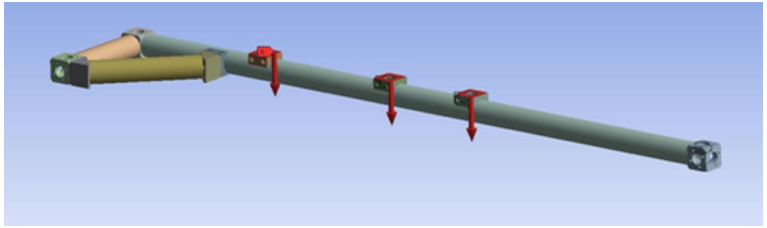
Selection of Hardware-Pneumatics

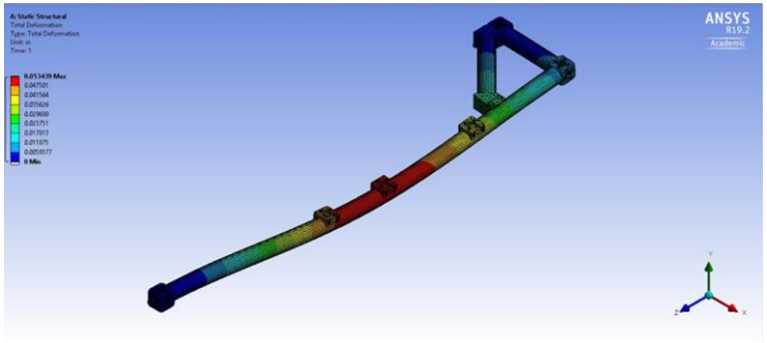
- Norgren Air Reservoir 3” Bore x 17” D-17469-A-17
- Norgren Pressure Regulator MSR200-06
- Norgren Air Cylinder 093-R
- Norgren Rotary Valve 3MV8

Selection of Hardware-Frame

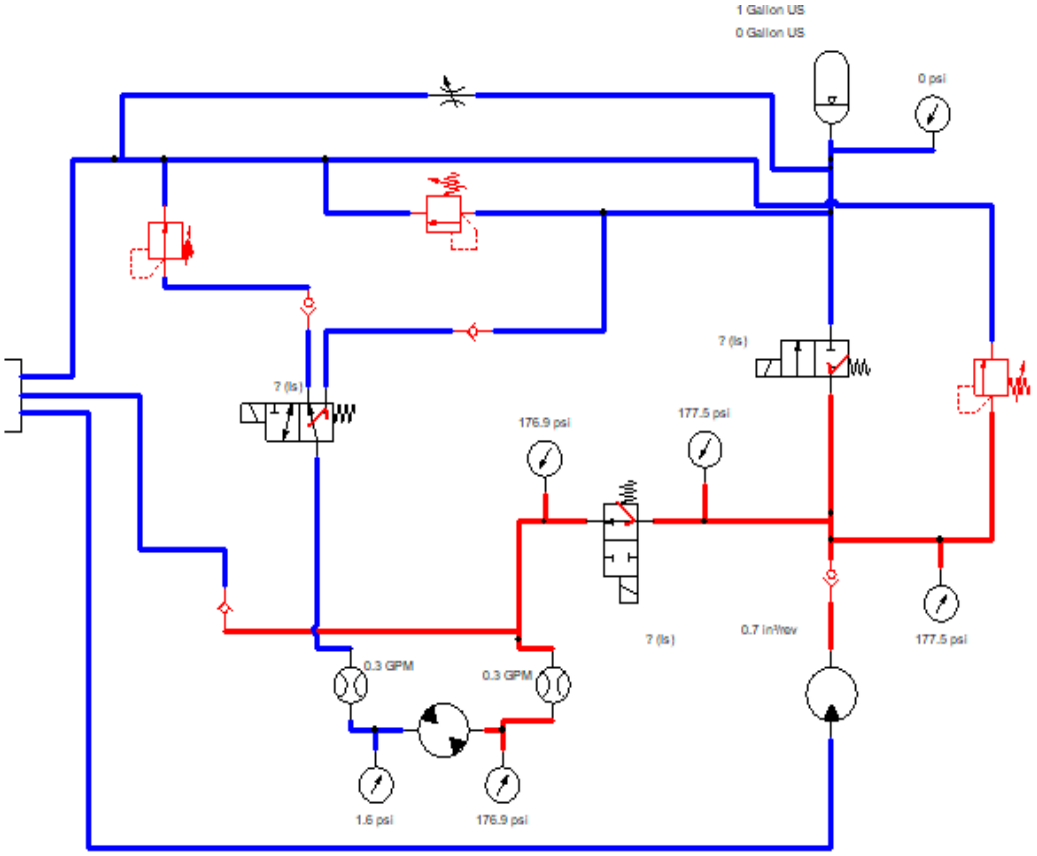
- 12”x 48” Aluminum Sheet used to create back Reservoir Casing, Pedal Plates, and Hydraulic Motor & Pump Mounts,
- Grainger 15 Tooth Gear used on Hydraulic Motor
- SHIMANO M361 Hybrid Crankset
- Goodyear Front Tires

Results and Analysis



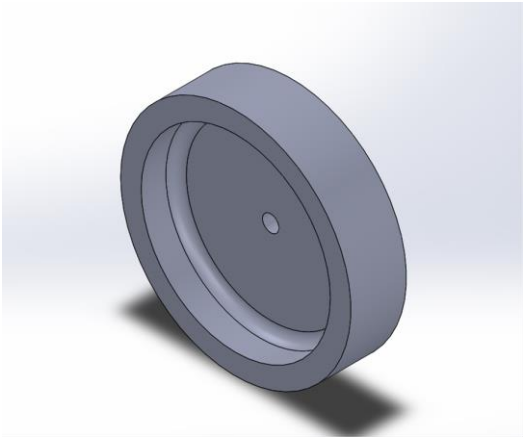


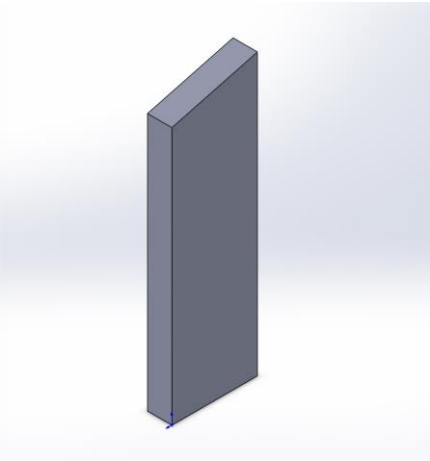
Total Deformation of the frame. Maximum total deformation is 0.053439 in



Vehicle Construction and Testing

- Chain Slipping off of Back Wheel Gear
  - 3d Printed Hub
  - Removed Links in chain
- Vehicle wouldn't move
  - Changed the gear ratio throughout the entire bike.
  - Vehicle wheels were toed out and had too much negative camber
- The front end was not sturdy enough causing chain to jump
  - Added “Pedal Plates”
  - Tightened every bolt
  - Added in a chain tensioner





Final Vehicle

Cad Model

Final Assembly

Lessons Learned

- Order Everything ASAP
  - The earlier you order, the sooner you can begin building/testing.
- Don't assume that everything was put together correctly from previous years
  - Test everything!
- Have a plan and backup designs/components
  - Designs may work on on Solidworks and simulations. But until you actual build it you realize how it can be different from the real world.
- Don’t rely solely on calculations and simulations
  - They can be a good starting point, but those are ideal conditions. The vehicle will have inefficiencies that are unaccounted for in the simulations.

Acknowledgment

We would like to thank our industry mentor Edgar Torres and Bucher Hydraulics for all the guidance and materials for this project. We would also like to thank our faculty advisors Ghazi Malkawi and Lucas Greenlee along with Ernie Parker, Kent Sowatzke, & Stephanie Scaccianoce of the NFPA for working closely with us during the designing, ordering and reconstruction of our Fluid Powered Vehicle.

Additional Thanks to:

- National Fluid Power Association
- Bucher Hydraulics
- Northern Illinois University
- Sunsource
- Norgren
- Lubrizol
- Parker Hannifin
- Eaton
- IFP Motion Solution
- Danfoss
- Vest
- Sunsource Fluid Power

Questions