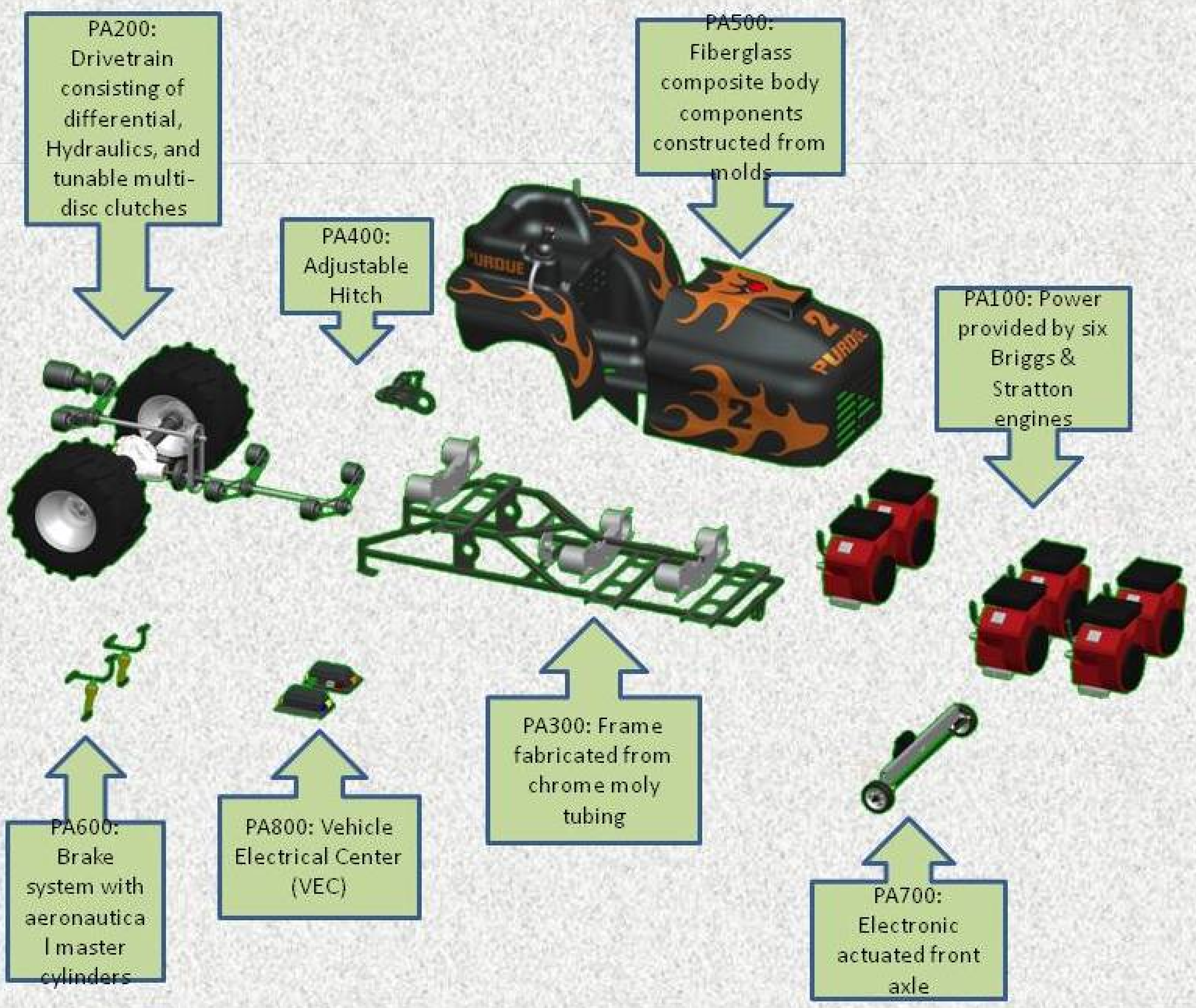
Design

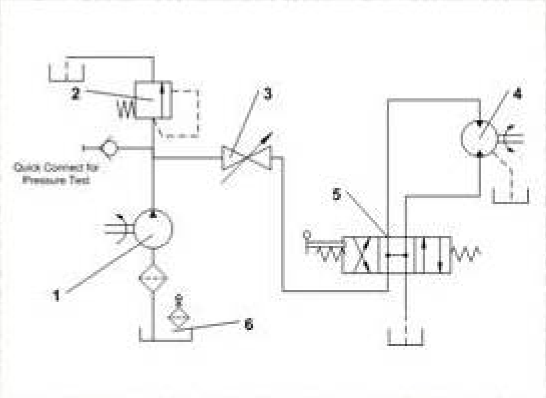
PQS08 was designed with the goal to meet all of our objectives as efficiently as possible. Below are the subassemblies of the tractor along with the key features of each system.



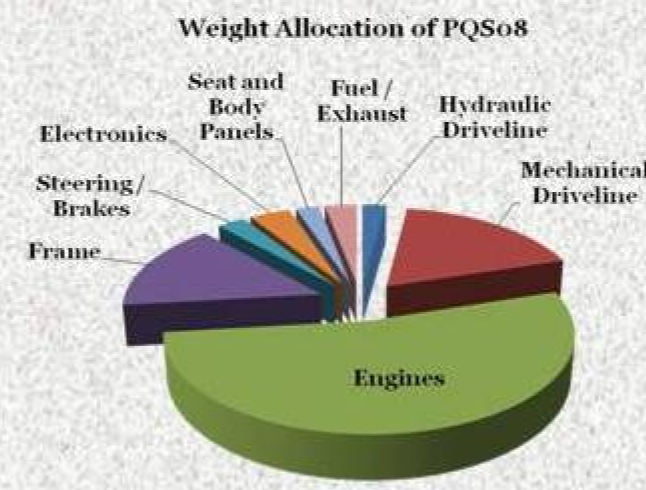
Parallel Path Driveline:

For low idle maneuverability and reverse, PQS08 incorporates a compact, independent hydrostatic power path. Specifications are:

- zero to six mph forward speed
- 175 lbf of horizontal motive force.
- Precise control of vehicle motion



No.	Part No.	Name	Remarks
1	PP292	Pump	Parker Hannifin Model D09 Fixed Displacement Gear Pump Order Number: D09-AA2-L-250-K Displacement: 0.210 in /rev Pump Flow at 3600 RPM: 11.14 GPM, 2500 PSI Max. Continuous Operating Pressure: 2500 PSI Max. Continuous Operating Speed: 4000 rpm
2	PP294	Relief Valve	Parker Hannifin integrated relief valve (packaged with pump) Relief Pressure: 2500 PSI is preset at factory
3	PP298	Flow Control Valve	Maximum Pressure: At least 2500 PSI Exact model will be determined after sub-plate valve is in-house
4	PP291	Bi-Directional Gear Motor	Sauer-Danfoss Model Code: SKM1/100 CI06 Model Number: 121.12.058.00 Displacement: 0.607 in /rev Peak pressure: 2610 PSI Rated pressure: 2320 PSI Max Speed: 2000 rpm
5	PP293	Directional Control Valve	Parker Hannifin Model D1VL2CN Maximum Pressure: 5000 PSI Maximum Flow: 22 GPM Three position, spring centered Lever operated, open-center directional control valve
6	PP296	Reservoir	Parker Hannifin Kit No. 715631 2-Quart Capacity Tank Integrated into pump case

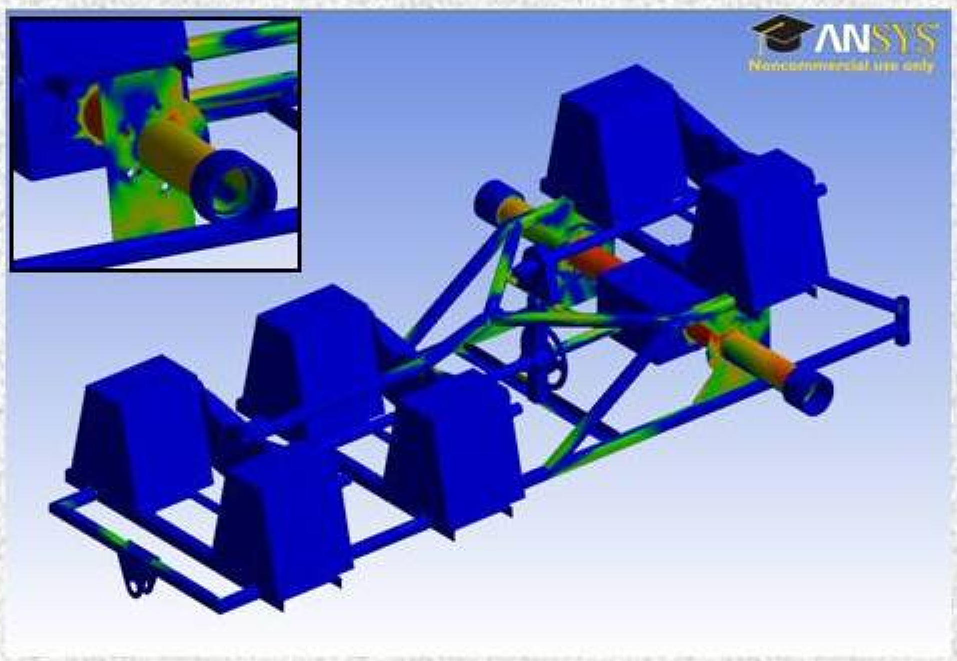


A detailed weight analysis was performed for each system of the tractor to aid in the design process and ensure our 900 pound weight limit is achieved.

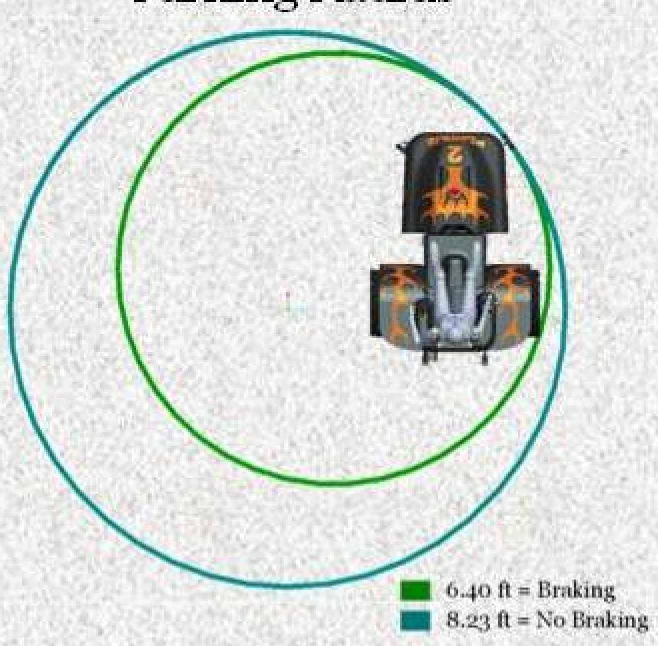
Calculations and Analyses

Loading Conditions for Frame FEA

Feature	x comp	y comp	z comp
External	**(lbf)**	**(lbf)**	**(lbf)**
Engine	0.000	-200.000	
Diff	0.000	-100.000	
Rear Driver's Station		-200.000	
Front Driver's Station (2x)		-100.000	
Fuel Tank		-50.000	
Actuator		-50.000	
Sled Chain		-763.889	-2380.44
Planetary		-20.000	
Internal	**(lbf)**	**(lbf)**	**(lbf)**
Chain			
Left Eng (3)	237.688	-33.236	
Right Eng. (3)	-225.064	-83.343	
Jackshaft to C.S.	0.000	-480.000	
C.S. @ sprockets	-12.623	116.579	
C.S. rear sprocket	0.000	480.000	
Bearing Cup Force	0.000	0.000	-1190.218
Moments	**(in-lb)**	**(in-lb)**	**(in-lb)**
Moment (axle wrap)	35424.000	0.000	
Moment (diff torque)	0.000	0.000	8640
Moment (planetary)	0.000	0.000	2160
Engines			-300



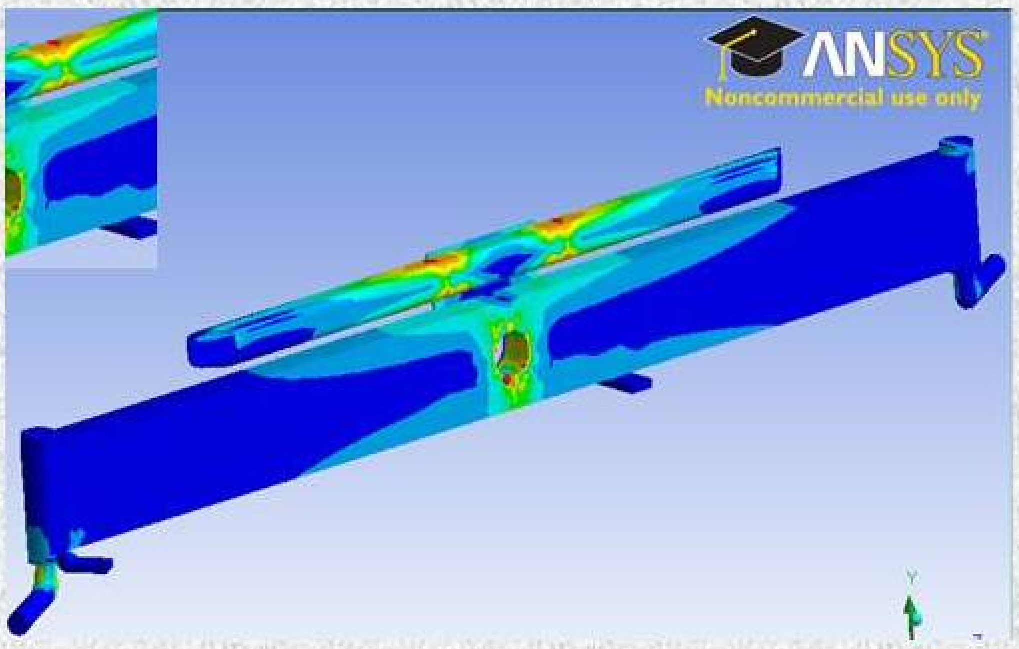
Turning Radius



Steering optimized with 107.5° Ackerman.

Front Axle FEA

1000 lbf load acts downward in middle of front frame rail. One bracket is hidden to better show stress distribution.



Hydraulic System

Required Motor Displacement:

$$Displacement_{motor} = \frac{2 \cdot \pi \cdot Torque_{RequiredMotor}}{Pressure_{System} \cdot Efficiency_{Motor}} = \frac{2 \cdot \pi \cdot 12.267 ft \cdot lbf}{2000psi \cdot 80\%} = 0.578 in^3$$

Common Shaft Speed:

$$Speed_{CommonShaft} = Speed_{Ground} \cdot \frac{Reduction}{2 \cdot \pi \cdot Radius_{Rolling}} = 6mph \cdot \frac{12.33}{2 \cdot \pi \cdot 12.1in}$$

$$= 1.023 \times 10^3 \, min^{-1}$$

Flow Rate:

$$Q = Displacement_{motor} \cdot Speed_{CommonShaft} = 0.578 in^3 \cdot 1.023 \times 10^3 \, min^{-1} = 2.571 \frac{gal}{min}$$

Pump Displacement:

$$Displacement_{pump} = \frac{Q}{Speed_{engine} \cdot Efficiency_{pump}} = \frac{2.571 \frac{gal}{min}}{3600 min^{-1} \cdot 80\%} = 0.206 in^3$$

Driveline Components

Chain Load:

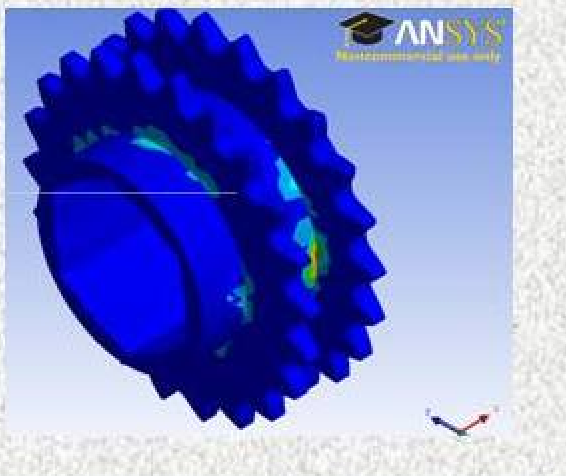
$$P_{chain} = \frac{Torque_{in}}{\left[\frac{PitchDiameter_{sprocket}}{CenterDistance_{between\ pitches}}\right]} = \frac{26 ft \cdot lbf}{\left[\frac{2.1595 in}{24 in}\right]} = 288.9506 \, ft \cdot lbf$$

Percent of Chain Tensile Strength:

$$\%_{TS} = \frac{\sigma_{tensile}}{P_{chain}} = \frac{2100 ft \cdot lbf}{288.9506 ft \cdot lbf} = 13.7596 \, \%$$

Minimum Required Shaft Radius:

$$r = \sqrt[3]{\frac{2 \cdot Torque_{spike}}{\pi \cdot \tau_{allowable}}} = \sqrt[3]{\frac{2 \cdot 3600 \frac{in}{lbf}}{\pi \cdot 20{,}500 \, psi}} = 0.4817 \, in$$



PURDUE UNIVERSITY

Quarter Scale Tractor Design.

John Andruch, James Bartlett, Joseph Dynes, Casey Fillinger, Brad George, Ben Schlipf

John Andruch　Joseph Dynes　Brad George
James Bartlett　Casey Fillinger　Ben Schlipf

Quarter Scale Tractor Design

Problem statement:

Completely design and build a pulling tractor to compete against other teams at the International ¼ Scale Tractor Student Design Competition from May 29th to June 1st.

Previous Purdue Pulling Tractors

Performance is Judged by:

- 4 Sled pulls
- Maneuverability Course

Design is Judged by:

- Manufacturability
- Serviceability
- Ergonomics
- Safety
- Sound Quality

Design Objectives:

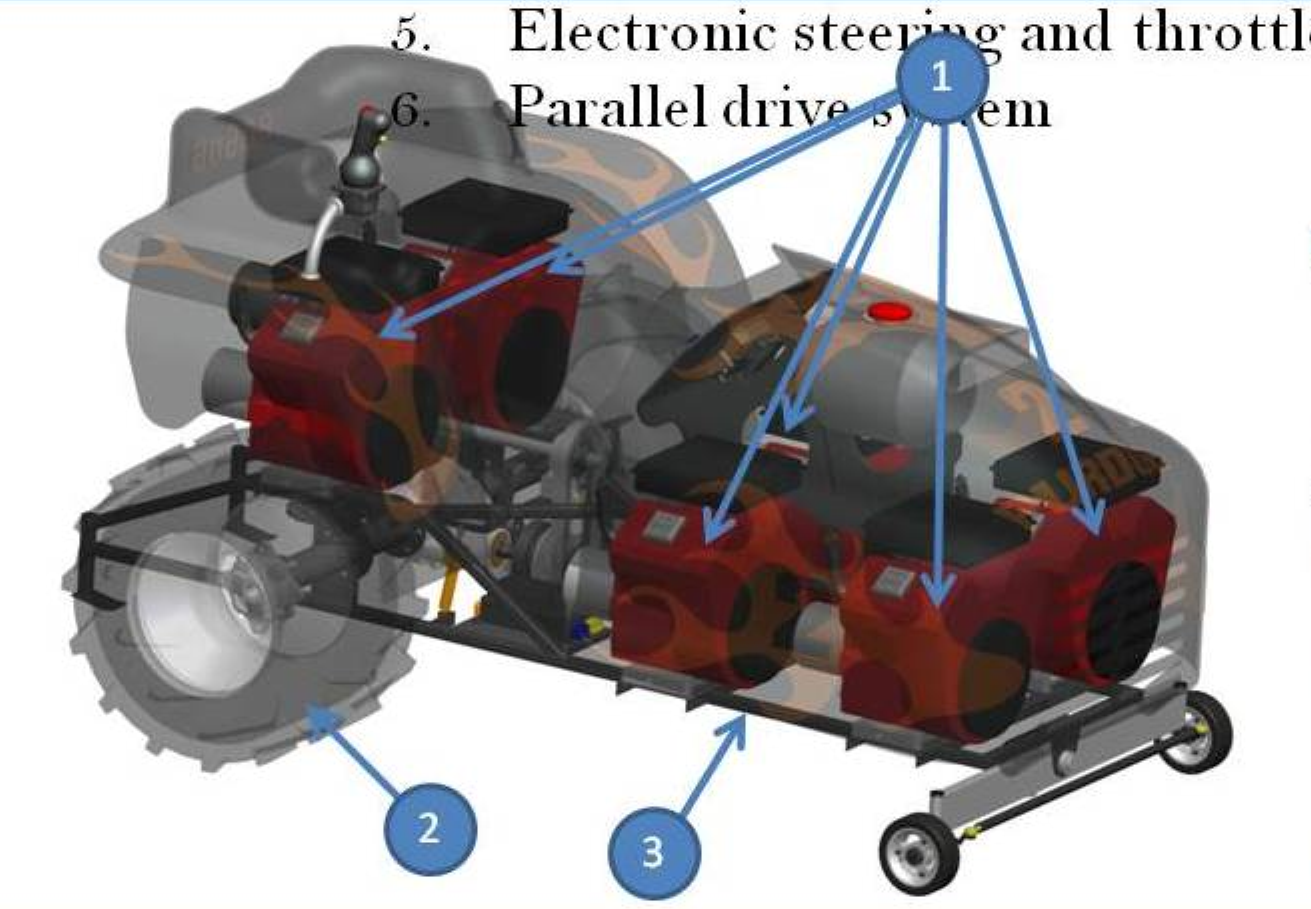
- Move Forward Rapidly for Pulling
- Hold the Weight of the Engines
- Move Forward and Rearward Slowly
- Stop and Steer Motion
- Allow the Operator to Control and Monitor the Tractor
- Hold the Operator Comfortably and Keep them Safe

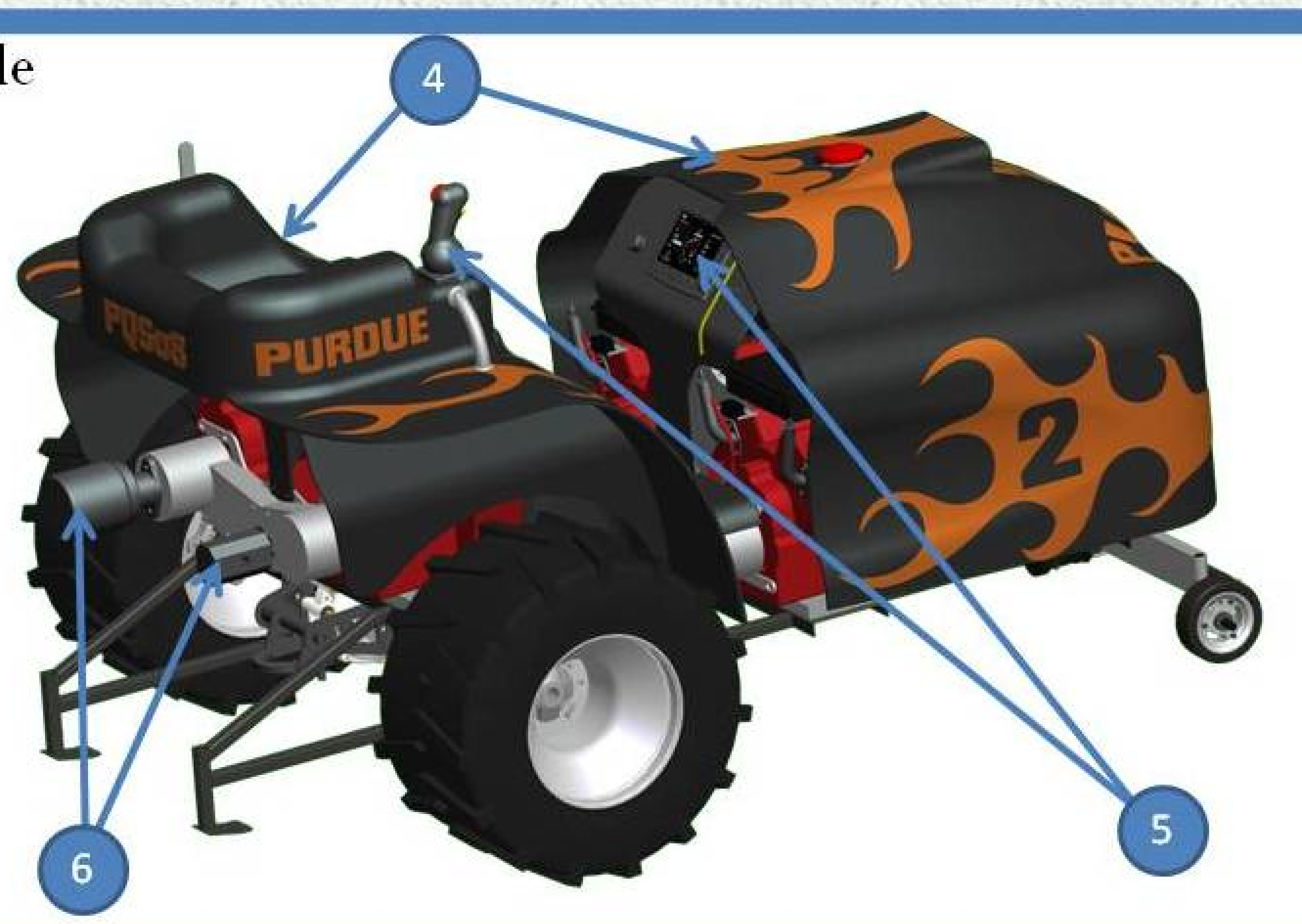
Novelty and Purpose of Project:

We are fine tuning our own engineering skills, creating new innovative solutions to problems, introducing underclassmen to hands-on engineering design, and promoting Purdue ABE.

Design Features

1. Six engines
2. Two wheel drive
3. Light-weight tubular frame
4. Composite body components
5. Electronic steering and throttle
6. Parallel drive system





Implementation

Building of the tractor began with sourcing materials and parts. Some parts were reused from previous years to save money and design time. Rear wheels and tires, brake disks and calipers, the rear differential and wheel hubs, and the front actuator were all components from the previous year. These components were shown from previous performance to be capable of handling the job. Many new components such as front wheels, clutches, and hydraulic components were sized and purchased.

Driveline Shielding:

- Purchased 31.625" x 4" and 41" x 6.5" of ¼" 5052 aluminum plate
- Purchased 71.5" x 22.125" of ¼" 6061 T6 aluminum plate
- Plasma cut 6061 into flat shields and 5052 into bent strengthening ribs
- Welded into three identical shields

Drive Shaft:

- Purchased 1" diameter splined 2024 T4 aluminum shaft
- Customized sprockets for quick-change utility

Frame:

- Purchased 40 feet of 1" x 1" x 0.049" chrome molybdenum steel alloy (4130) square tube
- Cut tube to length and assembled in jig for welding

Rear Axle:

- CV shafts customized to fabricate new involute splined rear axle shafts
- Axle tubes constructed using 4130 round tube with customized ends to hold bearing

Composite Seat and Hood:

- Created negative mold for seat and hood
- Will lay fiberglass sheets with foam structural inserts

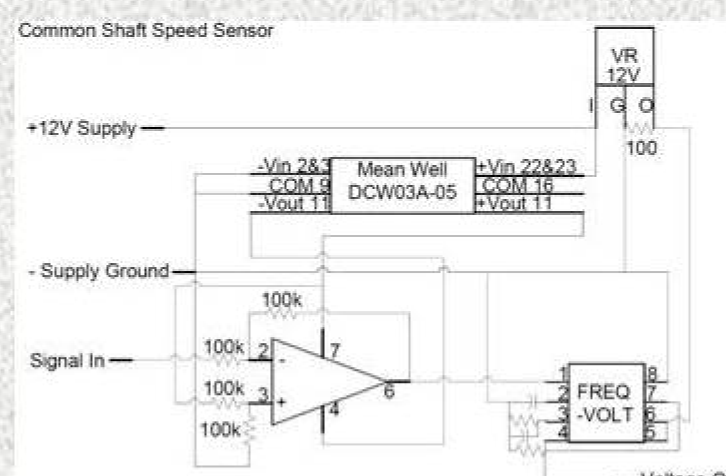
Front Axle:

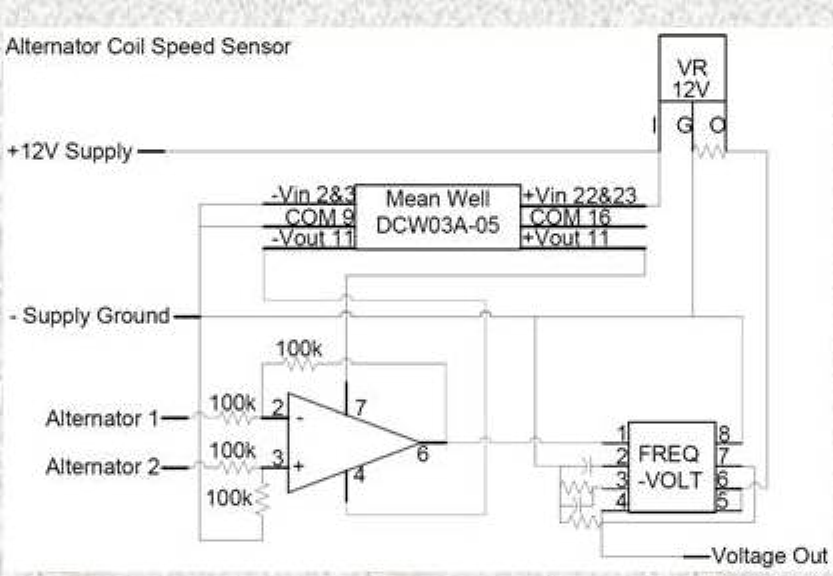
- Purchased 36 inches of 3" x 1" x 0.125" 6063 T5 aluminum rectangle tube
- Fabricated spindle tubes and center sleeve from 6061 T6 aluminum tubes
- Welded parts together

Testing

Common Shaft Speed Sensor

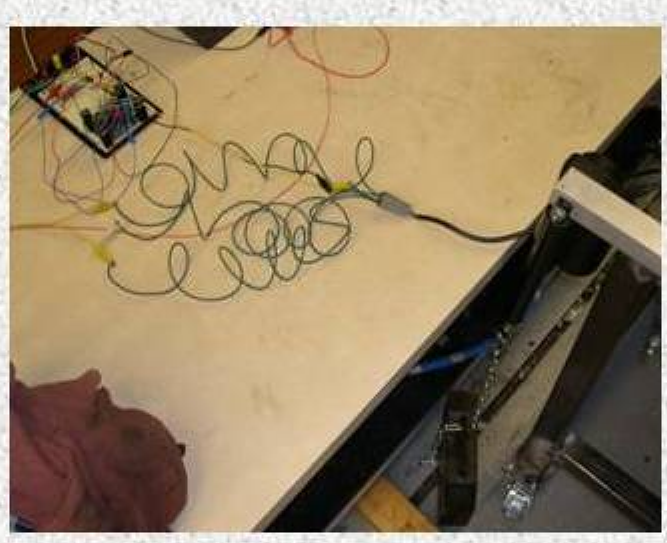
The Hall Effect speed sensor was used on previous tractors but never worked correctly. The testing revealed that the frequency to voltage converters needed a zero cross of the signal. A zero cross signal is obtained by using a differencing amplifier. Testing also showed that the previous tractors sensors would have never worked because they didn't have a zero cross signal





Weightless Engine RPM Sensors

The alternators are used as engine RPM sensors on the '07 tractor. The testing revealed the need for a differencing amplifier to protect the frequency to voltage converter



Proportional H-Bridge

H-bridge being used on test bed and on retrofitted '07 tractor. Proportional H-Bridge proved to offer better controllability.

Acknowledgements

Senior Design Instructor - Dr. Joseph Irudayaraj
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Purdue ASABE Club
Team Sponsors

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April 17th, 2008