PURDUE UNIVERSITY

CAPSTONE DESIGN EXPERIENCE 2018

Quarter Scale Tractor

Agricultural & Biological ENGINEERING

Yixian Niu (Agricultural Engineering), Wes Willson (ASM)

Background

The ASABE hosts the International ¼ Scale Tractor Student Design Competition each year where 27 universities build a tractor and compete in a unique 360-degree workplace experience. Teams are only given an engine and rear tires and the rest must be designed following strict rules.

Project Goals

The team's goals for this tractor design are:

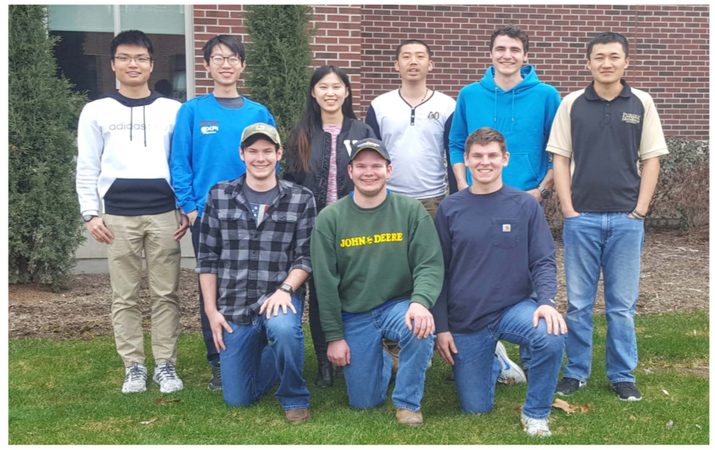
- Design a new drivetrain system to eliminate CVT (Continuously Variable Transmission) due to rules changes
- Improve the data acquisition system to get real time feedback
- Design a new exhaust system for lower noise
- Improve Frame and Suspension

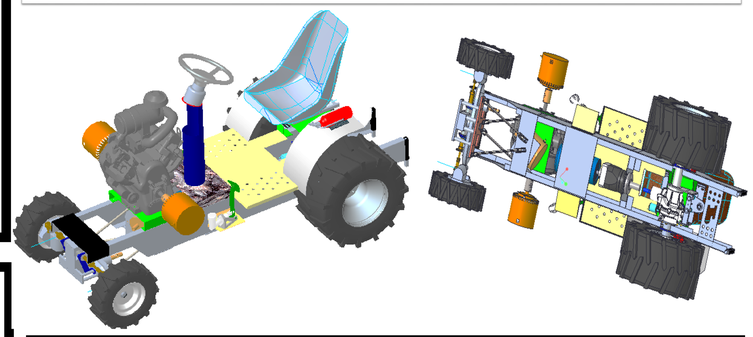
Design Constraints

Each team of engineers were constrained by the rules of the ASABE ¼ Scale Tractor Student Design Competition. The design constraints were:

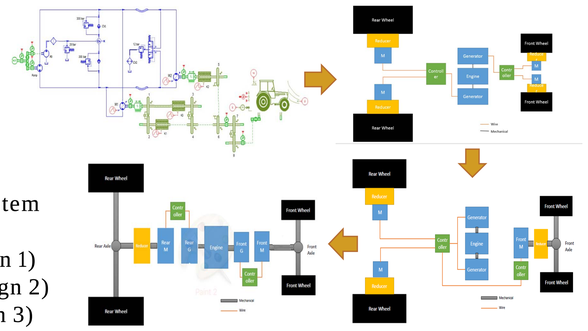
- **Weight** – Tractor may not exceed 900 lbs. maximum gross vehicle weight
- **Length** – No part of the tractor may protrude further forward than 96 inches from the center of the rear axle
- **Width** – No part of the tractor may be wider than 72 inches

There are several other limitations and rules that the team must meet to qualify for the competition, regarding component design, safety, noise, etc.





Drivetrain



- *Why Electronic:*
  - Competitive Efficiency
  - More precise control
  - Lower Noise
- *Alternative Designs:*
  - Closed Loop Hydraulic System
  - Electric System
  - ➢ Four Motor System(Design 1)
  - ➢ Three Motor System(Design 2)
  - ➢ Two Motor System(Design 3)

Constraints	Hydraulic	Electronic		
		Design 1	Design 2	Design 3
Must be able to test by March 15th	N	Y	Y	Y
Operate in forward and reverse	Y	Y	Y	Y
Must give variable wheel speed control	Y	Y	Y	Y
Total drivetrain weight under 540 lbs	N	N	Y	Y

		Electronic				Low Rank	Medium Rank	High Rank
		Design2		Design3				
Criteria	%	Rank	Score	Rank	Score	1-3	4-6	7-9
Manufacturability	20	4	80	9	180	Large # of parts	Medium # of parts	Small # of parts
Serviceability	10	6	60	7	70	Hard to disassemble	Medium to disassemble	Easy to disassemble
Weight Limitation	15	8	120	6	90	Over 400 lbs	200-400lbs	100-150 lbs
Efficiency	10	5	50	5	50	<80%	80-79%	79-90%
Cost	5	1	5	4	20	More than 10000$	8000-10000$	Less than 8000$
Torque	10	5	50	7	70	Less than 2500 ft lbs	2500-3000 ft lbs	Over 3000 ft lbs
Speed	10	8	80	9	90	Less than 6 mph	6mph - 8mph	Over 8 mph
Control difficulty	20	3	60	5	100	Difficult	Medium	Easy
Total	100		505		670			

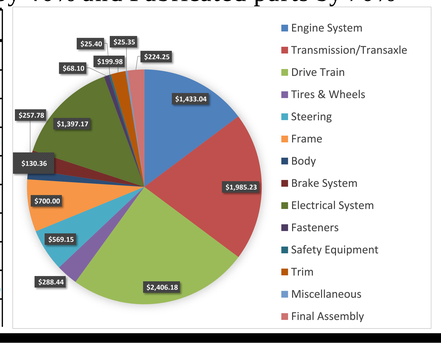
- *Final Design and Qualification Analysis:*

- Electric, Two Motor System has been chosen based on decision matrix.
  - *Decision Matrix 1:*
  - ➢ Design constraints are based on previous years' tractors and competition pull data.
  - ➢ Hydraulic and Electronic Design 1 are ruled out
  - *Decision Matrix 2:*
  - ➢ Criteria is based on competition rules
  - ➢ Electric Design 3 has a better overall performance

Economic Analysis

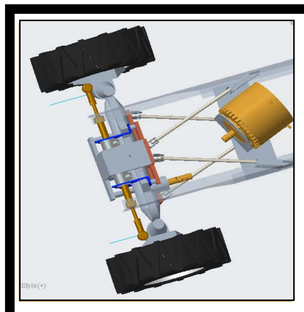
- Cost breakdown uses ASABE competition pricing constants
- All purchased parts are multiplied by 40% and Fabricated parts by 70%

Summary	
Manufacturing Variable Cost	$ 9,710.43
Period Manufacturing Cost (14%)	$ 1,359.46
Research & Development (6%)	$ 582.63
Estimated Full Production Units	3000
Adjusted Manufacturing Cost	$ 11,652.51
Suggested List Price	$ 12,400.00
Profit Margin	6%
Yearly Net Profit	$ 2,242,459
Total Number of Parts	174
Tractor Weight	850 lbs



Impact and Sustainability

- New design employs electric drivetrain system -- clean energy, easier to control and more power provided.
- Regardless of the rules, a quick-charge system should be added, then a smaller engine and generator could be used.
- Adding batteries could also make the system emissions free, which is preferred for indoor work like greenhouse.



Suspension

Improve operator comfort through the implementation of a flexible front axle suspension system.

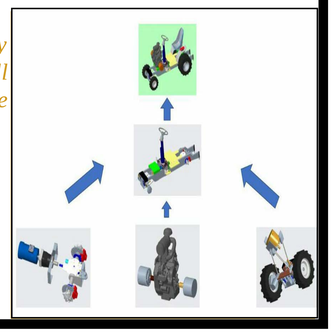
Constraints	Leaf Spring	Coils over Shocks	Pneumatic four-link
Easily Compressable	N	N	Y
Lateral Stability	N	N	Y
3-6" Spring travel	Y	Y	Y
Easily Implemented	N	N	Y

Manufacturability

Efficient fabrication and assembly practices ensure the customer will have the lowest possible cost for the highest quality product available.

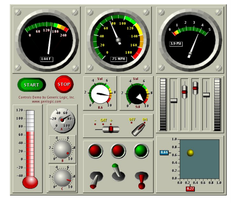
- Manufacturing Timeline:

Selecting—Testing—Subassembly--Final Assembly--Entire Tractor Testing.



Data Acquisition & Electronics Interface

- 2 motor controllers + 1 PC OEM level programmer + 1 Handled OEM level programmer
- Programmer can change:
  - slew rate, max power, creep, brake regen, contactor output and many more.
- Handled programmer also acts as Display:
  - Adjust and save parameter settings, monitor real-time data, and perform diagnostics and troubleshooting even during driving

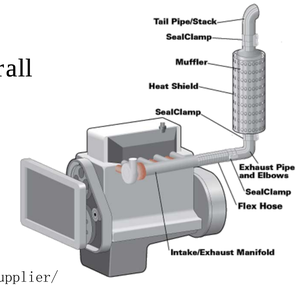


http://fsip.biz/Curtis1313Handset.html

Exhaust System

- *Goal:*
  - Minimize system noise levels while keeping overall horsepower at an acceptable level.
- *Improvements:*
  - One-side exhaust to have a broader view
  - Two Muffler in series

Alternative designs: only one OEM muffler



https://www.dearkoo.com/agricultural-exhaust-systems-supplier/

Technical Advisors:
David Willson

Instructors:
Dr. John Lumkes

Acknowledgements:
Special thanks to Scott Brand, the ABE department, Eric Kong, Ben Curtin, James Marschand, Zhongzhong Niu, Yikai Li, Jihang Liu, Wentao Chen

References:
(n.d.). Retrieved April 14, 2018, from http://fsip.biz/Curtis1313Handset.html
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