PURDUE UNIVERSITY | Agricultural and Biological Engineering

CAPSTONE/SENIOR DESIGN EXPERIENCE 2020

Title: Purdue Quarter Scale Tractor

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Background

The International 1/4 Scale Tractor Student Design Competition, hosted by ASABE, attracts student design teams from universities around the world for a weekend long competition to declare the best performing tractor. Teams must design, build, and test a complete pulling tractor platform starting from the provided 31 HP engine and rear Titan pulling tires for the target customer of a National Quarter Scale puller. Complications due to the COVID-19 pandemic have shifted the 2020 team's final goals and deliverables. The 2020 team strives to deliver a newly generated model for future students, able to go to competition, that can iterate upon this design given a durable drivetrain and structure.

Criteria

- Robust & Durable (withstand 3000 lb. chain force)
- Manufacturable & Serviceable (80% common fasteners)
- Maneuverable (70° turn angle)
- Ergonomic controls (accommodate 95th percentile)

Constraints

- Weight ≤ 900 lbs.
- Length ≤ 96 in.
- Width ≤ 72 in.
- Adequate Shielding
- Fully Customized Frame

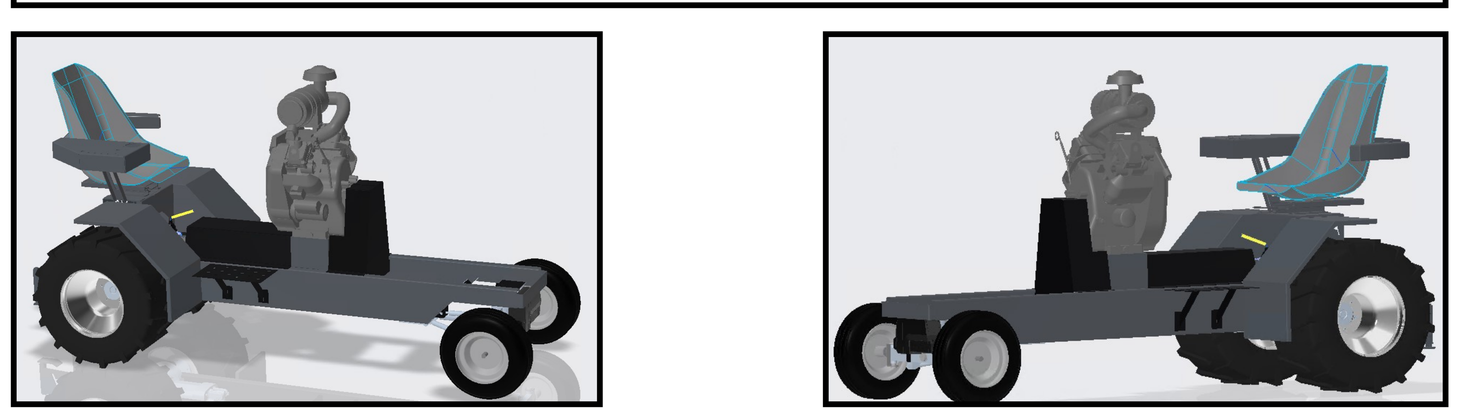

Figure 1: CAD Renderings of Tractor

Impact

- Demonstrated Purdue ABE course work and student design capabilities for an international collegiate stage
- Executed and/or planned fully manufacturable design (Design —> Build —> Verification & Validation)
- Established technical and communication skills in a team environment
- Robust and entirely new platform for future ABE students to test, iterate upon, and conquer the competition

Alternative Solutions

During the scope and research phase, many proposed solutions for the drivetrain configuration were considered and presented in the decision matrix below:

- Electric 4WD
- Manual 2WD
- Manual 4WD
- Hydrostatic 2WD
- Hydrostatic 4WD

Figure 2: Drivetrain Decision Matrix

Drivetrain Configuration	Simplicity	Cost	Durability	Maneuverability	Traction	Controllability	Manufacturability	Weight	Score
Score Weight	0.09	0.07	0.17	0.12	0.16	0.16	0.10	0.13	1
Electric 4wd	2.75	2.00	5.50	9.50	9.25	8.75	4.00	8.25	6.88
Manual 2wd	9.00	7.50	9.50	6.50	6.50	7.50	9.50	7.25	7.84
Manual 4wd	7.00	5.00	9.25	8.75	9.50	7.50	7.50	5.25	7.77
Hydrostatic 2wd	5.75	6.25	7.75	7.50	7.00	7.00	8.50	7.00	7.17
Hydrostatic 4wd	5.00	4.00	7.75	8.75	9.00	7.25	6.75	5.00	7.05

This process yielded Manual 2WD and 4WD as the most appropriate solutions. Referring back to the goals and criteria, Manual 2WD was selected as the best option as it provides a variety of optimized gear ratios and the greatest tractive pulling force with proven performance.

Design

Drivetrain

- Lightweight aluminum Midwest Super Cub 3-speed transaxle with custom sized gear sets chosen for a range of desired operating speeds and durable componentry
- Vogel spline clutch and Gates belted sprocket engine drop down reduction (2:1) were mated to a main driveshaft
- Calculations to the bottom right determined 3 forward speeds to maximize pulling force with final ratios from 43:1 to 55:1

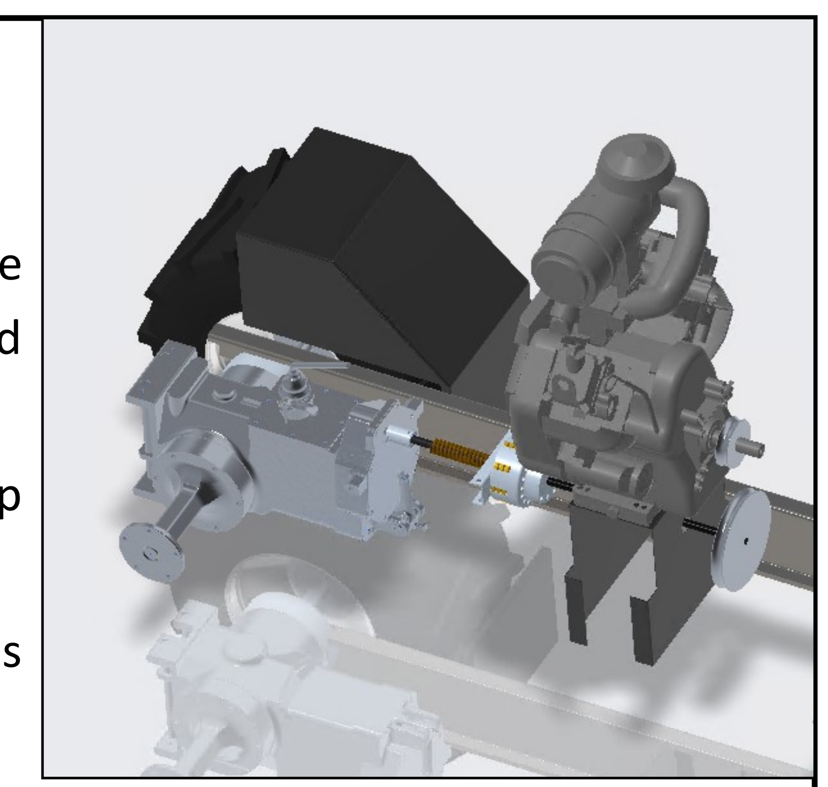

Figure 3: Drivetrain

Frame

- C-Frame construction provides increased rigidity, reduced weight, and easy attachment surfaces
- 70 inch wheel base for adjustable ballasting options

Steering

- Electronically actuated Ackerman steering utilizing a DanFoss joystick and Thomson Linear actuator for accurate and responsive control

Suspension

- 4-link airbag suspension for stability in durability event

Serviceability & Manufacturability

- Simple shielding for access to components
- Standardized hardware ensures the fewest amount of tools needed
- Mechanical drivetrain provides simplistic service elements

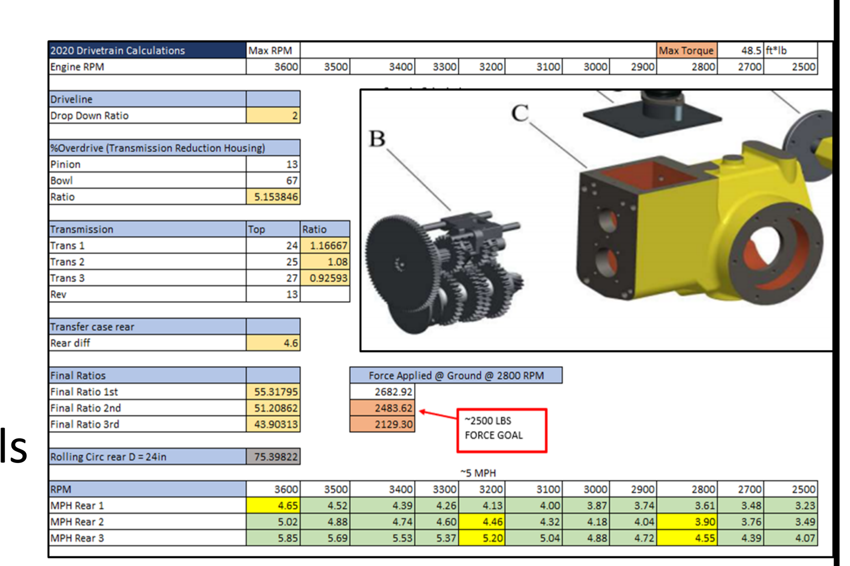

Figure 4: Drivetrain Calculations

Value Proposition

The rugged and versatile two-wheel drive mechanical drivetrain and structure of the 2020 Purdue Quarter Scale tractor provides a design based on proven concepts. This design will be capable of competing aggressively in pulling competitions while providing an iterative framework for completion by future teams. Other supporting design features benefit the customer with an adaptable tractor that is easily maneuverable and service friendly.

Validation and Verification Test Plans

Engine Dynamometer

- Ensure maximum engine torque is achieved under load
- Ensure belts/sprockets are prone to failure over several runs
- Monitor input and output shaft speed to ensure belt slip does not occur under heavy simulated loads

Competition Specific

- Ensure engine exhaust meets sound requirements under 94 db
- Expose tractor to rugged environments such as driving over parking stops fully ballasted to ensure durability and make suspension adjustments
- Perform full competition pulls with practice sled to refine ballast placement and collect live sensory data

Data Acquisition:

- Chain Force
- Vehicle Speed
- Wheel Slip
- Driveline speed
- Engine Torque

Product Implementation

The 2020 PQS Iron Team focused on important criteria to generate a newly bred pulling platform with durable design features that will excite a future design team for completion.

Careful considerations were taken when creating a final 3D model to seamlessly implement a building and testing phase by another party. The team expects the 2021 Iron Team to utilize the already purchased components, manufacture modeled components, incorporate complete data acquisition system, and validate design through harsh testing environments described.

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