MCHE 484

Fast Pedal Engineers

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Primary Objective

The Acadiana 500 is an annual relay race where teams of 8 race their own designed and manufactured tricycles. . The goal of this project was to design and fabricate a winning tricycle capable of exceeding expectation while adhering to the strict race rules.

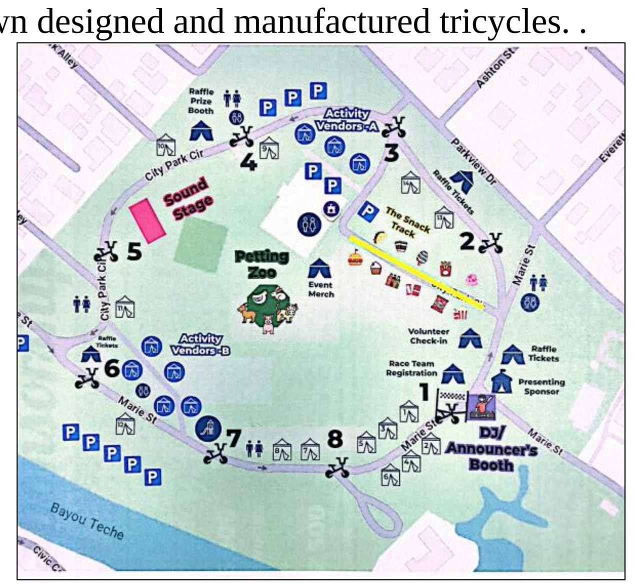

Figure 1: Acadiana 500 Track and Transitions

Race Rules:

- Propulsion: Direct-pedal from front wheel containing **NO** gears, motors, or chains.
- Transition zones: 8 zones where riders swap places; tricycle **must** maintain constant rolling movement or penalized.

Design Requirements & Constraints

Design Strategy: The Engineering team focused on the center of gravity (CoG). The lower of Center of Gravity, the less likely to experience tipping.

Weight Distribution: An even weight distribution was crucial for stability. The rear axle was designed to prevent excessive stress from weight on either the front or back, and no limitations for the seat allowed the rider to control weight distribution, improving stability, speed, and maneuverability during turns

Table 1: Acadiana 500 Tricycle Design-Rule Compliance Matrix

Requirement	Race Rule Specification	FPE Design	Compliance
Seat Height	22–24 in max 25 in (w/pad)	23–24 in (padded)	✅
Handlebar Width	≤ 20 in	19.5 in	✅
Rear-Axle Width	≤ 20 in	19.5 in	✅
Crank Arm Radius	≤ 4 in	4 in	✅
Pedal-to-Pedal Span	≤ 24 in	17.5 in	✅
Front Wheel Diameter	≤ 20 in	20 in	✅
Pedal Tip Distance from F. Wheel	≤ 12 in	8.75 in	✅
Pedal (Max Height × Width)	≤ 6 × ≤ 6	4 × 5	✅
Rear-Axle / Overall Trike Width	17–20 in	19.5 in	✅
Wheelbase	≤ 24 in	23.75 in	✅
Propulsion Method	No gears, motors, or chains	Direct pedal-to-wheel	✅
Braking / No Mech. Adv.	Foot-drag only in transition	Foot-drag / jump-off	✅

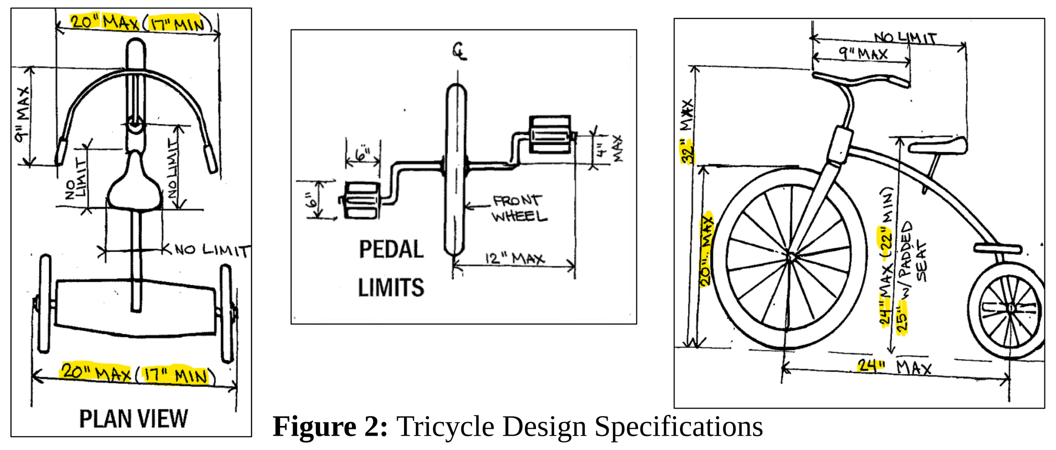

Figure 2: Tricycle Design Specifications

Concept Development

The team explored several concepts to meet all race regulations while providing the best performance under competitive conditions.

Importanace	Customer Requirements	Concept 1	Concept 2	Concept 3	Concept 4
10	Ensure rider safety under all conditions	9	7	9	9
9	Stable and responsive steering	9	7	6	10
10	Allow constant movement	10	9	9	9
8	Pneumatic tires for shock absorbance	9	8	7	9
8	Coaster use in front assembly	8	3	7	9
10	Front wheel pedal drive	10	10	10	10
10	No motors, chains, or gears	10	10	10	10
10	Achieve constant high speeds and good acceleration	9	7	8	8
9	Ergonomic seating and rider comfortability	7	9	9	9
10	Maintain dimensins: ≤20" wide, ≤24" long, ≤32" high	8	7	7	10
10	Seat height ≤ 25" (W/ Padding)	9	8	7	10
10	Supporting variety of rider weights and sizes	8	6	8	9
8	Assembly time	8	9	7	7
10	Stress withstanding capability	9	6	9	9
10	User friendly operation	10	8	8	9
8	Minimize design weight	9	6	8	9
7	Minimal cost	5	7	7	8
10	Meet intended functional and operational objectives	9	7	8	10
	Total	1461	1251	1346	1529
	Relative Total = Total/Number of Criteria	0.81	0.70	0.75	0.85

Figure 3: Morphological Chart

Final Design Overview

Figure 4: Rear Axle Tire Bushing SolidWorks Design

Figure 5: Final Tricycle Design

Manufacturing & Materials

TIG Welding: Key parts of the tricycle, such as the frame and seat support rails, were welded using TIG welding for precision and strength.
CNC Machining: Several parts, including the rear axle sleeve, stem extension, and seat anchor points, were machined using CNC equipment to ensure tight tolerances and a precise fit.
Lathe & Press: Components such as the rear axle bushings and brass spacers were fabricated on a lathe and press to ensure proper alignment and durability.

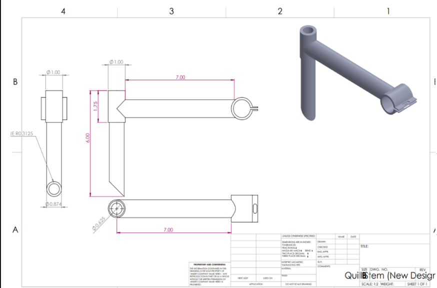

Figure 6: Quill Stem

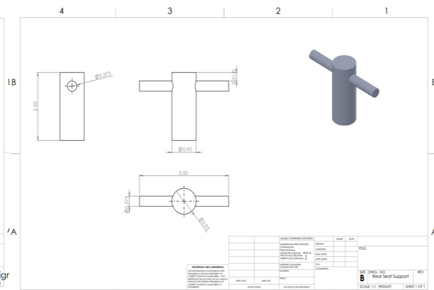

Figure 13: Rear Seat Support

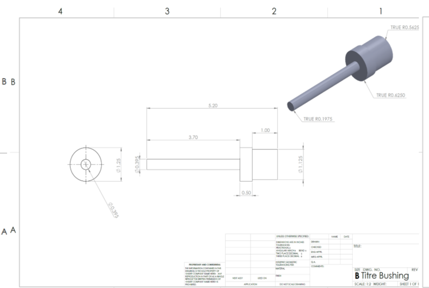

Figure 14: RearAxle Tire Bushing

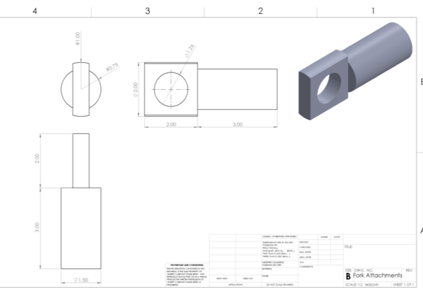

Figure 15: Front Fork Attachment

Table 2: Material Selection

Part	Material Used	Reason
Reusable Components	1020 Steel	Recycled bike parts (frame, handlebar, stem) for cost savings & reliable performance since already proven.
Pedals	Al & Steel	Lightweight while durable for strength
Stem Extension	1018 Steel	Custom modification to original stem, providing sufficient knee-clearance from handlebars.
Rear Axle & Bushings	4130 Steel & C360 Brass	High strength for load-bearing stress; Brass bushings reduce friction - smooth axle movement.
Pedal Extenders	Titanium Alloy	Lightweight, durable material; adds pedal clearance

Analytical Analysis

1. To determine the angle at which the tricycle tips over, the following formula is used:

$$\theta_{tip} = \arctan\left(\frac{\text{Rear Width}}{\text{CoG Height}}\right) = \arctan\left(\frac{19.5}{23}\right) \approx \mathbf{22.98°}$$

The tricycle can lean up to **22.98°** before tipping occurs.

2. To calculate the total mass of the tricycle and rider combined, we use the formula:

$$\boldsymbol{m} = \frac{\boldsymbol{weight}}{\boldsymbol{gravity}} = \frac{204.5\ \text{lbs}}{32.2\ \text{ft/s}^2} = \mathbf{6.356\ slugs\ or\ 42.15\ kg}$$

Where:

- Total Weight = **204.5** lbs (Tricycle: 34–35 lbs, Rider: 170 lbs)
- Gravity = **32.2** ft/s²
- The combined mass of the tricycle and rider is 6.36 slugs (42.15 kg).

Cross-sectional **Area** = A= πr^2, with the seat post at a diameter of 2 cm (r=0.39in=1cm)

$$A = \pi(1^2) = 3.1416\ cm^2 = \mathbf{3.1416 \times 10-4m^2}$$

Now calculate the applied stress:

$$\boldsymbol{\sigma} = \frac{\boldsymbol{A}}{\boldsymbol{F}} = \frac{850}{3.1416 \times 10^{-4}} = 2.71 \times 10^6\ Pa = \mathbf{2.71\ MPa}$$

Assuming a uniaxial stress, the Von Mises stress will be the same:

$$\boldsymbol{\sigma_{VM} = 2.71MP}$$

3. **Max Stress (Von Mises)**: The Von Mises stress is used to predict the yielding of materials under loading conditions.

- Max Stress from FEA: **2.795e08 N/m²**
- The material used for the frame has a yield strength of **6.204e08 N/m².**

4. The **Factor of Safety (FoS)** is a measure of how much stronger the material is compared to the max expected load. The factor of safety is calculated using the following formula:

$$\text{FoS} = \frac{\sigma_{yield\ of\ material}}{\sigma_{VonMisesStress}} = \frac{6.204 * 10^8}{2.795 * 10^8} = \mathbf{2.22}$$

The **FoS = 2.22**; the frame can withstand 2.22 times the max stress calculated by the FEA. This confirms that the frame is structurally safe.

Testing & Validation

Input Forces (FEA):

- Seat Post: 850 N   Rear Axles (2): 450 N   Handlebar: 150 N

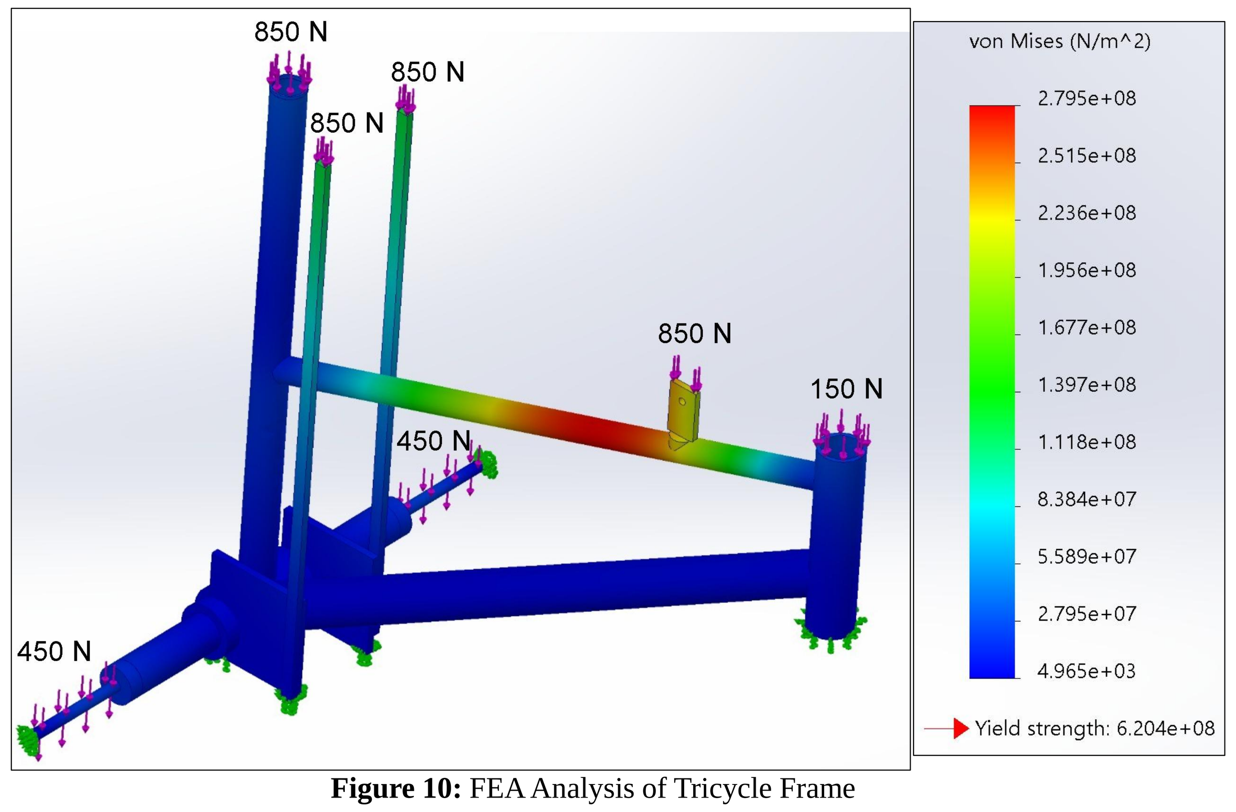

Figure 10: FEA Analysis of Tricycle Frame

The **Von Mises Stress** distribution from FEA shows how stress is distributed across the frame. Based on the color map:

- **Von Misses Stress (FEA):** Maximum Stress: 2.795e08
- **Yield Strength** of the frame: **6.204e08 N/m²**

This demonstrates the frame's structural integrity and its ability to handle forces during the race.

Cost Analysis

Mr. Jeff's total lab contribution: ≈ 10 h machining parts total + 4 h TIG welding on parts 10-17.

Table 3: Purchased Components — Cost and Source Summary

	Item / Sub-assembly	Qty	Material	Cost ($)	Source	Note
Re-used						
1	Bike Frame (triangular)	1	1018 Steel tube	0	Reused MTB	TIG welded
2	Handle-bars (straight)	1	1018 Steel tube	0	Reused MTB	Narrowed to 19 in
3	Stem (pre-extension)	1	1018 Steel	0	Reused MTB	Modified & Extended (TIG)
Purchased						
4	20 in front-wheel assembly	1	Steel / 6061-T6	31.99	Razer DXT (razor.com)	(hub + cranks + coaster)
5	Titanium pedal extenders, 0.79 in	2	Titanium Alloy	35.99	Amazon	Increases pedal clearance
6	Aluminum flat pedals (pair)	2	6061-T6 / Steel	27.99	Amazon	½-20 thread
7	Handle-bar grips (pair)	2	ABS Plastic	6.98	Amazon	5.2 in length
8	Banana saddle w/ support rails	1	Polyurethane / Carbon Fiber / 1018 Steel	55.99	Amazon	18 x 4.5 in
9	"Full Petal Engineers" Team Jerseys	9	Cotton	52.91	Mrs. Kaliszeski	S, M, L
Machined & Welded						
10	Stem extension (+7 in)	1	1018 Steel	0	UL Shop - Mr. Jeff	1.5 h lathe + 0.5 h weld
11	T-anchor (Seat Security)	1	6061-T6	0	UL Shop - Mr. Jeff	1.5 h 3-axis mill
12	Center tube (rear axle sleeve)	1	4130 Steel	0	UL Shop - Mr. Jeff	0.75 h lathe
13	Rear-axle bushing set (stepped axle + brass)	2	4130 Steel / C360	0	UL Shop - Mr. Jeff	2.0 h lathe + press
14	Brass Spacers	2	C360	0	UL Shop - Mr. Jeff	0.5 h lathe
15	Bushing-to-frame collars	2	1018 Steel	0	UL Shop - Mr. Jeff	0.5 h lathe
16	Fork bearing blocks	2	1018 Steel	0	UL Shop - Mr. Jeff	5 h mill + drill/tap
17	Side stiffener plates	2	1018 Steel plate	0	UL Shop - Mr. Jeff	Included in 5 h weld total
18	Seat support railing	2	1018 Steel tube	0	UL Shop - Mr. Jeff	Braced with screws (Side Plate and Seat)
			Total Cost	211.94		

Race Results

1st place: 3 min 31 s

- Only 2 penalties received
- Achieved fastest lap time (Final)

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