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Cardinal Velo: ASME Human-Powered Vehicle Challenge

Project Description

The Cardinal Velo competed in the 2022 ASME Human Powered Vehicle Competition. The team vision was to minimize the overall coefficient of aerodynamic drag (CdA) of a previous year's vehicle by creating a fairing. The project mimics the iterative design process of modern bike frames where each year, the former model is modified and improved. A fairing was designed, and its aerodynamic characteristics were analyzed using Solidworks® Flow Simulation software package. The team designed a fairing with a CdA of 0.204 m^2. The team utilized a local company to create a sandmold of the fairing model in order to have an exact mold for manufacture. CdA testing was completed by comparing power data from a pedal based power meter compared to real world speed. Real world power testing results suggest that the fairing reduced the CdA of the unfaired trike from 0.524 to 0.340 m^2.

Design Specifications

- The vehicle must be able to come to a complete stop from a speed of 25 km/hr within a distance of 6 meters.
- The vehicle must be able to turn within an 8 meter radius.
- The vehicle must be stable enough to travel for 30 meters in a straight line at a speed of 5-8 km/hr.
- Each front wheel must have it's own brake.
- The vehicle must have a rollover protection system (RPS) which protects any driver of the vehicle
  - Must not show any permanent deformation or fracture against subjected test loads of 2670 N and 1330 N, on the top and side respectively.

Power Components of Drag

- Aerodynamic Drag
  - $F_d = ½ \cdot CdA \cdot \rho \cdot v^2$
- Rolling Resistance
  - $F_r = g \cdot \cos(\text{atan}(G)) \cdot mg \cdot C_{rr}$
- Gravity
  - $F_g = g \cdot \sin(\text{atan}(G)) \cdot mg$
- Drivetrain Efficiency
  - $\eta = 98\%$
- Power Output
  - $P_{legs} = (F_d + F_r + F_g)v$
  - $P_{wheel} = \eta^{-1} \cdot P_{legs}$

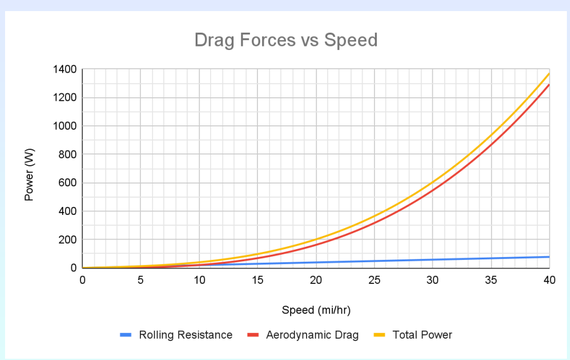


Figure 1: Power Components vs Speed

Trike Performance Characteristics

- Coefficient of Rolling Resistance: 0.00777
- Coefficient of Aerodynamic Drag: 0.2040 m^2
- Turning Radius: 5.6 m
- Braking Distance from 25 km/hr: 2.4 m
- Trike Mass: 34.29 kg
- Fairing Mass: 9.98 kg

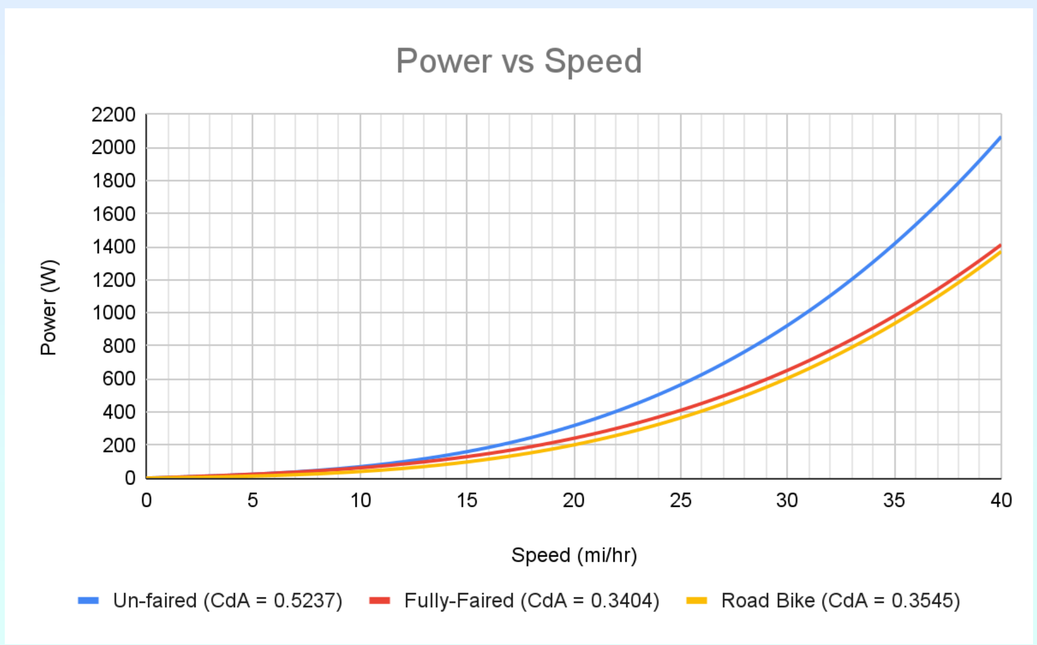
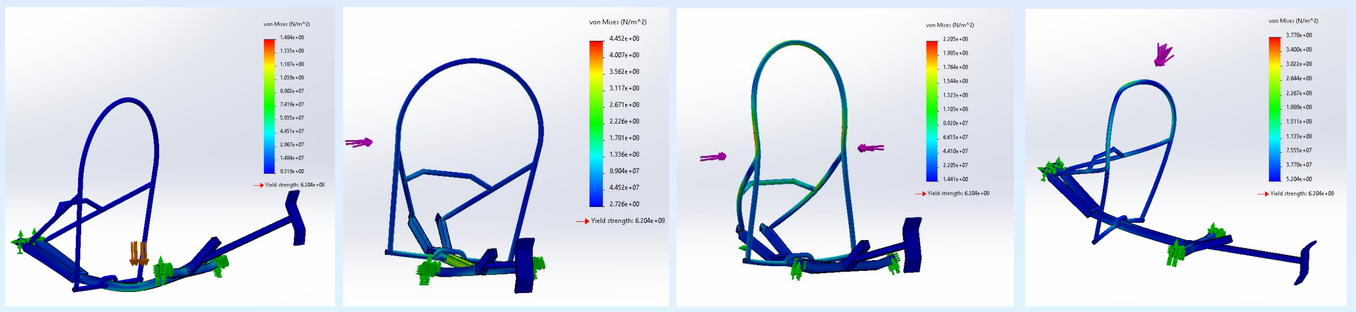


Figure 2: Power vs Speed of Road Bike vs Faired and Un-Faired Trike

Acknowledgements

- Funding: Lamar University
- Sand Mold Sponsor: KSB Standard Alloys

Frame and Rollcage Finite Element Analysis

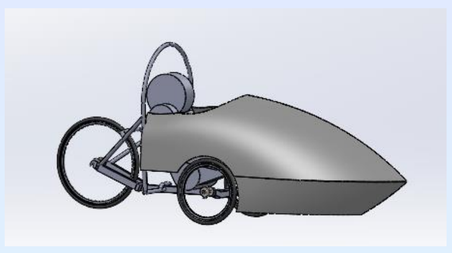


Static Load **Single Side Load** **Double Side Load** **Top Load**

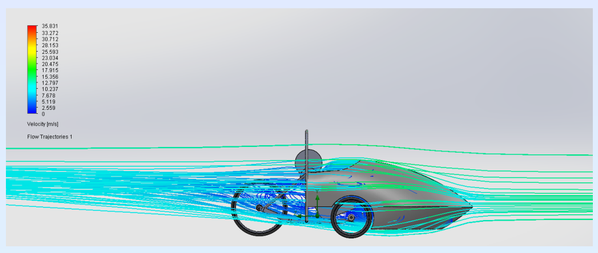
	von Mises Stress (N/m^2)	Displacement (mm)	Maximum Displacement Allowed (mm)
Static Load	1.240×10^8	2.194	51
Single Side Load	1.599×10^8	1.288	38
Double Side Load	3.610×10^8	5.692	38
Top Load	2.589×10^8	5.777	51

Table 1: FEA Results

Fairing Aerodynamic Analysis



Fully Faired Trike Model



Solidworks Flow Simulation CFD Study

- Final design based off of ease of construction
- Design CdA estimated to be 0.204 m^2

Real World CdA Testing

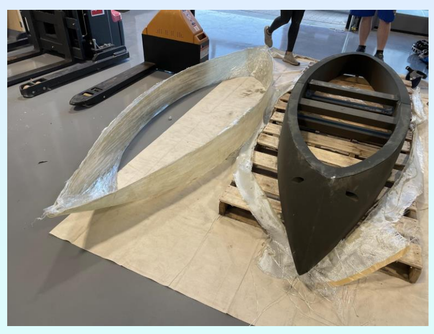
- Power Meter: Garmin Rally rk200
- Head Unit: Garmin Edge 130

	Expected CdA (m^2)	Real World CdA (m^2)
Road Bike	0.350	0.3545
Un-Faired Trike	0.280	0.5327
Fully-Faired Trike	0.204	0.3404

Table 2: CdA Results

Manufacture

Cardinal Velo utilized a sandmold provided by Standard Alloys to manufacturer the fairing. The sandmold allowed the team to have a solid exact model of the fairing negative space to utilize for fiberglass layup.



Sandmold - Bottom

Sandmold - Top

Completed Fairing

Recommendations and Learning

- Real world CdA testing is extremely difficult given variations in road gradient and uncontrollable weather conditions.
- The unfaired trike had a significantly worse CdA than even a standard non-aerodynamically optimized road bike.
- The perfect design doesn't matter if constructability isn't considered.
- Current trike design is not optimized for high speed.
  - Current trike frame is heavy and unstable when applying high power.
  - Increase wheel base for improved stability at speed.
- The sandmold as a precision cast fiberglass layup mold worked extremely well.