Human Powered Vehicle Engineering Analysis

Matt Gerlich, Alex Hawley, Phillip Kinsley, Heather Kutz, Kevin Montoya, Erik Nelson

November 19, 2013

Overview

- Project Description
- Analysis
  - Frame
  - Ergonomics
  - Fairing
  - Steering
  - Drivetrain
- Gantt Chart
- Conclusion
- References

Project Description

- ASME Human Powered Vehicle Challenge
- Clients – Perry Wood & ASME
- “Design a human powered vehicle that can function as an alternative form of transportation.”
- Objectives
  - High Speed
  - Aerodynamic Drag
  - Maneuverable

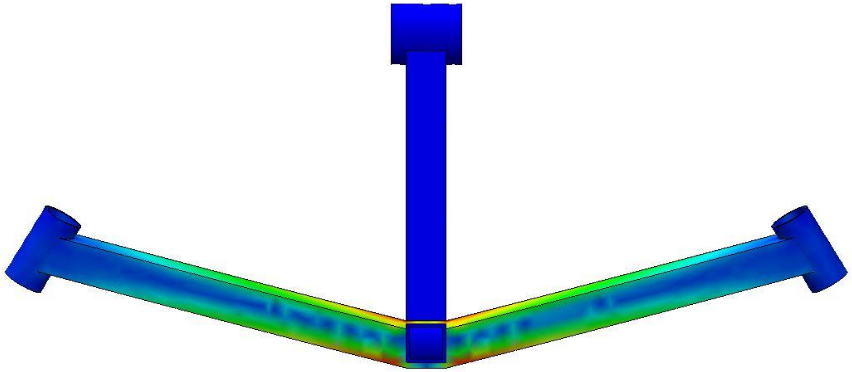
Frame

- 3 Sections: Center Tube, Outriggers, Roll Bar
- 5 Configurations
- Analyzed stresses, deflection, and weight
  - Hand calculations
  - Finite Element Analysis (FEA)

Table 1- Hand Calculation Results

Configuration	1.5”ODx.058”ST	2”ODx0.125”AL	1.5”x1.5”X0.125”AL	1.75”ODx0.125”AL	2”x1”x0.125”AL
Main Tube Deflection [in]	0.392	0.230	0.342	0.353	0.225
Outrigger Deflection [in]	0.183	0.107	0.159	0.165	0.105
Main Tube Lateral Deflection [in]	0.196	0.115	0.171	0.176	0.356
Outrigger Lateral Deflection [in]	0.069	0.040	0.060	0.062	0.125
Weight [lb/in]	0.075	0.071	0.066	0.061	0.066
Outrigger Stress [psi]	46598	13077	14593	17551	12813
Outrigger Stress Max [psi]	55917	18961	22473	25448	19732

Figure 1- Square Outrigger Stress



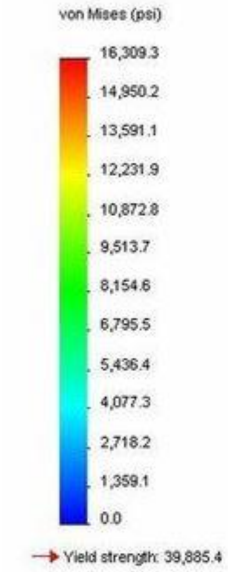
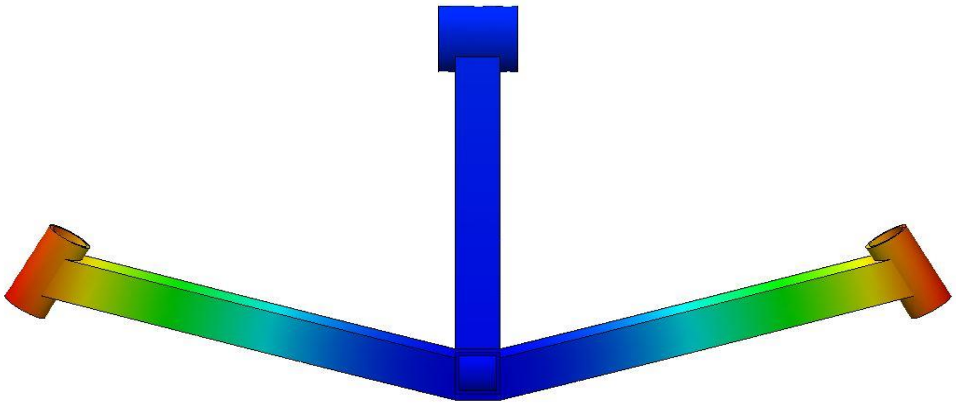


Figure 2- Square Outrigger Deflection



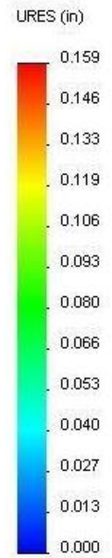


Table 2- Outriggers FEA vs. Calculated Results

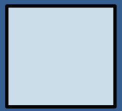
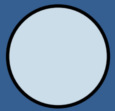
Configuration	 1.5x1.5x0.125AL	 1.75ODx0.125AL
Calculated Deflection [in]	0.159	0.165
FEA Deflection [in]	0.159	0.139
Calculated Nominal Stress [psi]	14593	17551
Calculated Max Stress [psi]	22473	25448
FEA Stress [psi]	16309	21897

Figure 3- Top Load Roll Bar Deflection

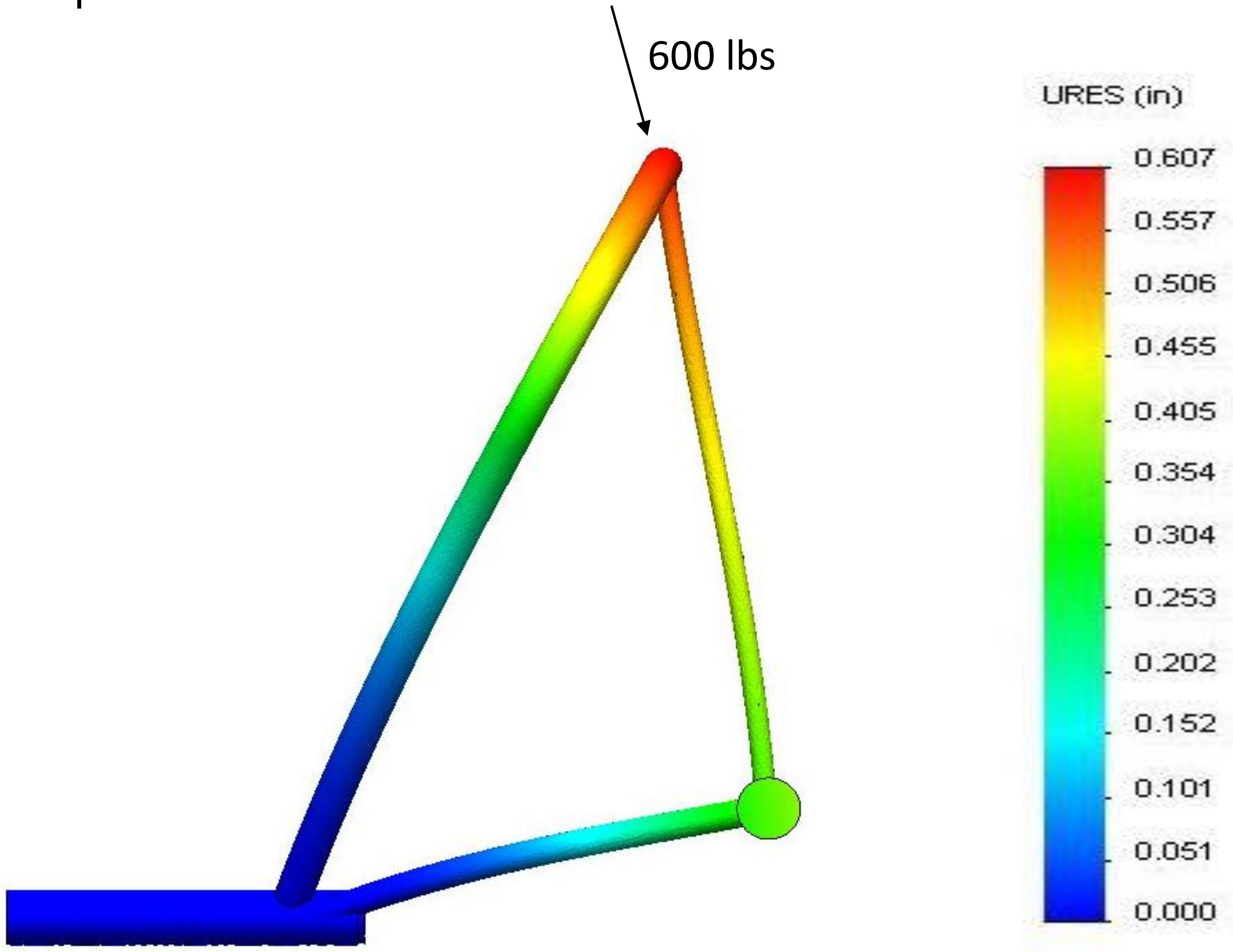
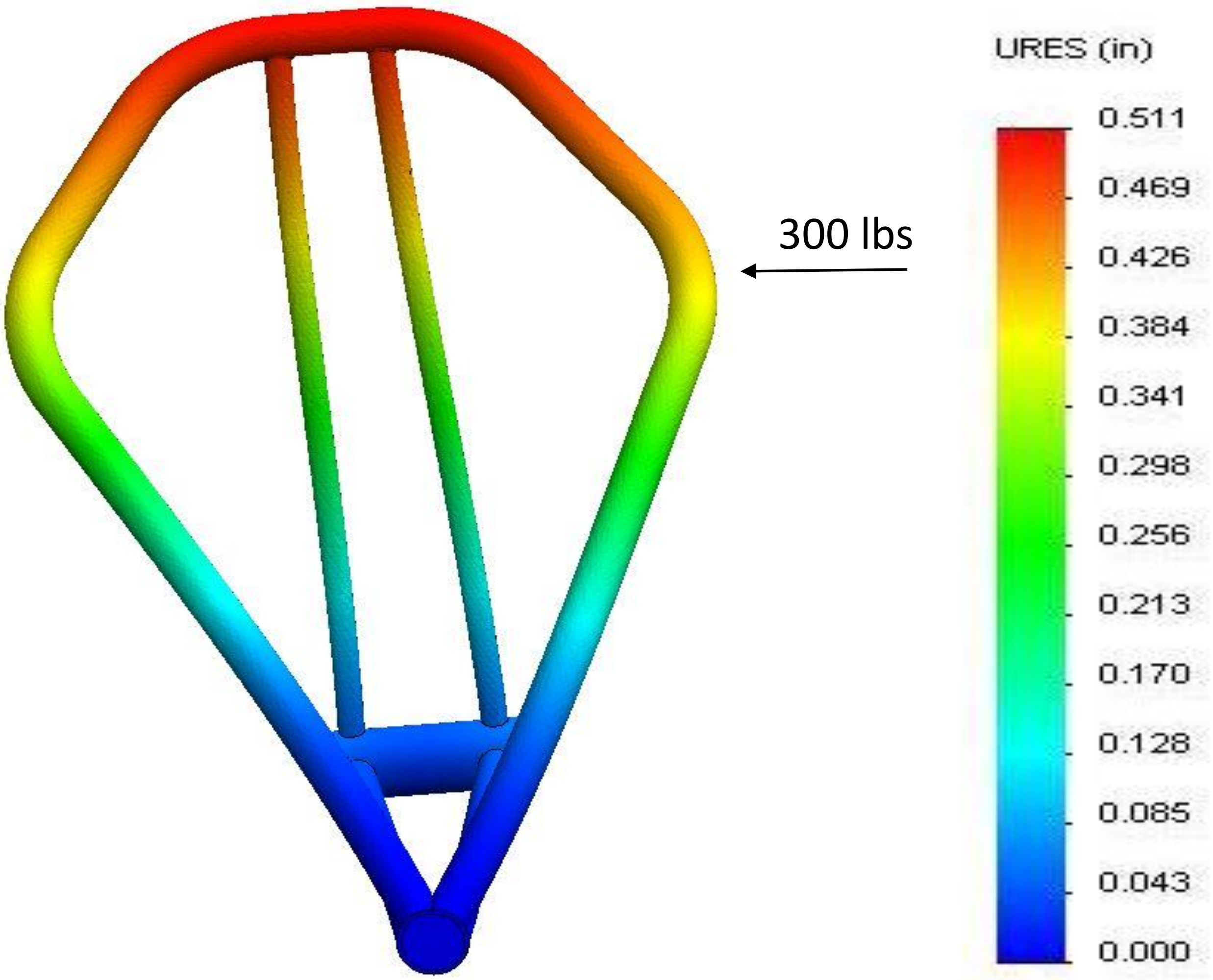


Figure 4- Side Load Roll Bar Deflection

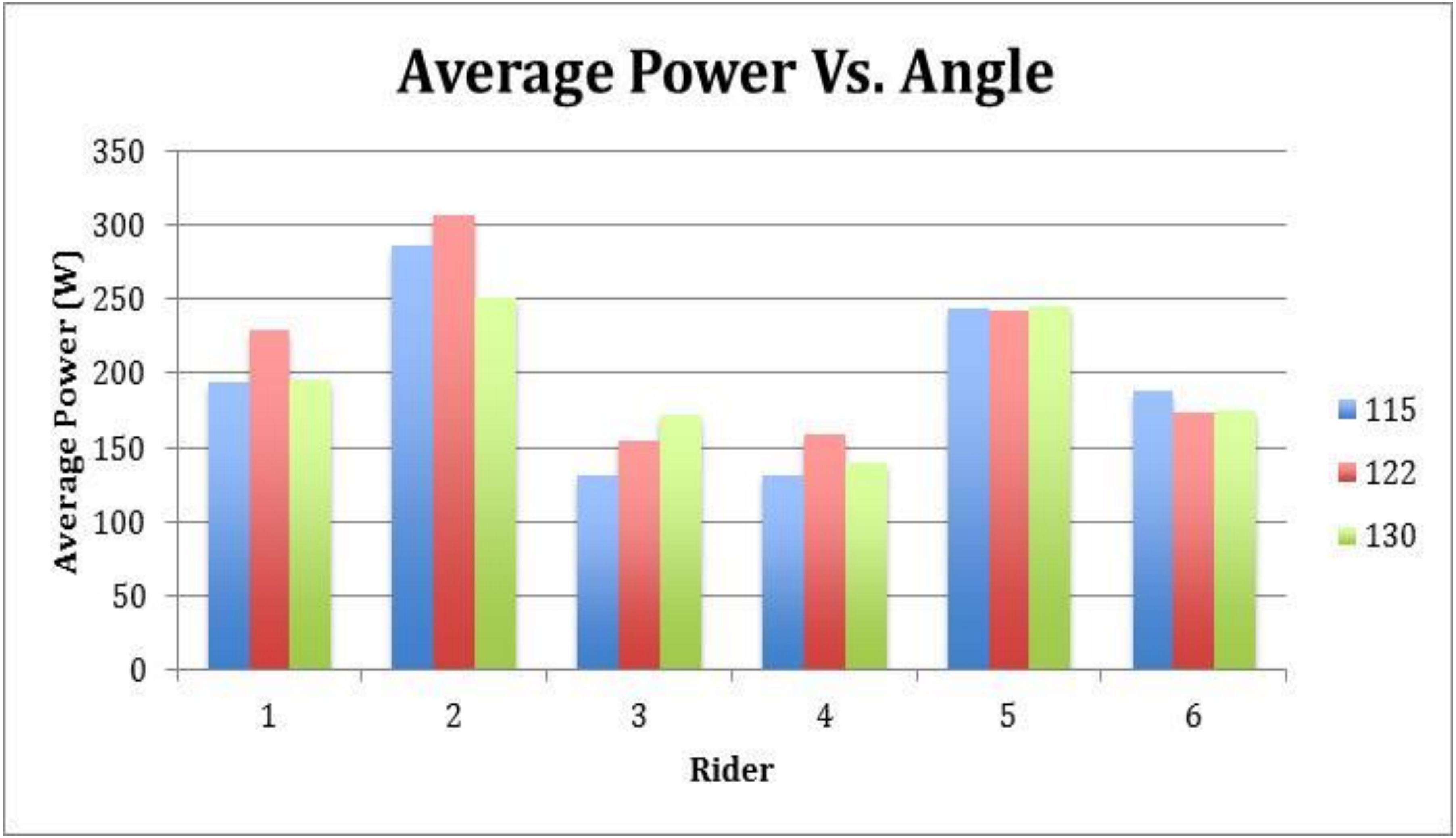


Ergonomics

- Rider Position Study
  - Three test angles
    - 115°, 122°, 130°
  - 1 min. sprint
  - 3 min. endurance
  - Power and cadence (average and max)

Figure 5- Rider Position Angle

Figure 6- Average Power at Various Angles



Fairing

- SolidWorks Flow Simulation
- General dimension changes
  - Length: 96-108 in
  - Width: 18-24 in
  - Height: 33-39 in
- Assumptions
  - Air
  - Temperature
  - Velocity
  - Roughness

Table 3- Coefficient of Drag Comparison

Length (in)	Width (in)	Height (in)	Speed (in/s)	Force (lbf)	Area (in^2)	Cd
96	18	37	704	0.59	681.5	0.038
96	20	37	704	0.51	716.5	0.031
96	22	37	704	0.54	760.0	0.031
96	24	37	704	0.61	803.7	0.033
102	18	37	704	0.41	670.3	0.026
102	20	37	704	0.49	702.1	0.030
102	22	37	704	0.56	753.5	0.032
102	24	37	704	0.51	790.6	0.028
108	18	37	704	0.54	670.5	0.035
108	20	37	704	0.48	701.4	0.030
108	22	37	704	0.43	740.0	0.025
108	24	37	704	0.57	788.4	0.032

Steering

- Steering Geometry
  - Caster Angle
  - Camber Angle
  - Kingpin Angle
- Steering Knuckle FEA
  - Aluminum
  - Chromoly

Figure 7- Caster Angle

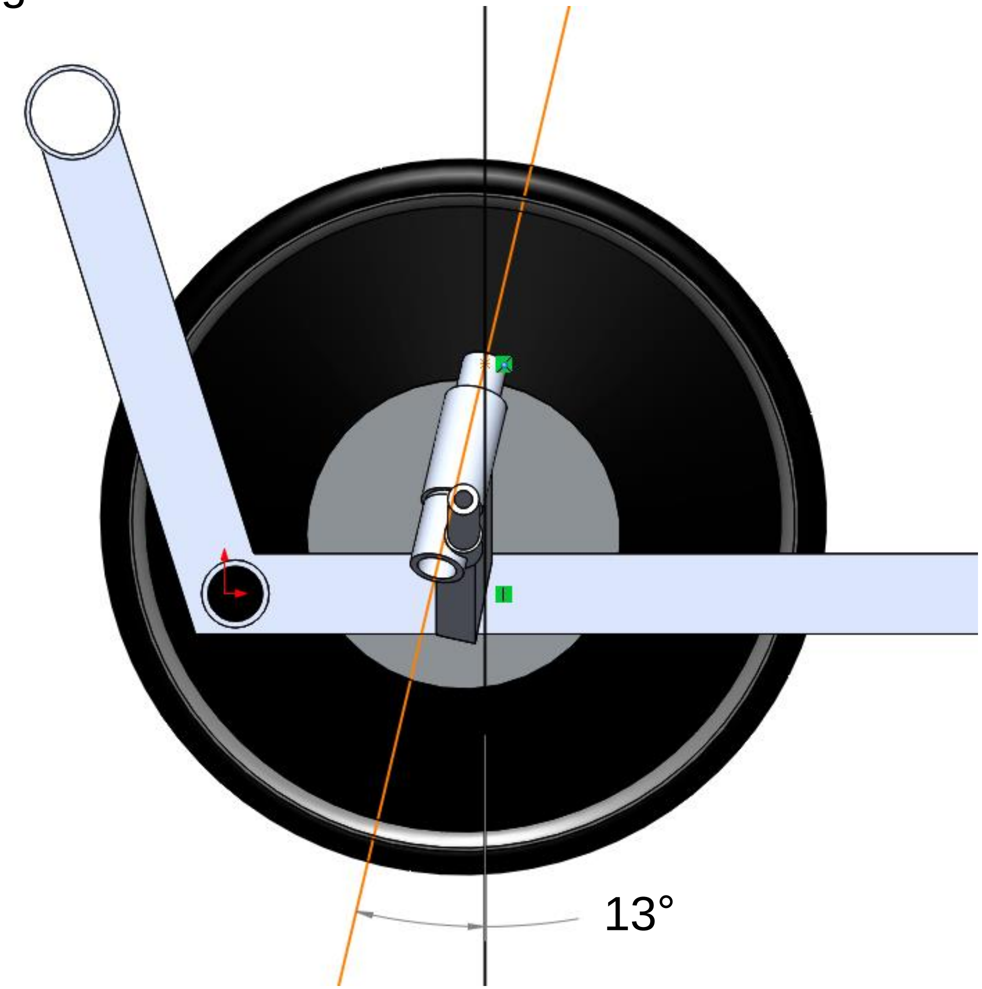


Figure 8- Camber Angle

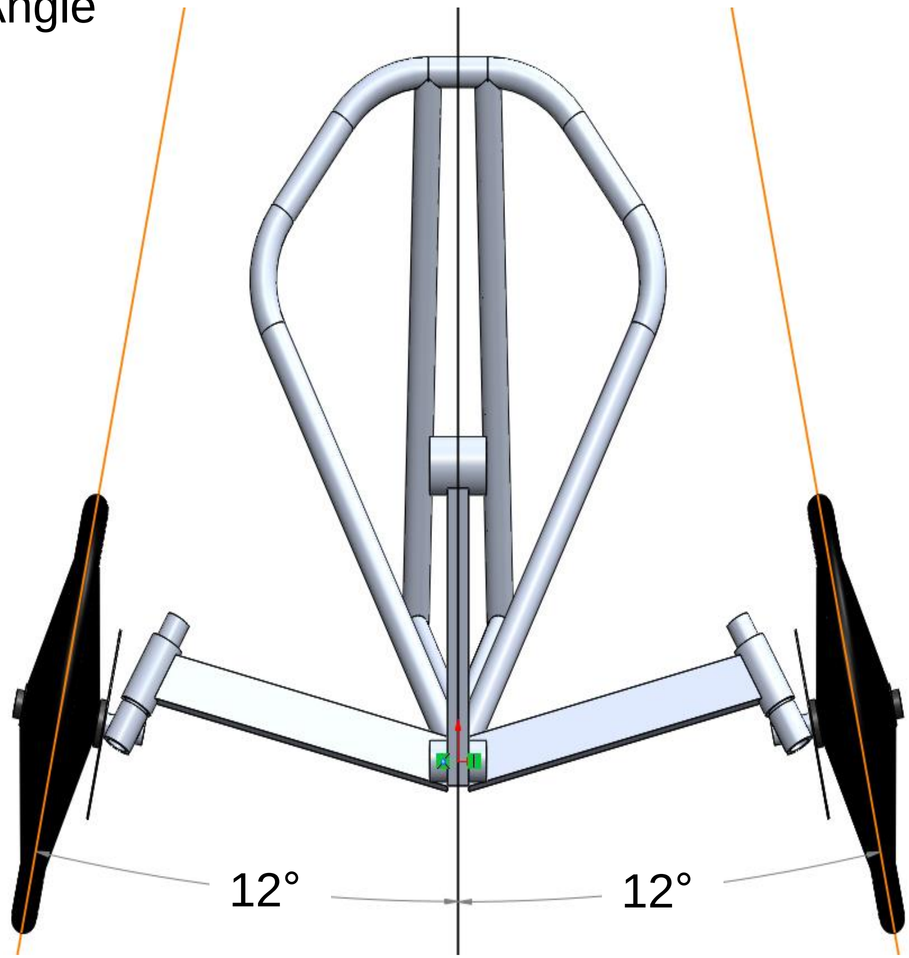


Figure 9- Kingpin Angle

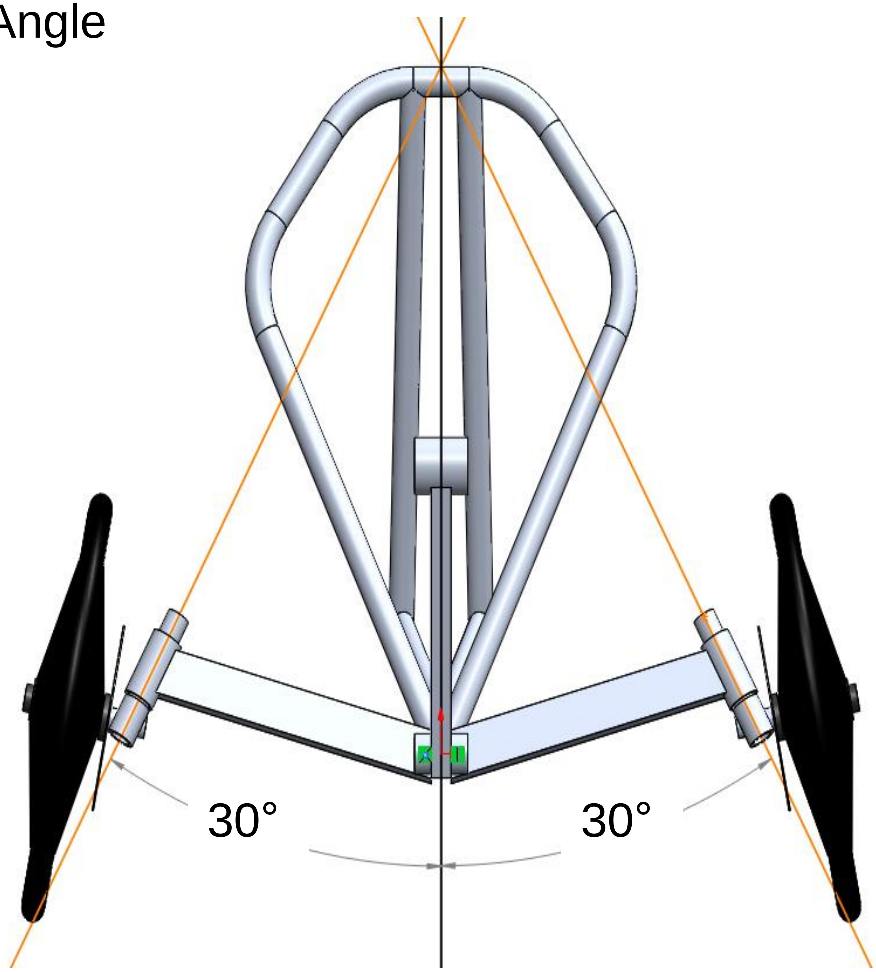


Figure 10- Aluminum FEA

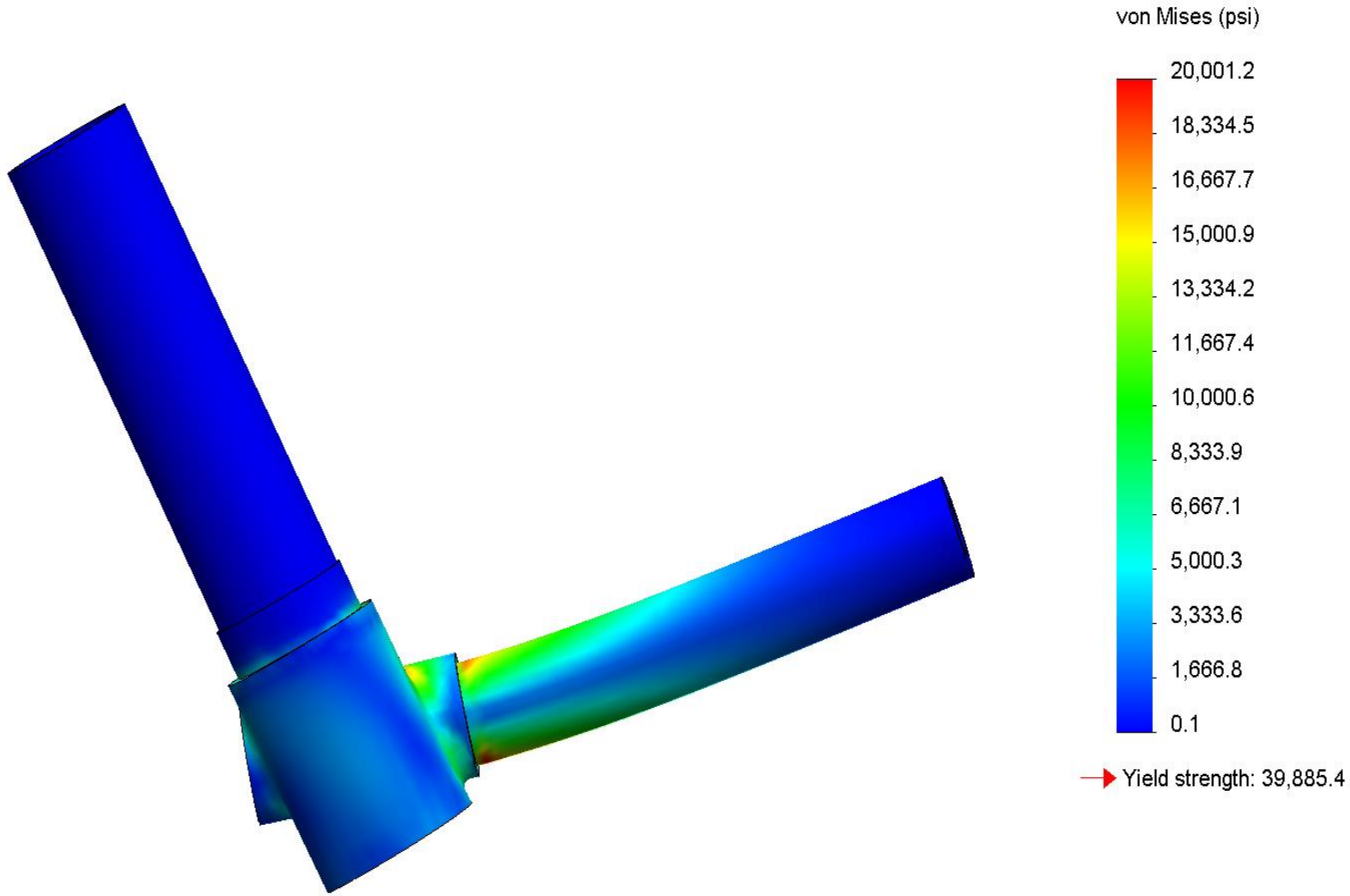
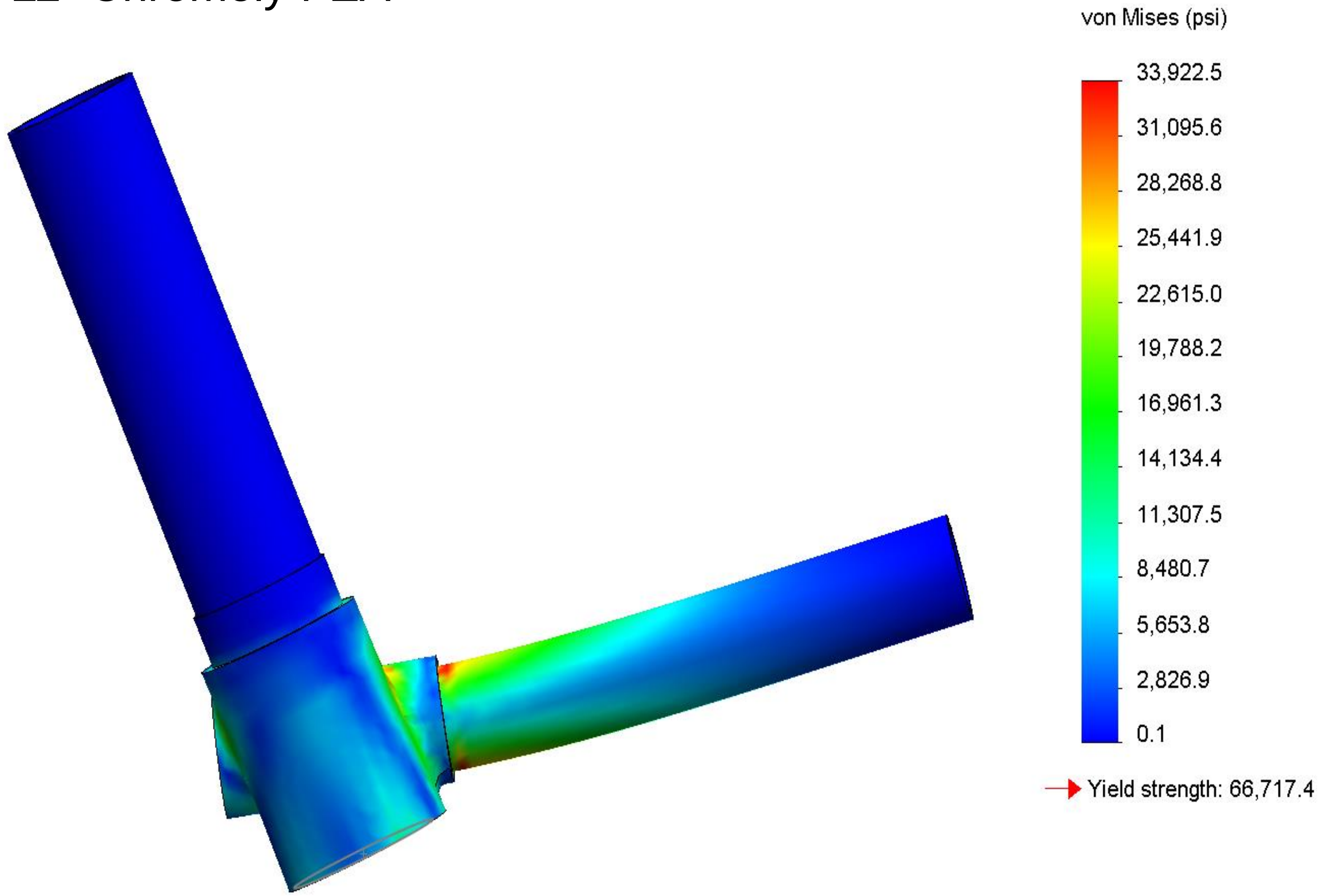


Figure 11- Chromoly FEA



Drivetrain

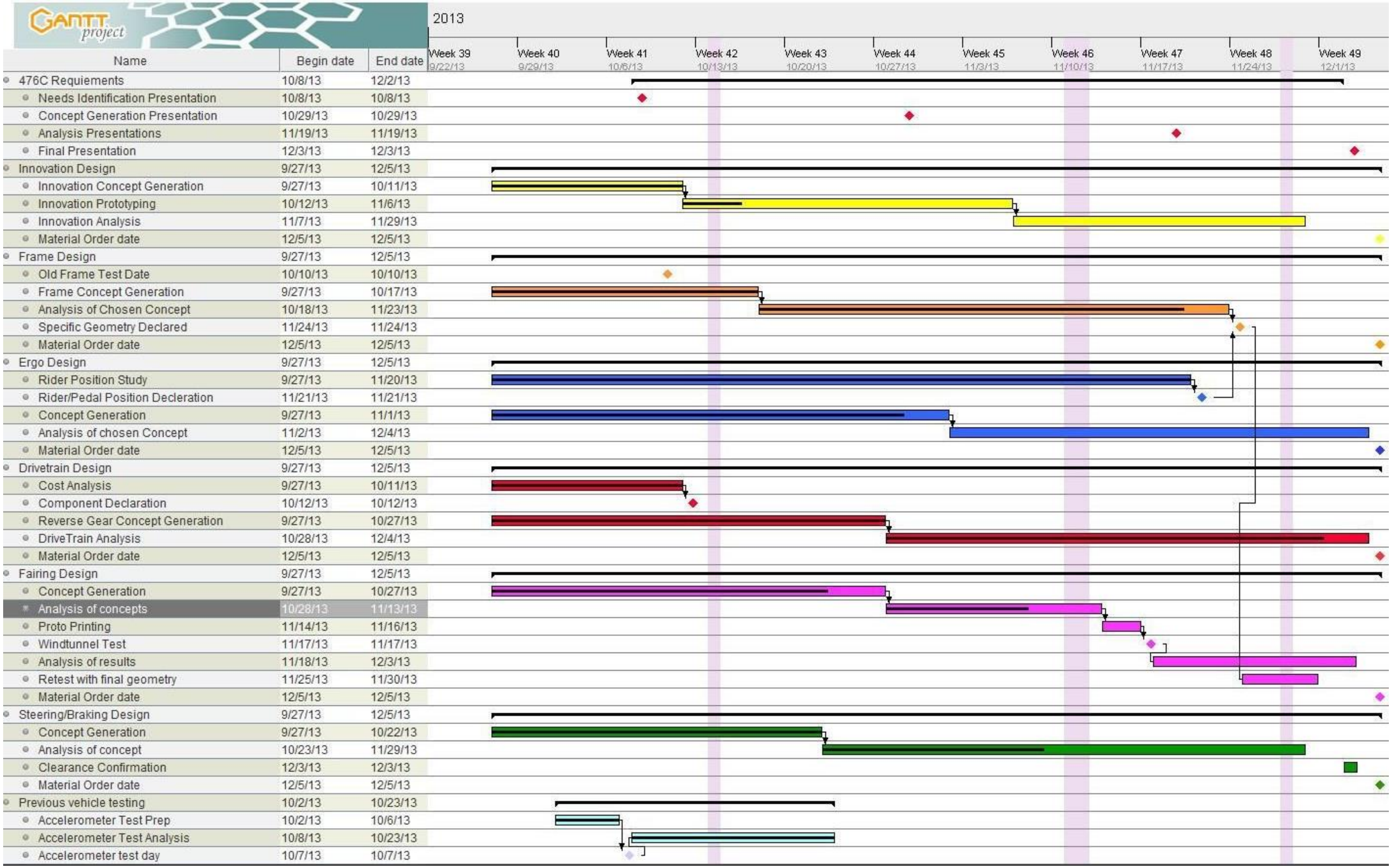
- Reach 40 MPH
- Lowest possible gear ratio
- Cadence values from rider position study

Table 4- Gear Ratios and Speeds

Gear Ratio	Speed at 90 RPM (MPH)	Speed at 110 RPM (MPH)
1.50	10.56	12.91
1.69	11.88	14.52
1.93	13.58	16.60
2.25	15.84	19.36
2.57	18.11	22.13
3.00	21.13	25.82
3.38	23.77	29.05
3.86	27.16	33.20
4.50	31.69	38.73
4.91	34.57	42.25

Project Plan Gantt Chart

Figure 12- Project Plan



Name	Begin date	End date
476C Requiements	10/8/13	12/2/13
Needs Identification Presentation	10/8/13	10/8/13
Concept Generation Presentation	10/29/13	10/29/13
Analysis Presentations	11/19/13	11/19/13
Final Presentation	12/3/13	12/3/13
Innovation Design	9/27/13	12/5/13
Innovation Concept Generation	9/27/13	10/11/13
Innovation Prototyping	10/12/13	11/6/13
Innovation Analysis	11/7/13	11/29/13
Material Order date	12/5/13	12/5/13
Frame Design	9/27/13	12/5/13
Old Frame Test Date	10/10/13	10/10/13
Frame Concept Generation	9/27/13	10/17/13
Analysis of Chosen Concept	10/18/13	11/23/13
Specific Geometry Declared	11/24/13	11/24/13
Material Order date	12/5/13	12/5/13
Ergo Design	9/27/13	12/5/13
Rider Position Study	9/27/13	11/20/13
Rider/Pedal Position Decleration	11/21/13	11/21/13
Concept Generation	9/27/13	11/1/13
Analysis of chosen Concept	11/2/13	12/4/13
Material Order date	12/5/13	12/5/13
Drivetrain Design	9/27/13	12/5/13
Cost Analysis	9/27/13	10/11/13
Component Declaration	10/12/13	10/12/13
Reverse Gear Concept Generation	9/27/13	10/27/13
DriveTrain Analysis	10/28/13	12/4/13
Material Order date	12/5/13	12/5/13
Fairing Design	9/27/13	12/5/13
Concept Generation	9/27/13	10/27/13
Analysis of concepts	10/28/13	11/13/13
Proto Printing	11/14/13	11/16/13
Windtunnel Test	11/17/13	11/17/13
Analysis of results	11/18/13	12/3/13
Retest with final geometry	11/25/13	11/30/13
Material Order date	12/5/13	12/5/13
Steering/Braking Design	9/27/13	12/5/13
Concept Generation	9/27/13	10/22/13
Analysis of concept	10/23/13	11/29/13
Clearance Confirmation	12/3/13	12/3/13
Material Order date	12/5/13	12/5/13
Previous vehicle testing	10/2/13	10/23/13
Accelerometer Test Prep	10/2/13	10/6/13
Accelerometer Test Analysis	10/8/13	10/23/13
Accelerometer test day	10/7/13	10/7/13

Conclusion

- The frame will use 1.5 in x 1.5 in aluminum square center tubing and outriggers to minimize weight and deflections.
- The rider position will be at an angle of 122 degrees for visibility and efficiency.
- The fairing will have an approximate length of 108 in, width of 22 in and height of 37 in to give a minimal coefficient of drag of 0.025.
- The steering knuckle will be made out of aluminum to reduce weight while maintaining a factor of safety of 2.
- The drivetrain will minimize the gear ratio while achieving a max speed of over 40 mph.

References

[1] R.C. Hibbeler, *Structural Analysis,* New Jersey, Pearson Prentice Hall, 2012

[2] R. G. Budynas and J. K. Nisbett, *Shigley's Mechanical Engineering Design,* New York, McGraw-Hill, 2011

[3] Philip J. Pritchard and John C. Leylegian, *Introduction to Fluid Mechanics*, Manhattan College: John Wiley & Sons, Inc., 2011.

[4] R. Horwitz Author. (2010). The Recumbent Trike Design Primer (8.0) [Online]. Available: http://hellbentcycles.com/trike_projects/Recumbent%20Trike%20Design%20Primer.pdf

[5] R.C. Hibbeler, *Engineering Mechanics – Statics*, Pearson Prentice Hall, 2010

Questions?