WCU Solar Car

Western Carolina University
School of Engineering + Technology

Problem Statement

- Design code to optimize drag force efficiency of the vehicle while adhering to 2020/21 American Solar Challenge guidelines
- Design, test and fabricate roll cage while adhering to the 2020/21 ASC regulations

Requirements

Req #	Requirement	Description	Verification	Requirement Type
1	Car Dimensions	Car must be =< 5m x 1.6m x 2.2m (LxWxH)	Measurement	Functional
2	Array <= 4m^2	Total solar array area must be <= 4m^2 (assuming silicon-based solar cells)	Measurement	Functional
3	Car Dimensions	Ground clearance must be <= 50mm	Measurement	Functional
4	Deceleration of 4.72m/s	Car must be able to continually stop from 50km/hr to 0km/hr with deceleration of at least 4.72m/s	Measurement/ Demonstration	Performance
5	Battery weight <=20kg	All Li-ion battery packs must weigh no more than 20kg	Weight	Performance
6	Top Speed <= 65mph	The vehicle must be limited to a top speed of 65mph	Measurement	Performance/ Safety
7	Tire contact patch >= ½ car width	The distance between the front and rear wheels contact patch must be no less than ½ of the car's width	Measurement	Performance/ Safety
8	Redundant Braking (Front/Rear)	Must have at least one redundant braking system. (two master cylinders)	Visual	Safety
9	Redundant Power Switch	Must have two main power switches to isolate battery pack during fault.	Demonstration	Safety
10	Driver's vision >= 700mm	Driver's eyes must be 700mm above ground	Measurement	Safety
11	Hand Brake Activated	Vehicle's parking brake must hold >= 10% of its weight (Driver Included)	Measurement/ Demonstration	Safety
12	Main fuse <= 200% max current draw	The main fuse must be rated <= 200% of the maximum rated current draw of battery pack or 75% of the rated wire current capacity	Visual	Safety
13	Car lighting	Car must have daytime running lights/ headlamps, front, side, and rear turn signals, and a rear brake light with a high center mount brake light	Visual/ Measurement	Safety
14	Roll Cage Safety	Roll Cage must withstand theoretical rollover 5G's from Z axis, 4G's from the X axis and 1.5G's from Y axis	Measurement	Performance/ Safety
15	Roll Cage Safety	Conduct Finite Element Analysis of proposed roll cage	Measurement	Safety
16	Roll Cage Safety	Roll cage will not deform by more than 25 mm and will not fail (exceed ultimate strength) at any point when subjected to the following load cases	Measurement	Safety
17	Roll Cage Safety	There must be 50 mm of clearance in all directions between any member of the Occupant Cell and the helmets of the occupants seated in the normal driving position.	Measurement	Safety
18	Roll Cage Safety	Roll Cage needs to deflect body/array panels of the car up and away from the occupants in the event of an accident.	Measurement	Safety
19	Roll Cage Safety	There must be 50 mm of clearance in all directions between any member of the Occupant Cell and the helmets of the occupants seated in the normal driving position.	Measurement	Safety

Approach

Draft 1 of the roll cage design was extremely over-engineered (Figure 1). Could withstand significant Gs in testing with minimal deformation, well beyond what was required by the ASC. The next step was to optimize the design and fabricate of a roll cage while designing a Matlab code to calculate drag force efficiency for the vehicle. The requirements matrix was completely redone to reflect the team narrowing the scope of the project to just focus on the roll cage for our project deliverable.

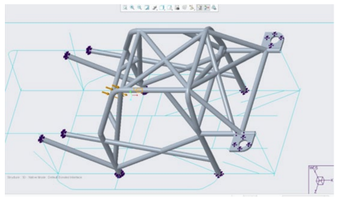


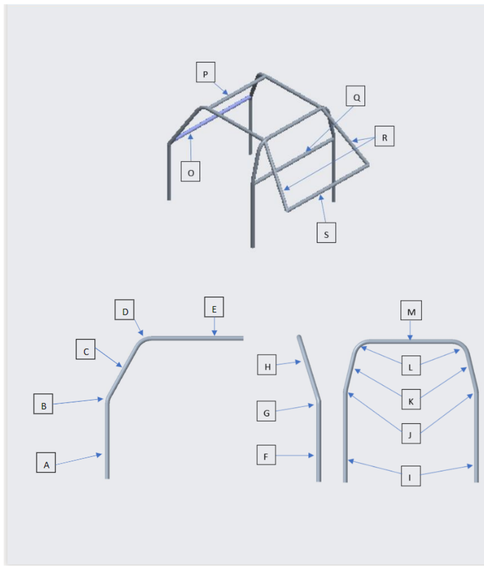
Figure 1: Draft 1 of the Roll Cage

Req #	Requirement	Description	Requirement Type
1	Withstand Rollover	Roll Cage design must withstand theoretical rollover 5G's from Z axis, 4G's from the X axis and 1.5G's from Y axis	Performance/ Safety
2	Strength of Cage Design	Conduct Finite Element Analysis of proposed roll cage	Safety
3	Roll Cage Safety	Roll cage will not deform by more than 25 mm and will not fail (exceed ultimate strength) at any point when subjected to the following load cases	Safety
4	Roll Cage Safety	There must be 50 mm of clearance in all directions between any member of the Occupant Cell and the helmets of the occupants seated in the normal driving position.	Safety
5	Roll Cage Safety	Roll Cage needs to deflect body/array panels of the car up and away from the occupants in the event of an accident.	Safety
6	Roll Cage Safety	There must be 50 mm of clearance in all directions between any member of the Occupant Cell and the helmets of the occupants seated in the normal driving position.	Safety

Final Design

Final Roll Cage Design (Figure 2)

- Chromoly 4130 tube used for the entire roll cage
- Measurements for tube lengths and bend angles for each section, broken down into A and B Pillars with support bars



A-Pillar (Side View)	
A	19.10 inches
B	150-degree bend at 2 inches
C	20.55 inches
D	120-degree bend at 2 inches
E	22.97 inches
Total Length	66.62 inches with 1.13-inch tube with .07-inch sidewall

A-Pillar (Front View)	
F	19.10 inches
G	165.5-degree bend at 2 inches
H	20.55 inches

B-Pillar	
I	24.57 inches
J	160- degree bend at 2 inches
K	12.17 inches
L	110-degree bend at 2 inches
M	20.66 inches
Total length	102.14 inches with 1.13-inch tube with .07-inch sidewall

Support Bars	
O	32.36 inches
P	32.38 inches
Q	33 inches
R	21.63 inches
S	33 inches
Size	1.13-inch tube with .07-inch sidewall

Figure 2: Roll Cage Breakdown

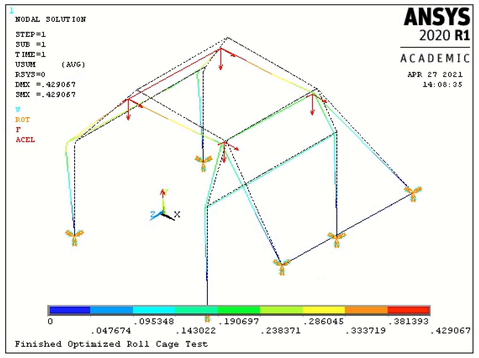


Figure 3: FEA Analysis

PRINT U NODAL SOLUTION PER NODE

***** POST1 NODAL DEGREE OF FREEDOM LISTING *****

LOAD STEP = 0	SUBSTEP = 1
TIME = 1.0000	LOAD CASE = 0

THE FOLLOWING DEGREE OF FREEDOM RESULTS ARE IN THE GLOBAL COORDINATE SYSTEM

NODE	UX	UY	UZ	USUM
1	0.0000	0.0000	0.0000	0.0000
2	0.38029E-002	0.58694E-003	0.14643E-00	0.15140E-001
4	0.37517E-001	0.23493E-002	0.12579	0.13129
5	0.47680E-001	0.27961E-002	0.15280	0.16009
6	0.72743E-001	-0.22125E-001	0.21830	0.23116
7	0.76209E-001	-0.25218E-001	0.21945	0.23367
8	0.28520E-001	0.29155E-003	0.21449	0.21833
9	0.28482E-001	0.29811E-001	0.21432	0.21825
10	0.39444E-001	0.26915E-002	0.15168	0.15675
11	0.32369E-001	0.22616E-002	0.12373	0.12792
13	0.37341E-002	0.56496E-003	0.14033E-001	0.14533E-001
14	0.0000	0.0000	0.0000	0.0000
15	0.0000	0.0000	0.0000	0.0000
16	-0.15121E-002	-0.34971E-003	0.16219E-002	0.22448E-002
18	-0.40327E-001	-0.69922E-002	0.20607	0.21009
19	-0.33531E-001	-0.99409E-002	0.22878	0.23141
20	0.86338E-001	-0.16161	0.38798	0.42907
23	0.78662E-001	-0.10062	0.30529	0.33093
25	0.0000	0.0000	0.0000	0.0000
26	-0.27704E-002	-0.64081E-003	0.21569E-002	0.35690E-002
28	-0.13573	-0.12814E-001	0.20932	0.24980
29	-0.13393	-0.14529E-001	0.23231	0.26854
30	0.44271E-001	-0.10909	0.38448	0.40210
33	0.35356E-001	-0.53939E-001	0.30663	0.31334
42	0.0000	0.0000	0.0000	0.0000
46	0.0000	0.0000	0.0000	0.0000
51	0.48571E-001	0.44389E-002	0.15224	0.15986
53	-0.37458E-001	-0.55019E-001	0.22969	0.23914
54	-0.69702E-001	0.58424E-002	0.23140	0.24174

MAXIMUM ABSOLUTE VALUES

NODE	28	20	20	20
VALUE	-0.13573	-0.16161	0.38798	0.42907

The chosen roll cage design after conducting an FEA only deformed 0.42", applying forces experienced in a rollover required by ASC and an estimated weight of 650lbs (Figure 3)

Results

Final Matlab code outputs for Required Power vs Acceleration, Required Power vs Velocity, Power vs Road Angle (Figures 4, 5, & 6 respectively)

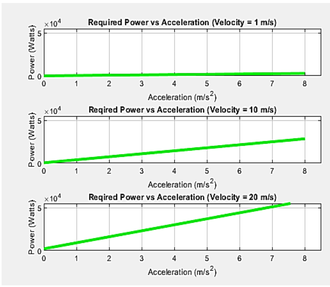


Figure 4: Required Power vs Acceleration

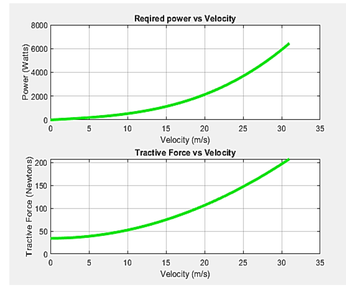


Figure 5: Required Power vs Velocity

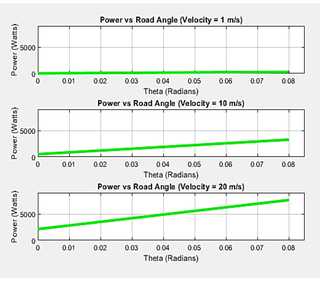


Figure 6: Power vs Road Angle

Summary

This capstone team has provided a foundation for the future capstone and WCU Solar Car members to build from in order to compete in the American Solar Challenge. The new roll cage design was optimized for saving weight and increased rigidity by changing complexity and materials used.

Team & Acknowledgements

- Team Members: Brian Planz (ET), Brandon Leonard (ET), Dave Gichner (EE), Karl Miller (EE), Kendall Petty (ME), Lucas Lombard (ECET)
- Sponsor/Mentor: Dr. Granda