HPVC

(ASME human powered vehicle challenge)

21Spr06-ASME HPVC
Trent Todd
Abel Aldape
Martin Dorantes
Preston Berchtold

Project Description

- Critical Design Review
- Design, Fabrication, Testing
- NAU ASME
  - Child Sized Vehicle
- Perry Wood P.E.

Figure 1: NAU Past HPV

Project Subsystems

- Roll cage
- Material selection
- Braking
- Drive train

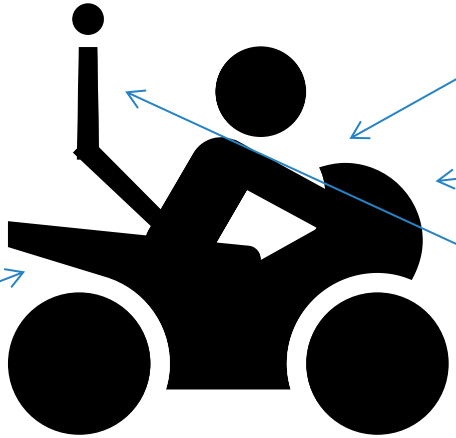

Figure 2: Subsystem Outline

- Steering
- Fairing advantages
- Ergonomics

SOTA Review: Material Selection

Aluminum 7005 alloy

- Zinc is major alloying element
- Requires heat treatment after welding
- Fracture toughness
- Corrosion resistance
- Less susceptible to stress-corrosion-cracking (SCC)
- 1/3 the density of steel (0.098 lb/in^3)
- Lightweight

Carbon fiber

- Easily repairable
- Strength is directionally dependent
- More expensive
- Labor-intensive manufacturing process
- UV-resistive coating
- Low density (0.072 lb/in^3)
- Lightweight

SOTA Review: Fairing Selection

- Reduces aerodynamic drag
- Higher speeds at lower human power
- Overall better performance at the cost of extra weight

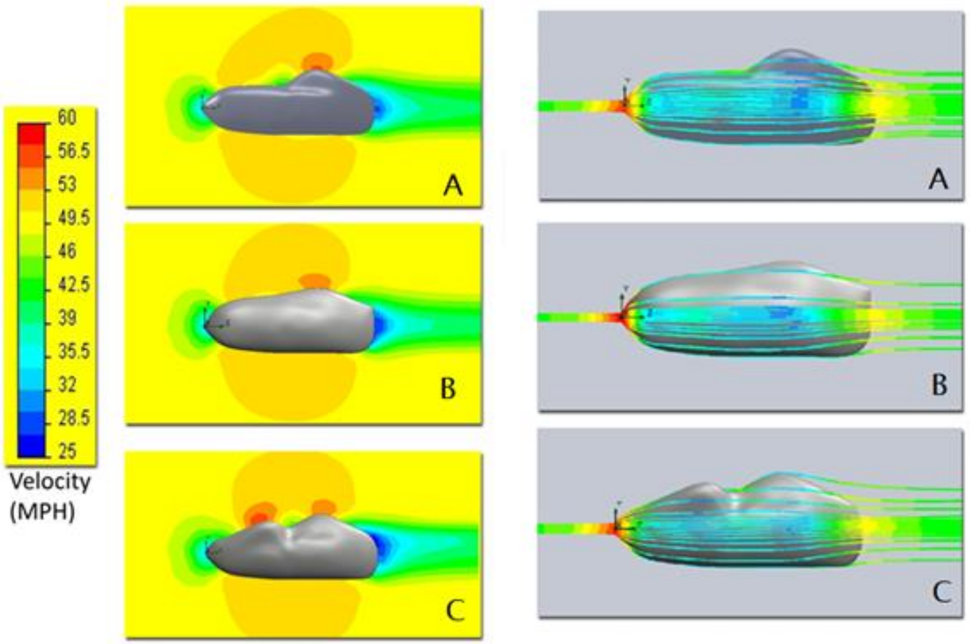

Figure 5: Velocity contour plot & pressure streamlines of HPV

Figure 6: Lightning F-40 with fairing

SOTA Review: Roll Cage

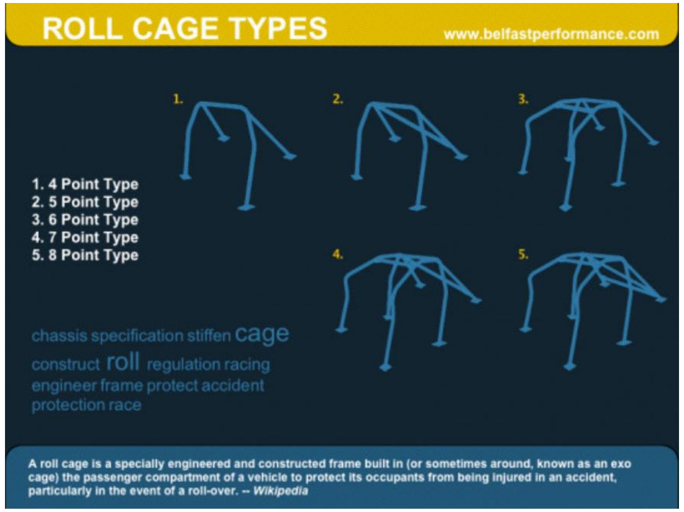

Figure 7: Roll Cage Diagram

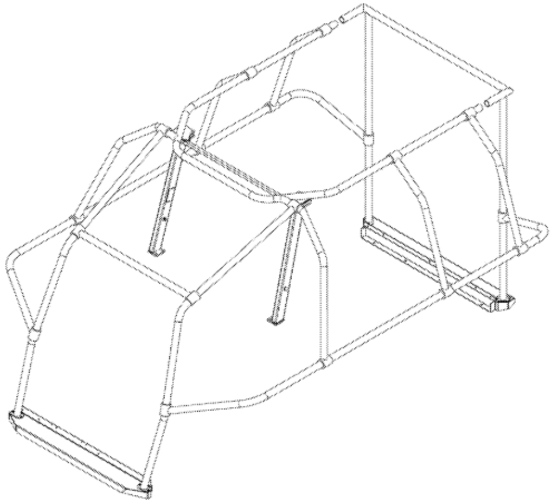

Figure 8: Roll Cage Patent

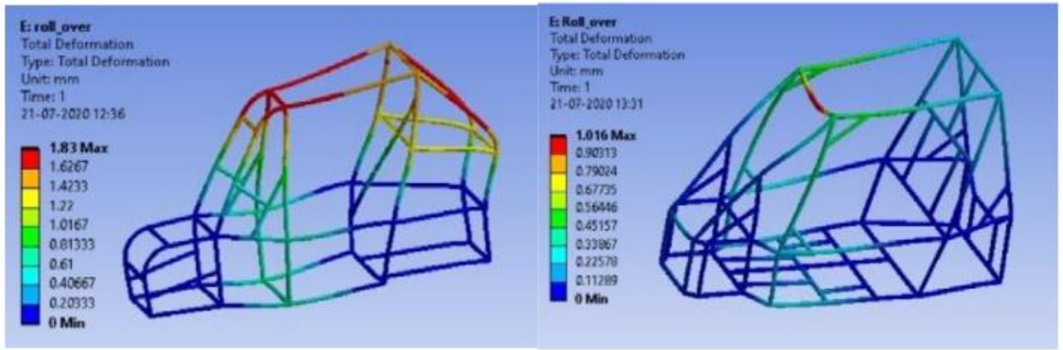

Figure 9: Example Roll Cage Testing

Material Selection

- Steel, Aluminum or Carbon Fiber

Roll Cage Design

- 4pt, 5pt, or 6pt cage

- Structure Outline

  [Main Hoop, Support Hoop, links, supports etc.]

- Structural Design

  [No broken or fractured structure links]

SOTA Review: Steering

Direct Steering

- Pros: More precise steering, mechanical simplicity
- Cons: Vibrations, less stable at higher speeds

Indirect Steering

- Pros: Adjustable steering ratios, ergonomics, adaptable to many designs
- Cons: Mechanically complex, heavier, less precise and lower speeds

Other considerations:

Tilt steering, bikes design (ex. trike vs bike), alignment geometry (caster, toe), front vs rear steering

Rule Constraint: Must be able to turn within an 8 m radius*

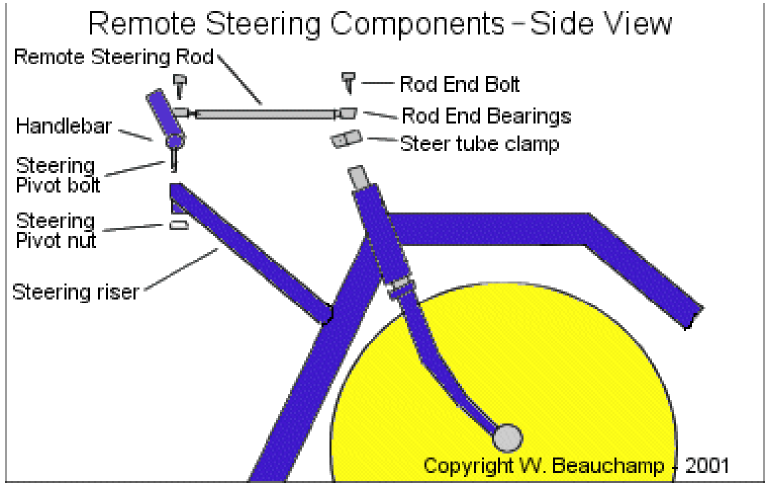

Figure 10: Remote steering

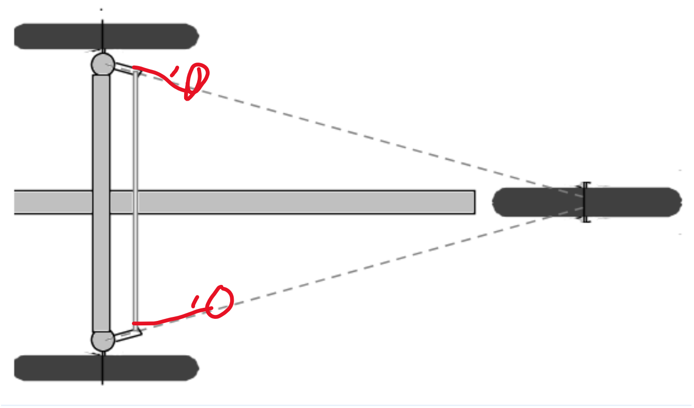

Figure 11: Ackman compensation steering, tadpole bike

SOTA Review: Drivetrain

Front wheel drive

- Pros: Shorter and more efficient chain-line, can allow for a larger front wheel
- Cons: Steering complications, wheel spin, instability when pedaling, mechanically complex

Rear wheel drive

- Pros: Makes the front of the bikes less complex, stability, traction
- Cons: Complex chain placement, longer distance to transmit power

Other considerations:

Bike design, shaft vs chain, single vs multi-speed, crank size, gearing ratios

Figure 12: FWD bike example

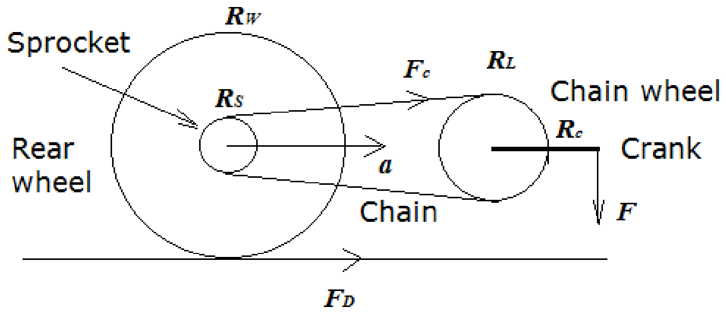

Figure 13: Chain, crank, sprocket force diagram

SOTA Review: Ergonomics

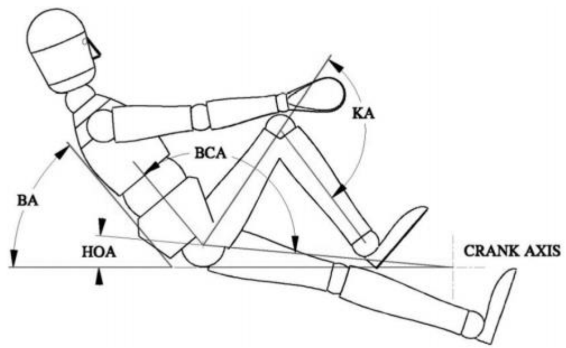

Figure 15: Important Angles for Power Output

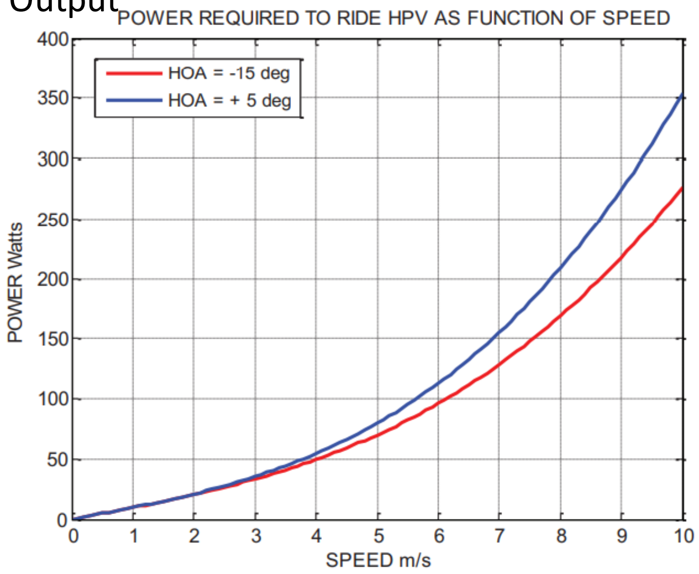

Figure 16: Speed as a function of Power

Maximize Power Output

Pros

- More Stability
- Smaller-Lighter
- Low COG

Cons

- Less Aerodynamic
- Less efficient
- More complex

- Tadpole Trike Design
- BCA: 130-140 degrees
- HOA: -15 degrees

Figure 17: NAU's 2014 Tadpole Trike Design

SOTA Review: Braking

Constraints:

- Must be able to stop going from 25 km/hr in 6 meters
- Must have brakes on every front wheel

Caliper Brakes

- Commercially Available
- Adequate Stopping power
- Less fastening requirements

Figure 18:Caliper Brakes

Cantilever Brakes

- More Stopping Power
- Made for Mountain biking or wet environments
- Requires individual arm mounts

Figure 19: Cantilever Brakes

Literature Review

Abel:

- Design of Human Powered Vehicles- Textbook
- Fundamentals of Biomechanics- Textbook

Martin:

- Aerodynamic Fairing for a Human Powered Vehicle (Lightning F-40)
- 2008 North American Handmade Bicycle Show
- Durability of Carbon Fiber Reinforced Polymer (CFRP) Strands

Preston:

- Shigley's Mechanical Engineering Design Textbook
  - Sprockets & Screws
  - Chains & Belts
- ASTM Standards
  - F2043.1497 [Classification]
  - F2843.26930 [Condition 0]
  - F2802.38084 [Condition 1]
  - F2868.17577 [Condition 2]

Trent:

- The Recumbent Bike Forum
  - HPV design and ideas
- Shigley's Mechanical Engineering Design Textbook
  - chapters 11, 13, 17

Customer and Engineering Requirements

Client: Perry Wood

- CR's established based off client and the rules for the 2021 Human Powered Vehicle Challenge

CR's	ER's
▪ Capable of high speeds	▪ Braking distance (m)
▪ Lightweight	▪ Weight (kg)
▪ Safe	▪ Cost ($)
▪ Cargo space	▪ Velocity (m/s)
▪ Loaded weight	▪ Turn radius (m)
▪ Large field of view	▪ Safety factor
▪ Roll over protection	▪ Strength (Mpa)
▪ Aerodynamic	▪ Stability
▪ Manufacturability	▪ Vision clearance (Degrees)
▪ Rider adjustability	▪ Volume (m^3)
	▪ Seat displacement (m)
	▪ Drag (N)
	▪ Deflection (mm)

Table 1: CR's and ER's

Quality Function Deployment

Roof Matrix

	Braking (25 km/hr stop within 6 m)	Weight	Price	Velocity	Turn radius (8m)	Saftey Factor	Strength	Stability	Vision clearance	Volume	Seat displacement	Drag	Deflection (rollcage)
Braking (25 km/hr stop within 6 m)													
Weight	++												
Price	-	--											
Velocity	--	-	-										
Turn radius (8m)	--	-	-	--									
Saftey Factor	++	+	--	--	++								
Strength	-	+	+	-	-	++							
Stability	-	-	-	-	-	++	-						
Vision clearance	--	-	-	-	-	++	-	-					
Volume	-	+	+	+	-	+	-	+	-				
Seat displacement	+	-	-	+	-	++	-	+	++	++			
Drag	++	+	-	++	+	++	+	++	-	+	-		
Deflection (rollcage)	-	+	+	+	+	++	++	+	-	++	+		

PHASE I QFD

	Customer Needs (What)	Customer Weights (1-5)	Braking (25 km/hr stop within 6 m)	Weight	Price	Velocity	Turn radius (8m)	Saftey Factor	Strength	Stability	Vision clearance	Volume	Seat displacement	Drag	Deflection (rollcage)
		Preferred (up or down)	-	+	-	+	-	++	-	+	-	++	+		
Performance	High speed	4	3	9		9	3	3				3		6	
	High maneuverability	4	9	6		3	9			6	3	3		1	
	Cargo weight	2	3	9		3	1		1		1	3			
	Safety	5	9	3		3	3	9	6	3	6		1		9
Production	Lightweight	3	6	9	3	6			3			6			3
	Cargo space	1						1		1	1	3	1		
	Large field of view	3						6			9				
	Aerodynamic	3			3	6				1		9		9	
	Manufacturability	3	3	3	9			6	6	1		6	3		9
	Seat adjustability	2						3					9		
	Rollover protection	4		3	3	3	6	9	6	6	1	3			9
		Absolute Technical Importance (ATI)	126	141	57	117	89	136	83	70	76	108	33	55	117
		Relative Technical Importance (RTI)	10%	12%	5%	10%	7%	11%	7%	6%	6%	9%	3%	5%	10%
		Unit of Measure	km/h^2	kg	$	kph	m		mpa	m	degree	m^3	cm	N	m/m
		Techical Target	-52.08	<50	<1600	> 25	< 8	>3	>1	> 1	> 170	>1			>1

Engineering Requirements (How)

Table 2: QFD

Schedule

Project Planner

Select a period to highlight at right. A legend describing the charting follows.

Period Highlight: #

Plan Duration | Actual Start | % Complete | Actual (beyond plan) | % Complete (beyond plan

ACTIVITY	PLAN START	PLAN DURATION	ACTUAL START	ACTUAL DURATION	PERCENT COMPLETE
Team Charter	1	2	1	2	100%
SOTA Review	3	6	3	6	95%
CR's + ER's	8	1	8	1	85%
QFD	8	2	8		70%
Presentation 1	8	2	4		85%
Decomposition	15	2			70%
Concept Generation	15	3			0%
Concept Evaluation	15	1			0%
Budget Planning	8	30	8		50%
Presentation 2	18	5			0%
Preliminary Report	20	1			0%
Website Check 1	15	3			0%
Prototype/Cad	18	6			0%
Presentation 3	35	3			0%
Final Proposal	35	4			0%
Final BOM and CAD	35	5			0%
Final Prototype	35	2			0%
Website Check 2	35	6			0%

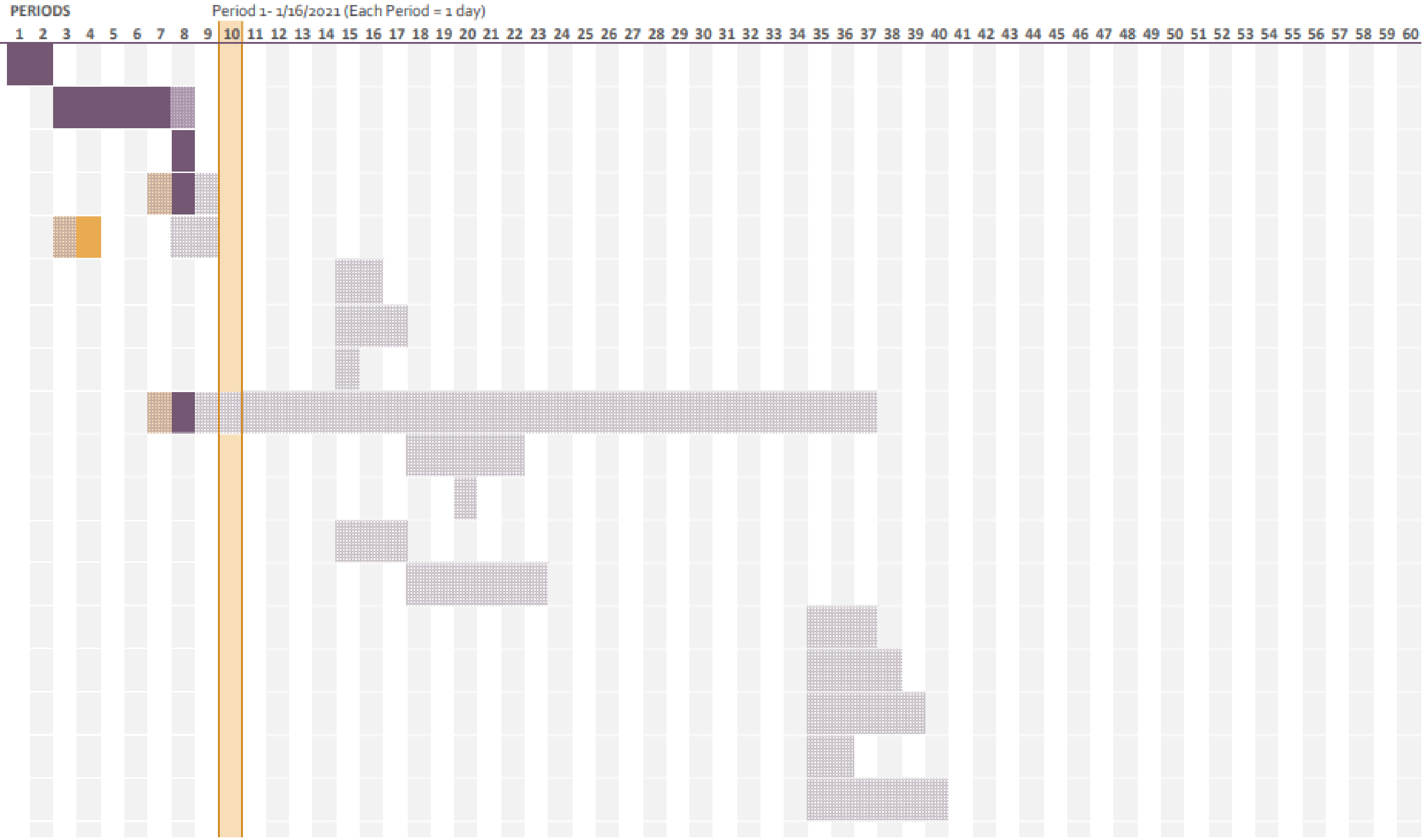

Table 3: Gantt Chart

Budget

- Guaranteed $1500 from client for project
- Additional Funding up to $3000 with approval of AZ ASME Chairman
- Budget frozen upon determination of competition involvement [No current expenses]

Item	Anticipated Cost
Bike Parts (Chain, Gears, Brakes etc.)	~$700
Tools	~$100
Material (Aluminum, Steel, Carbon Fiber etc.)	~$500
Safety Equipment (Seatbelt, Safety Seat, etc.)	~$200

Table 4: Budget Outline

Anticipated expenses were determined from past NAU teams, in additional to UC Berkley, Polytechnic Pomona, and UC Davis

Conclusion

- Now that our team has a better understanding of components that make up a human powered vehicle, we are better prepared to move forward in the project.
- Currently our team is interested in the Tadpole style recumbent bike.
- Child size bike

Questions?

Sources

1. *ASME: Standard Classification of Bikes*, F2043.1497, 2018
2. *ASME: Bikes: Condition 1*, F2802.38084, 2019
3. *ASME: Bikes: Condition 2*, F2868.17577, 2019
4. *ASME: Bikes: Condition 1*, F2614.40736, 2019
5. B. E. S. S. Aakash, D. M. Reddy, B. Ramachandran, and C. balaji N. S. Abhishikt, "Design and analysis of roll cage chassis," *Materials Today: Proceedings*, 03-Oct-2020. [Online]. Available: https://www.sciencedirect.com/science/article/pii/S2214785320358351. [Accessed: 01-Feb-2021].
6. M. Roy, "Roll Cage For All Terrain Vehicle," 18-Aug-2020.
7. The Mechanic Doctor, "How To Build A Roll Cage - Everything You Need To Know," *The Mechanic Doctor*, 07-Jan-2020. [Online]. Available: https://www.themechanicdoctor.com/how-build-roll-cage/. [Accessed: 01-Feb-2021].
8. R. G. Budynas, J. K. Nisbett, and J. E. Shigley, *Shigley's mechanical engineering design*. Boston: McGraw-Hill, 2008.
9. W. Beauchamp, "Remote Steering Construction," *The Recumbent Bicycle and Human Powered Vehicle Information Center*. [Online]. Available: http://www.recumbents.com/wisil/remotesteering/default.htm.
10. B. Knaus, P. Basmadjian, and N. Supat, California Polytechnic State University, San Luis, CA, rep., 2010.
11. "Types of Recumbent Bikes," *Where The Road Forks*, 26-Sep-2020. [Online]. Available: https://wheretheroadforks.com/types-of-recumbent-bikes/. [Accessed: 01-Feb-2021].
12. Tanks, J. & Sharp, Stephen & Harris, Devin & Ozyildirim, Celik. (2016). Durability of Carbon Fiber Reinforced Polymer (CFRP) Strands in a Simulated Concrete Environment.
13. Kim, K. Y., Park, W. L., & Bang, Y. H. (2011). A study on durability of carbon fiber reinforced polymers in civil applications. http://iccm-central. org/Proceedings/ICCM18proceedings/data/3.% 20Poster% 20Presentation/Aug22% 28Monday, 29, P1-58.