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CONCEPTUAL DESIGN OF TUBULAR CHASSIS OF A CUSTOM ELECTRIC ALL-TERRAIN VEHICLE

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Keywords

Electric all-terrain vehicle (eATV), Tubular chassis, Human Digital Modelling, Lightweight design, SAE BAJA

Abstract

The growing popularity of electric all-terrain vehicles (e-ATVs) necessitates lightweight chassis designs for enhanced efficiency and extended range. This study presents the development of a novel, optimized tubular chassis specifically designed for e-ATVs. The design iteratively optimizes tube diameters, wall thicknesses, and bracing strategies to achieve a superior strength-to-weight ratio. Additionally, the feasibility of integrating composite materials for specific, non-critical components is explored to further reduce weight without compromising structural integrity.

1. Introduction

The transportation landscape is undergoing a significant shift towards sustainable solutions. Electric vehicles (EVs) are playing a pivotal role in this transition, offering cleaner and more efficient alternatives to traditional gasoline-powered options. Within the EV segment, electric all-terrain vehicles (eATVs) are gaining traction due to their ability to navigate diverse terrains with minimal environmental impact. Conventional chassis designs for all-terrain vehicles (ATVs) prioritize strength over weight, a strategy well-suited for combustion engines but detrimental to eATV performance. The increased weight translates to reduced efficiency and limited range, two key limitations for eATVs. To address this challenge, this study focuses on the development of a novel, lightweight tubular chassis specifically tailored for eATVs.

The Indian market for all-terrain vehicles (ATVs) is currently dominated by traditional petrol - powered models, with a market size estimated at USD 470.55 million in 2023 [Next Move Strategy Consulting]. However, a nascent electric ATV segment is beginning to take shape, presenting intriguing possibilities for the future. While electric ATVs currently hold a small portion of the overall ATV market, industry analysts predict significant growth for the electric segment.

According to Next Move Strategy Consulting, the entire Indian ATV and UTV market, including both electric and petrol, is expected to reach USD 929.98 million by 2030, indicating a Compound Annual Growth Rate (CAGR) of 9.4% from 2024 to 2030 [Next Move Strategy Consulting]. This growth suggests a potential increase in electric ATV adoption alongside the rise of the overall market.

The BAJA SAE vehicle's chassis, or roll cage, is the core structure. It supports all components, prioritizing both strength and lightweight design for optimal performance. Functioning as a safety cage during rollovers, the chassis is a crucial element for both vehicle capability and driver protection. [1]. Race car chassis design is a balancing act. It needs to be stiff to fight twisting forces in corners for precise handling, but also lightweight for better acceleration and agility. This is achieved through special materials and simulations, with the goal of a responsive car that sticks to the track. [2] The granular approach provides an accurate understanding of the model's overall behavior under various conditions. [3] This paper investigates chassis safety through several tests: frontal crash, rear impact, side collision, rollover, bumps, and torsion. These simulate real-world stresses to ensure the chassis protects occupants in all crash scenarios. [4] The roll cage prioritizes occupant safety in crashes, especially rollovers, through its high-strength, impact-absorbing design. While offering secondary mounting and stiffness benefits, its core function is protecting the occupant's life. [5] The BAJA SAE India rulebook dictates the CAD model's construction, employing a three-

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-tiered member system. Primary members, built for maximum strength, form the core of the chassis. Secondary members offer additional support, while tertiary members focus on non-structural functions like mounting components. This ensures a safe, strong, and lightweight chassis that adheres to competition regulations. [6] Reducing weight while maintaining strength is a top priority. It leads to performance improvements (handling, prosthetics) and environmental benefits (less material). Advanced materials and manufacturing are making this lighter, stronger future a reality. [7] For increased range and efficiency, a high strength-to-weight ratio is key. Engineers consider not just the material properties but also availability and manufacturability to find the optimal balance for safety, efficiency, and cost effectiveness. High-strength steel alloys are an affordable option. [8]

However, the integration of a powerful electric motor and battery pack presents unique design challenges. The weight distribution needs careful consideration to maintain optimal handling, while the chassis must possess the structural integrity to withstand the high torque generated by the electric drivetrain and the demands of off-road maneuvering.

2. Modelling Of Chassis

The basic references for the design are from the BAJA SAE INDIA RULEBOOK 2024, this includes the all the restrictions including the ergonomics for the driver, such as the knee, shoulder and head clearances. Developing a 3D CAD model of the chassis using solid modelling software, CATIA, including all critical features like motor mounts, battery tray, suspension mounting points, and driver seat location, ensuring proper clearances for drive train components and steering system. Designing bends with large radii to minimize stress concentration and potential for cracking.

This is done in accordance to the rule book by keeping the bend radii 6 inches. Accounting for standard tube lengths available to minimize material waste and ensuring accessibility for welding seams and proper joint design for strength.

The Chassis models are created by taking into account a range of design aspects, including section modulus, manufacturability, availability, weld-ability, and economics.

2.1 Chassis Model

Chassis Member Terminology:

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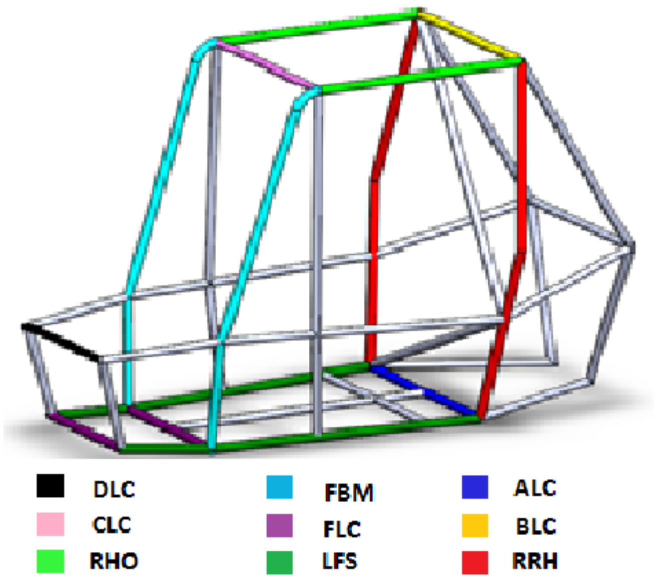

Figure 1: Primary Members [SAE BAJA Rule Book 2023]

Primary members

The primary members consist of 4 pairs of members and 5 lateral cross members. The members are:

ABBREVEATION	MEMBER NAME	NUMBER OF MEMBERS
DLC	SIM Lateral Cross Member	1
CLC	Upper Lateral Cross Member	1
RHO	Roll Hoop over-head member	2
FBM	Front Bracing Member	2
FLC	Front Lateral Cross Member	2
LFS	Lower Frame Side Member	2
ALC	Aft Lateral Cross Member	1
BLC	Overhead Lateral Cross Member	1
RRH	Rear Roll Hoop	2

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Secondary members:

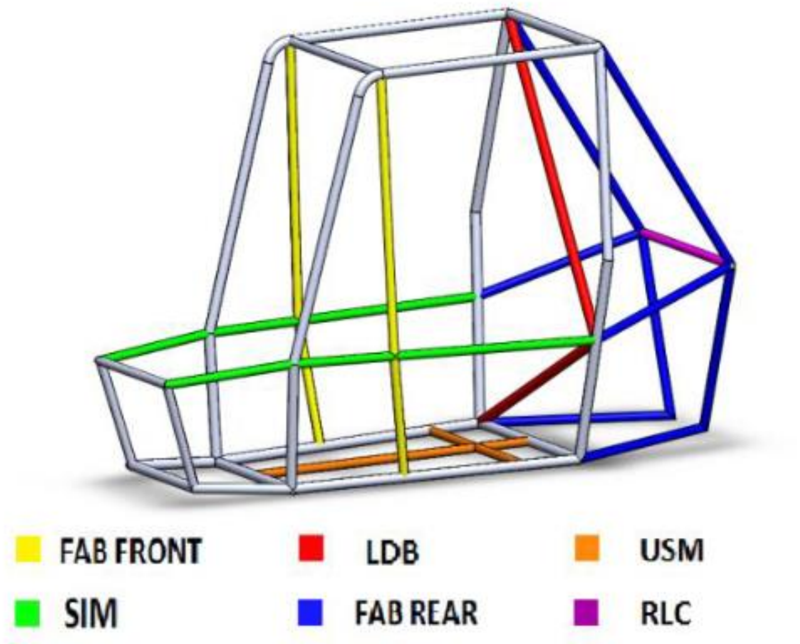

Figure 2: Secondary Members [SAE BAJA RuleBook 2023]

ABBREVEATIONS	NAME OF MEMBER	NUMBER OF MEMBERS
FAB Front	Fore/Aft Bracing Members	2
SIM	Side Impact Members	2
LDB	Lateral Diagonal Bracing	1
FAB REAR	Fore/Aft Bracing Members	8
USM	Under Seat Members	2
RLC	Rear Lateral Cross Member	2

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The cad model was designed based on the parameters mentioned in the rulebook. Roll cage members shall be exclusively made from steel tubing and may be constructed in either a straight or bent configuration. Straight members must not exceed a maximum length of 1016 millimetres (40 inches) between designated Named Points, or alternatively, comply with the stipulations outlined in Rule B.3.2.4, which states, If Additional Support Members are used, the supported Roll Cage Member will be evaluated for length and/or additional bends between Named Point and the location of the Additional Support Member, concerning Additional Support Members. Bent members are subject to a maximum bend angle of 30 degrees, excluding bends occurring at Named Points. Additionally, their maximum length between Named Points cannot surpass 838 millimetres (33 inches), or they must adhere to the regulations set forth in Rule B.3.2.4 regarding Additional Support Members, as mentioned above. Tight bend radii (less than 152 millimetres or 6 inches) terminating at Named Points are considered acceptable and do not classify the member as bent, regardless of the angle. A bend culminating at a Named Point signifies that the point lies either at or between the points of tangency associated with the bend. All mandated dimensional specifications between roll cage members are determined by measuring the centrelines of the members, with exceptions noted elsewhere in the regulations. The joining points of Primary and Secondary members, as detailed hereafter, must be situated within 51 millimetres (2.0 inches) of the designated Named Point, with exceptions noted elsewhere. Mitered joints exceeding a 5-degree angle in the tubing will be categorized as bends. Conversely, mitered joints with an angle less than 5 degrees will be considered butt joints and subject to the provisions outlined in Rule B.3.2.14 concerning Butt Joints. Mandatory members comprised of multiple segments, such as the SIM and LFS, will be evaluated as continuous members extending from Named Point to Named Point, with exceptions noted elsewhere.

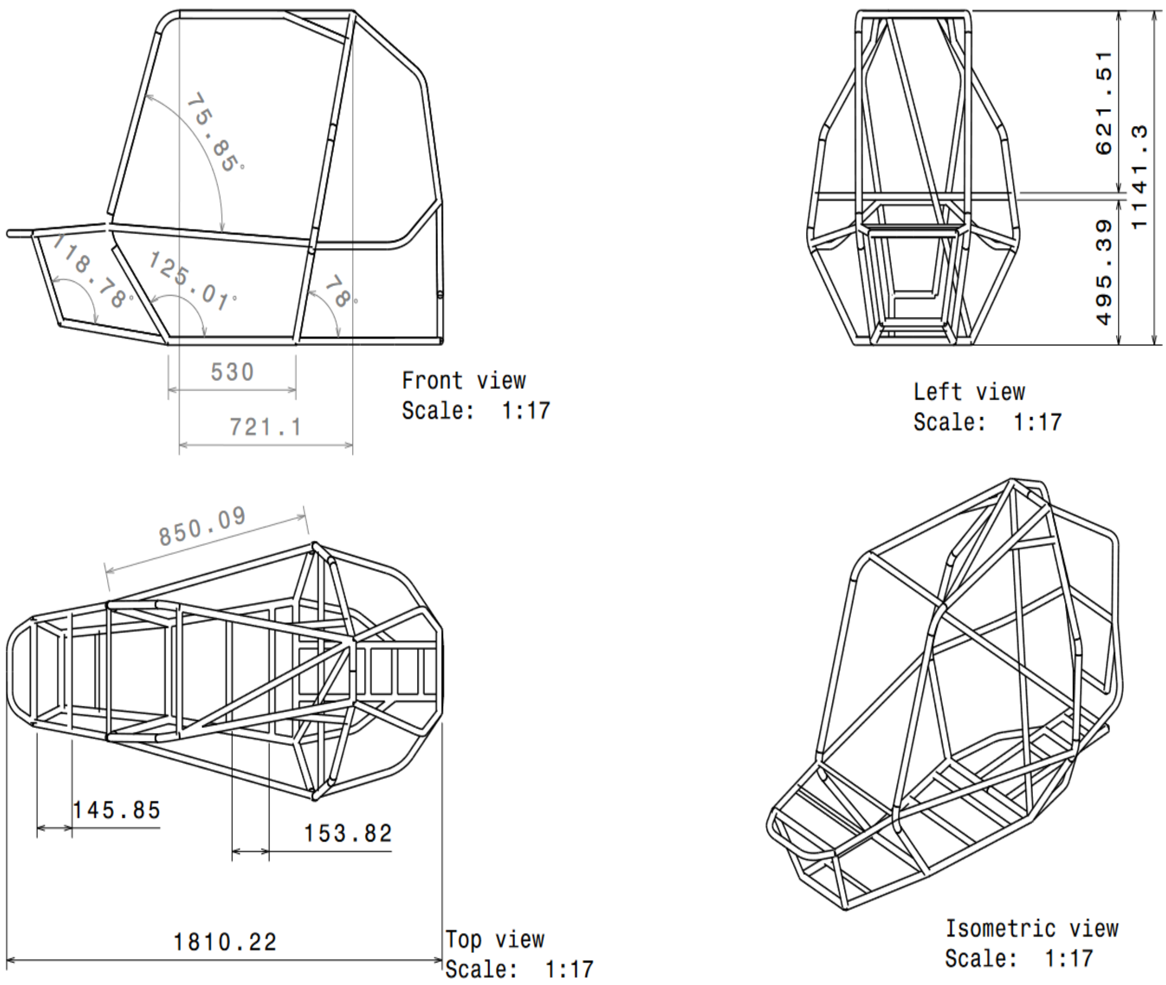

Figure 3: Drafts Drawings of the chassis

3. Results and Future Scope

The conceptual design presented in this work utilizes a tubular chassis for the custom electric all-terrain vehicle (e-ATV). The design is based on the SAE BAJA Rulebook which is ergonomically designed.

Static structural and dynamic analysis may be conducted on this model using Ansys to test and optimize the strength of the chassis. Different impact loads may be considered and the stress and the deformation values may be Evaluated.

The human digital model based on Indian anthropometric data can be created in CATIA V5. By placing the mannequin in an electric vehicle, RULA and REBA analyses can be carried out to check ergonomic feasibility. By implementing both RULA and REBA, valuable insights into potential ergonomic shortcomings of the ATV design can be gained. This information can then be used to refine the design to create a more comfortable and user-friendly experience for the driver, ultimately reducing the risk of work-related injuries. [12,13,14]

Fabrication and testing are needed to ensure design considerations meet the safety criteria.

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The writers affirm that they have no connections to, or engagement with, any group or body that provides financial or non-financial assistance for the topics or resources covered in this manuscript.

6. Conflict Of Interest

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

7. Plagiarism Policy

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