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Structural Optimization of ATV chassis Using FEA Analysis

Tejas sunil Parve.
Department of Mechanical Engineering
Dr. Vishwanath Karad MIT World Peace University,
Maharashtra, India.

Swanand S. Pachpore
Department of Mechanical Engineering
Dr. Vishwanath Karad MIT World Peace University,
Maharashtra, India.

Adityaraj Dilip Kate
Department of Mechanical Engineering
Dr. Vishwanath Karad MIT World Peace University,
Maharashtra, India.

Pradeep V Jadhav
Department of Mechanical Engineering
Bharati Vidyapeeth University College of Engineering
Maharashtra, India.

Abstract— **The primary supporting structure of a vehicle is its chassis. In static as well as dynamic conditions, it supports all of the vehicle's stresses. Channel sections, tube sections, and box sections are the three types of sections used to accomplish this, depending on the structural requirements. In the work that is being given, the author made an effort to construct and optimise a tube frame chassis that is secure, comfortable, and as light as is practical. CAD software was used for the initial design of the chassis, and FEA concepts were used for the rollover analy-sis and weight reduction. The outcome of the effect study was found to be significant and can be used in both prototype and actual manufacturing.**

Keywords— Chassis,Weight Optimization, Rollover Analysis, Impact Analysis

1. INTRODUCTION

The vehicle's space frame or chassis is referred to as the roll cage. The roll cage connects the engine train, control, and suspension systems, among other crucial functions. Since the driver must be comfortable in order to operate the vehicle effectively, driver ergonomics and safety come first [1]. Important design elements that affect desirable attributes like weight distribution and suspension functionality include mounting points and overall frame shape. The roll cage must also be lightweight and sturdy enough to support all of the weights placed on it. In the case of a collision with a structure or an accident with another vehicle, as indicated in fig. 1[2][22], it must also be able to protect the driver and important vehicle components.

Figure 1: Roll-Cage of Vehicle [2]

The safe design of the chassis was found to be essential because, in the case of a violent inci-dent, it should have little impact on the local environment and have no long-term detrimental effects on the community. As a primary goal, the author of the article in question has tried to present a robust and dependable All Terrain Tubular chassis that can withstand a range of loading situations, including static and dynamic loadings, and can safeguard the driver and vital vehicle components when colliding with other cars or hard objects [3]. Along with the primary goal, the author also designed an off-road vehicle chassis with the right tube diameter, wall thickness, and material to withstand a range of stress situations to have a high [4] Factor of Safety, the least amount of weight, and a reasonable cost[20].

2. METHODOLOGY

1. Fixing Minimum Dimensions of Roll Cage: The minimum dimensions of the roll cage were decided taking the driver into consideration. Since the primary task of the roll cage is to protect the driver in case of any accident, driver comfort ability was given paramount importance. The roll cage should be able to accommodate a person of height comfortably.

2. Base Model Selection: The design parameters were space considerations, manufacture-ability, safety Features, cost, quality, weight, better ergonomics, pleasing aesthetic looks as already stated in design goals. Also, a torso of the driver was modelled in accordance with the anthropometric charts developed.

3. Comparison of models based on specified criteria: To compare the models, and to come out with a final base model, a table of comparison was thought off. This table was made taking some parameters into consideration like weight, height of Centre of gravity, etc. Results of the FEA analysis were also taken into consideration for finalization of the optimized model with different approaches [17].

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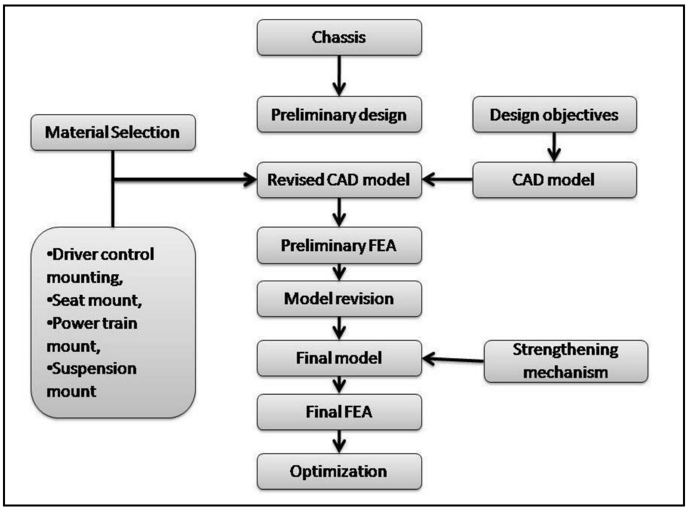

Figure 1: Methodology for Structural Analysis [15]

3. DESIGN OF CHASSIS

The materials indicated in table I below are used to construct the chassis or roll cage. Steel grade[5], [6] must be chosen for the chassis under consideration since it is widely available in a variety of grades and sections, has a high elongation, and is ductile by nature. Because of its geometric property to withstand stress and deform uniformly independent of their axis, circles and round tubes were chosen[23]. Because there is a tension between safety and performance, the author's study focuses primarily on the weight to strength ratio. Strength and weight must be carefully managed. Instead of solely depending on the strength of the material, the design must be designed to achieve structural rigidity [7], [8].

Parameter	Description
Material	Steel (Properties as per Design Data Guide)
Cross Section	Tubular (Circular)
FoS	1.25
Overall Vehicle Length	< 2500 mm
Ground Clearance	< 200 mm
Overall Vehicle Width	< 820mm

Table II: Weight comparison of Chassis

Both the general frame geometry and particular tube geometries received a lot of design con-sideration during the original design phase of the chassis. The total frame size was decreased as much as possible to conserve weight [11]. To increase their effectiveness in force resolution, members that are primarily loaded in tension or compression are also resolved. They were designed with certain tube forms, like the front and rear damper mounts, to manage the stresses that would be placed on them[24]. The conventional shock tower form used in many desert buggy designs had an influence on the curved hoop shape of the rear damper mount member[21]. As indicated, the goal is to resolve the immediate damper force in a single compo-nent with only a few bracing elements adding additional stiffness shown in fig.4.

The conceptual models illustrated in fig. 3 are taken into account with the design parameters specified in the preceding sections, given the material and vehicle constraints.[25]

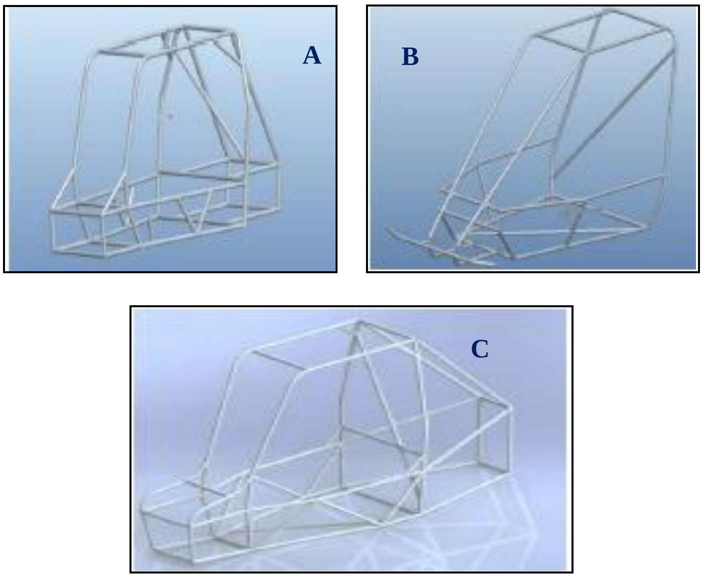

Figure 3: Conceptual Chassis Models (3 Variants)

To assess the models and come up with a final base model, a table of comparison, as seen in table II, was created. Weight, center of gravity height, and other factors were taken into con-sideration when designing this [9], [10].

Model	Initial Weight (Kg)
A	98
B	83
C	78.76

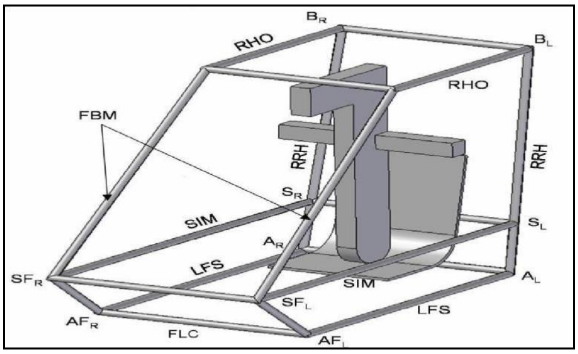

Figure 4: Elements of the Chassis

Based on material characteristics such carbon content, a decision matrix has been plotted for the available grades of steel as shown in Fig. 5 to help determine the right grade of

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material for the chassis. Chromoly AISI 4130 has been chosen because of its weldability, availability, yield strength, elongation, and tensile strength [12][16].

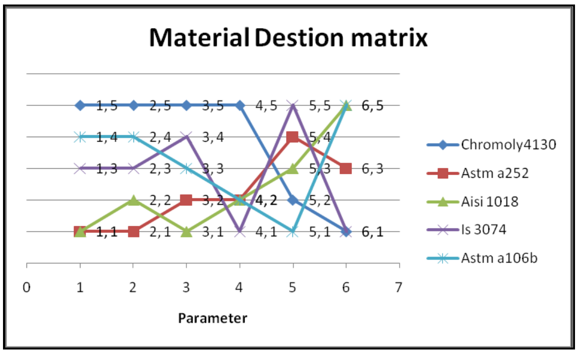

Figure 5: Decision matrix for material

To guarantee the structural integrity of the chassis and driver safety throughout the demands of competition, a 3D conceptual formulation of the frame was constructed and subsequently evaluated using finite element analysis software [13]. The damper loads for anticipated jump landing heights were calculated using the proposed finite-difference computational simula-tion. FEA analysis was utilized to increase frame rigidity, decrease overall weight, and ensure chassis integrity[18]. The vehicles were commonly seen landing in the air one to several vertical meters after taking off from jumps. In the case that the automobile drifted sideways around a bend and either the front or rear outside wheel struck a boulder or tree, it was observed that the 3G side load used in the literature design was also a significant and crucial loading scenar-io[19]. Another constant was that after reviewing numerous test films it was determined that many jumps are uneven, which causes the vehicles that launch from them to tumble in the air and land unevenly on one side. Because the one-wheel landing and 3G sides loading were viewed as worst-case scenarios[14], the yield strength rather than the fatigue limit is what lim-its the resulting peak design stresses. In order to arrive at the final design, front impact, rear impact, side impact, heave test, roll over test, front bump, rear bump, and twist ditch tests were all conducted[25]. The FEA model was created using the following parameters: Element category: h-element, Element shape: tetrahedral, Element type: pipe, FEA analyze approach: top-down approach, Element character: solid, Nodes/element: 4 nodes [15], Von-misses stress and total deformation was considered, as shown in fig. 6.

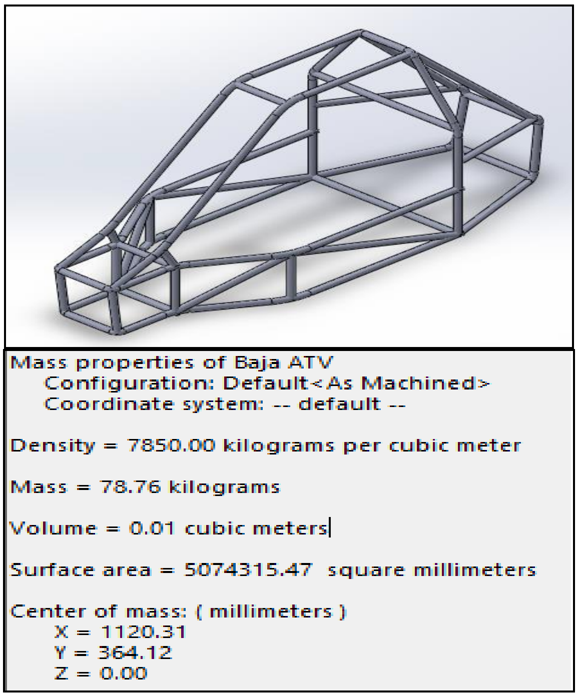

Figure 6: FE Model and Properties

4. FE RESULTS

Load of 33 KN was applied for front impact; maximum stress was determined to be 330 MPa; and FoS was determined to be 1.39, which is determined to be safe as shown in fig. 7.

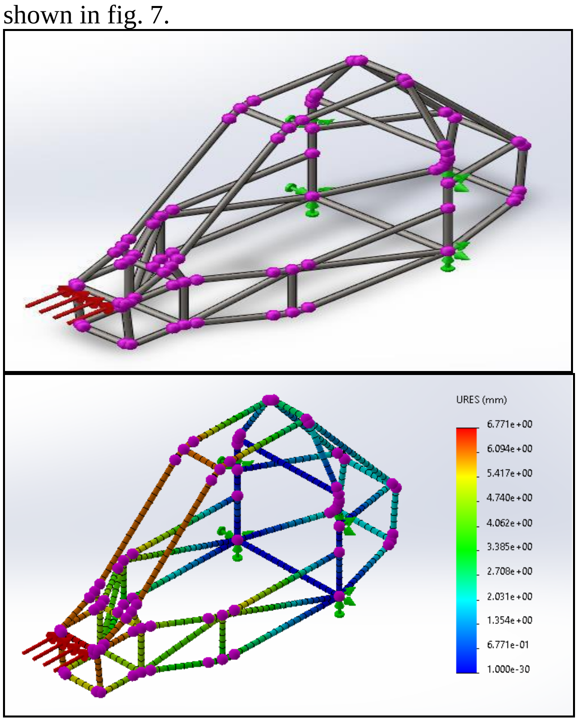

Figure 2: Frontal Impact Boundary Condition and Results

Similar results were reported for side and rear impacts, where a load of 13.75 N was applied, and the maximum stresses were found to be 179.9 MPa and 2.57 MPa and 1.587

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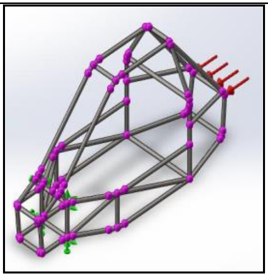
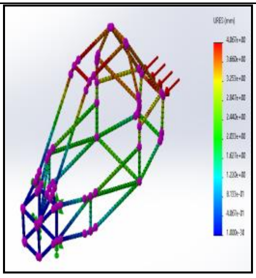
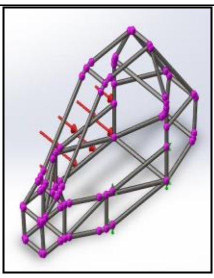
MPa and 2.57 MPa, respectively[16]. A load of 2.773 KN was applied for the heave test, and the maximum stress was determined to be 141.1 MPa, with a FoS value of 1.25. A load of 9750 N was ap-plied for the roll-over test, and the maximum stress and force were both determined to be 111.7 MPa and 3.908, respectively, as shown in Fig. 8.



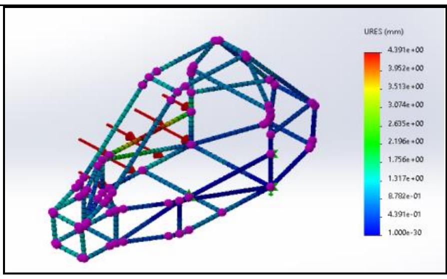
Rear Impact Boundary Conditions



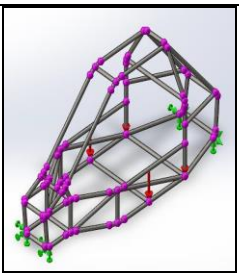
Rear Impact Test Displacement



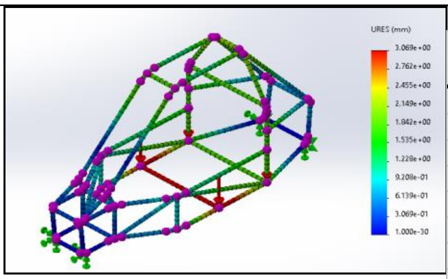
Side Impact Boundary Conditions



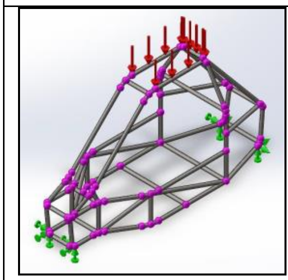
Side Impact Test Displacement



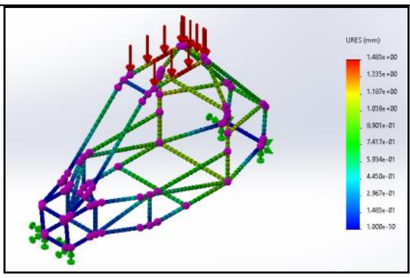
Hleave Test Boundary Conditions



Heave Test Displacement



Rollover Boundary Conditions



Roll over Displacement

Figure 3: Various Boundary Conditions and Results Obtained

With the use of finite element analysis and chassis optimization, the safety, rigidity, stress distribution, and weight of the frame were all improved. Each FEA simulation targeted certain tubes or components to optimize the tubular structure. Each study focused on high stress are-as and reduced them by adding bracing elements to change stiffness and distribute load to other areas.[22] Additionally, the wall thickness and tube size were adjusted until each one was under uniform strain[23]. As indicated in fig. 9, unnecessary large-diameter members that experience little stress are swapped out for smaller-diameter members that can bear the applied stresses. Designs with FOS values much above 1.25 are made in a way that keeps the value of FOS within a narrow range but above 1.25, and the results are compared in table III.

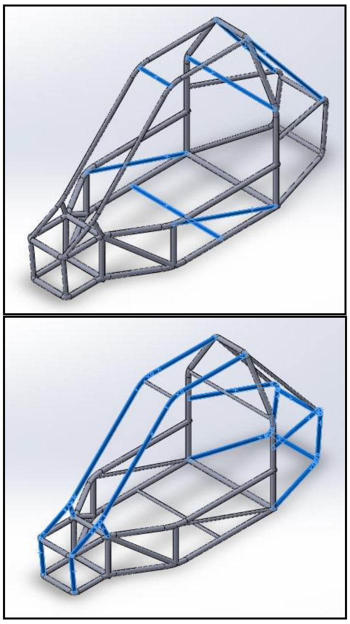
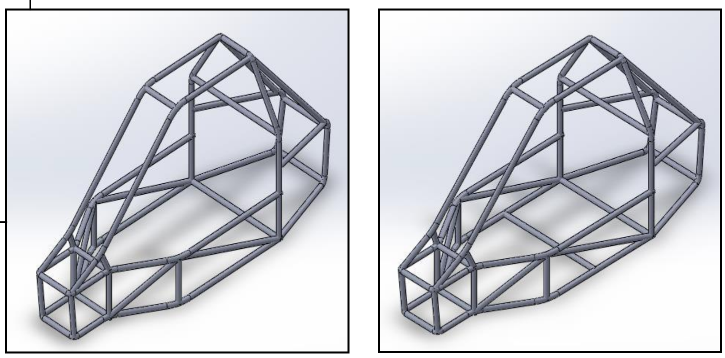


Figure 4: Optimized Chassis with reinforced Members

Sr. No	Parameter/Test	FOS Values		Result
		Before	After	
1	Front Impact	1.39	1.273	Considerable as more than 1.25
2	Rear Impact	2.557	1.313	
3	Side Impact	2.533	1.817	
4	Heae Test	3.214	2.119	
5	Roll Over	3.908	2.606	
6	Front Bump	3.485	2.952	
7	Rear Bump	2.603	1.472	
8	Torsional Rigidity	3.965	2.124	

Table I: Result Comparison

Weight optimization was done since, after installing the reinforced members, it was discov-ered that the weight had gone up by 4%, or 3.15 kg, as shown in Fig. 10.



A) Old Frame B) New Frame

Figure 5: Chassis with Reinforced Members

4. CONCLUSION

Following conclusions can be drawn from the carried out FEA study of the chassis in the pre-sented article, which was examined for a variety of standard load cases.

1. By using virtual design and analysis to their fullest potential, designers were able to build designs that satisfied requirements for safety, durability, and maintainability.
2. Design goals were met, producing a finished item that could withstand the rigorous of off-road driving while yet providing the driver with the necessary comforts.
3. The weldability of the improved chassis structure was further examined and found to be substantial.
4. FOS was more than selected and the weight was also optimized by 23.90%.

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