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Design & Development of Chassis of Electric All-Terrain Vehicle

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Abstract: *This paper presents the design, structural validation, and mass optimization of an All-Terrain Vehicle (ATV) roll cage framework. To circumvent the high costs and time constraints of physical prototyping, a virtual engineering workflow was established using SolidWorks for 3D computer-aided modeling and ANSYS for Finite Element Analysis (FEA). The primary base framework was geometrically constrained using 95th percentile human ergonomic data to optimize cabin space, while the vehicle firewall was inclined at 9° to provide thermal isolation from the powertrain. Under simulated impact boundary conditions, the structural integrity, stress distribution, and deformation profiles were evaluated to determine the structural Factor of Safety (FOS). Through an iterative simulation loop, non-critical structural members were eliminated. Furthermore, by selecting a high-strength material compliant with the 0.18% minimum carbon content regulatory mandate, tube wall thickness was safely reduced from 3.0 mm to 1.57 mm. The final optimized design achieves a significant reduction in overall chassis mass while preserving structural safety margins.*

Keywords: All-Terrain Vehicle (ATV), Roll Cage, Computer-Aided Design (CAD), Finite Element Analysis (FEA), Structural Optimization, SAE BAJA

I. INTRODUCTION

An All-Terrain Vehicle (ATV) is defined by the American National Standards Institute (ANSI) as a vehicle operating on low-pressure tires with a straddle seat and handlebar steering. Engineered for extreme manoeuvrability across rugged landscapes, ATVs are widely utilized in critical sectors such as construction, military logistics, mineral exploration, and emergency rescue. In modern automotive engineering, physical manufacturing must be preceded by virtual modeling and simulation to minimize development timelines and prototyping costs.

The structural core of an ATV is its roll cage, designed around three primary engineering pillars: safety, optimization, and driver comfort. Its foundational purpose is to provide a rigid, three-dimensional protective envelope that ensures operator survival high-energy rollover or impact events, during while simultaneously serving as a lightweight mounting chassis for components like the powertrain, steering, and suspension.

This study focuses on the computer-aided modeling and numerical optimization of a robust ATV roll cage. The structural geometry was developed within **SolidWorks**, while virtual stress and deformation analyses were executed via **ANSYS** Finite Element Analysis (FEA). By identifying high-stress concentrations and structural redundancies through simulation, iterative alterations were made to the geometry and material properties. Ultimately, this paper demonstrates how optimizing structural members and reducing tube wall thickness from 3.0 mm to 1.57 mm yields a high-strength, low-mass roll cage that maximizes vehicle performance without sacrificing driver safety.

II. METHODOLOGY & PROJECT LAYOUT

To systematically resolve structural demands and satisfy the regulations of the SAE BAJA and Mega ATV Championship rulebooks, the project was executed according to a structured six-stage engineering workflow:

- **Problem Definition:** Identified the need for a lightweight yet strong ATV chassis capable of withstanding static and dynamic off-road loads while improving vehicle performance and acceleration.
- **Literature Survey:** Reviewed existing research on ATV chassis design, frame configurations, material selection, and structural analysis to identify research gaps and design requirements.
- **CAD Design:** Developed conceptual sketches and created a detailed 3D model of the ATV roll cage/chassis using SolidWorks software.
- **Material Selection:** Compared different materials based on mechanical properties, density, cost, and weldability to select the most suitable material for the chassis.
- **Finite Element Analysis (FEA):** Performed structural analysis under various loading conditions using ANSYS to evaluate stress distribution, deformation, and factor of safety.
- **Prototype Development and Testing:** Fabricated the chassis using cutting, bending, and welding processes, followed by structural inspection and validation.
- **Cost Estimation and Documentation:** Prepared cost analysis, technical specifications, and comprehensive project documentation based on the design and manufacturing process.

III. STRUCTURAL DESIGN & GEOMETRY

The geometric architecture of the roll cage was designed using advanced weldment features within SolidWorks. To minimize localized stress concentrations, sharp intersections and abrupt angles were systematically avoided, favoring smooth transitions instead. The primary floor profile was designed on a horizontal reference plane, with length and width bounds constrained by the physical clearance needed to fully house a **95th percentile human male operator**.

An integrated structural firewall isolates the cockpit compartment from the electric motor, powertrain, and battery assemblies. According to international safety guidelines, this firewall can be inclined up to 20°relative to the base vertical normal. For this vehicle, a **9° rearward inclination** was implemented to balance driver packaging constraints and vehicle weight distribution. The firewall is skinned with a heat-resistant material designed to withstand high operational thermal outputs, and it provides structural hard points for mounting the driver safety harness and a fire extinguisher. The upper canopy structure was engineered to provide clear fields of view, straightforward driver egress, and dedicated structural pickup locations for the steering assembly and suspension links.[5]

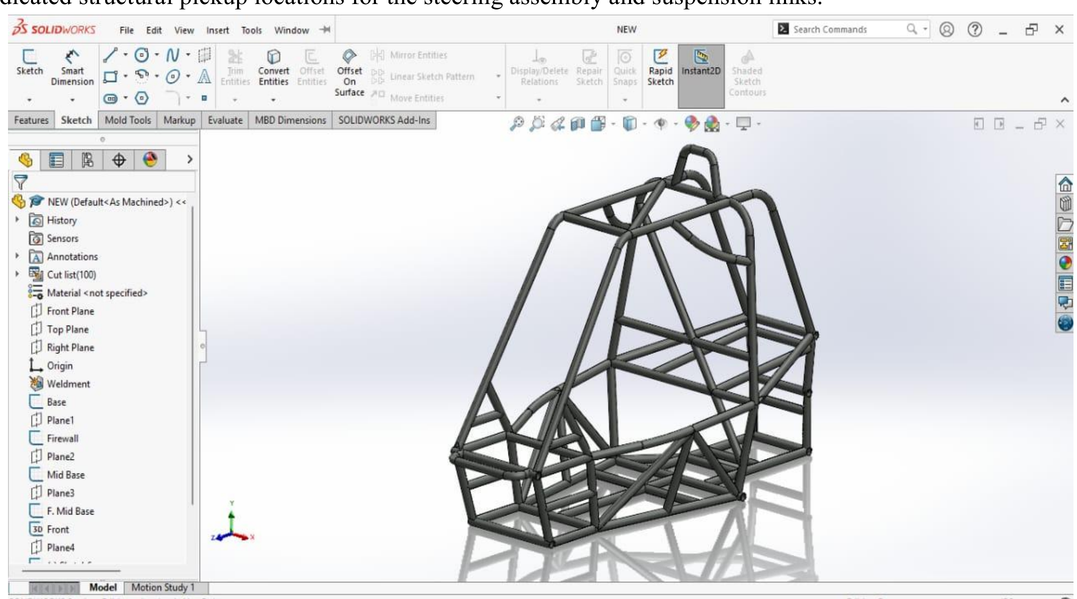

Figure 1: Isometric 3D geometry and structural wireframe layout designed in SolidWorks

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IV. MATERIAL SELECTION

To satisfy safety regulations, the primary structural tubing must possess a minimum carbon content of 0.18%. A material selection matrix was constructed to evaluate standard low-carbon AISI 1018 steel against high-strength AISI 4130 Chromoly steel based on mechanical performance indices.

Table 1. AISI4130 Chromoly material properties.

Property	AISI 1018	AISI 4130
Density (g/cc)	7.87	7.85
Poisson's Ratio	0.29	0.28
Young's Modulus (Gpa)	205	210
Carbon Content (%)	0.18	0.30
Tensile strength (Mpa)	440	560-670

Thus, upon taking every single above-mentioned attribute into consideration, the material selected was **AISI 4130 (Chromoly)**.[5]

V. FINITE ELEMENT ANALYSIS

The roll cage model was analyzed in **ANSYS Workbench** under front, side, rear, and rollover impacts. **AISI 4130 steel** was used as material, and results showed stresses within safe limits with a **factor of safety above 2**.The tests which were conducted are as follows:

Front impact test

For front impact the load is applied on the front most members and the fixed member is last member. The ATV is moving at the top speed of 60 km/hr. The front impact analysis image was shown in fig.2

Few approximations were taken

Weight=300kg, Speed (Max.) =60 km/hr

V (initial) =16.67m/s, V (final) =0

Impact time=0.30sec

Work done=|0.5Mv (final) ^2 - 0.5Mv (Initial) ^2

=0.5x300x (0) ^2 -0.5x300x (16.67) ^2|

=41683.33Nm

Work done=Fxd

d=t*v (initial) =0.30x16.67=5.001m

F=41683.33/5.001=8334.99N

F≅9000N

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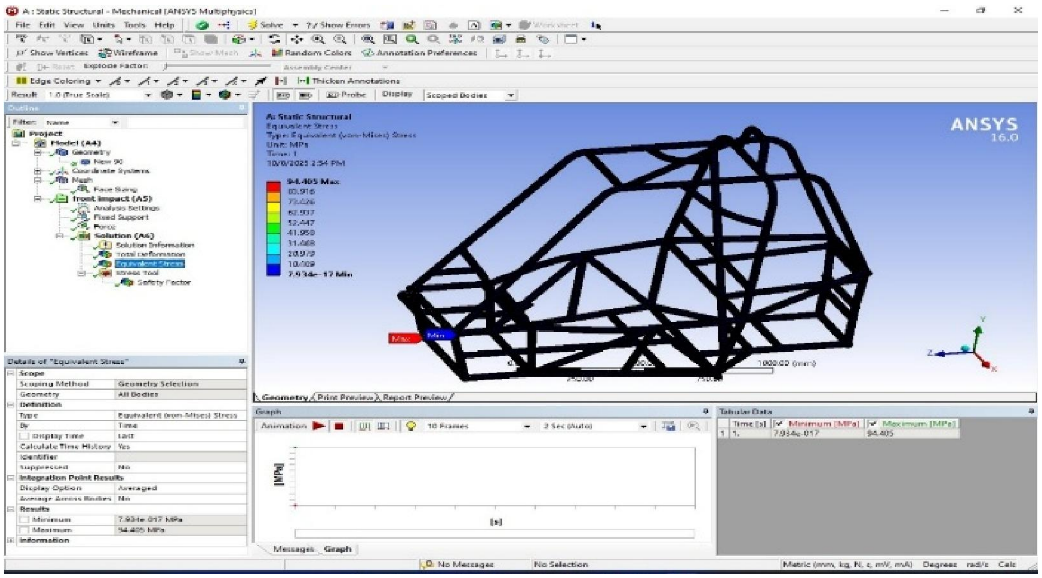

Figure 2. Front impact analysis

Side impact test

For side impact, the load is applied on the side most member. And the fixed member is other side member. The side impact analysis image was shown in fig.3

Here we will test how much stress the roll cage can take from sideways.

Impact time (t) =0.30sec

Velocity (v) =16.67m/s

Again by same method we have calculated the workdone.

Work done=|- 0.5Mv^2|

=|-0.5x300x (16.67) ^2|

Work done=41683.335J

d=v*t

d= 0.30×16.67

d=5.001m

F=Work done/d

F=41683.335/5.001=8335N

F≅9000N

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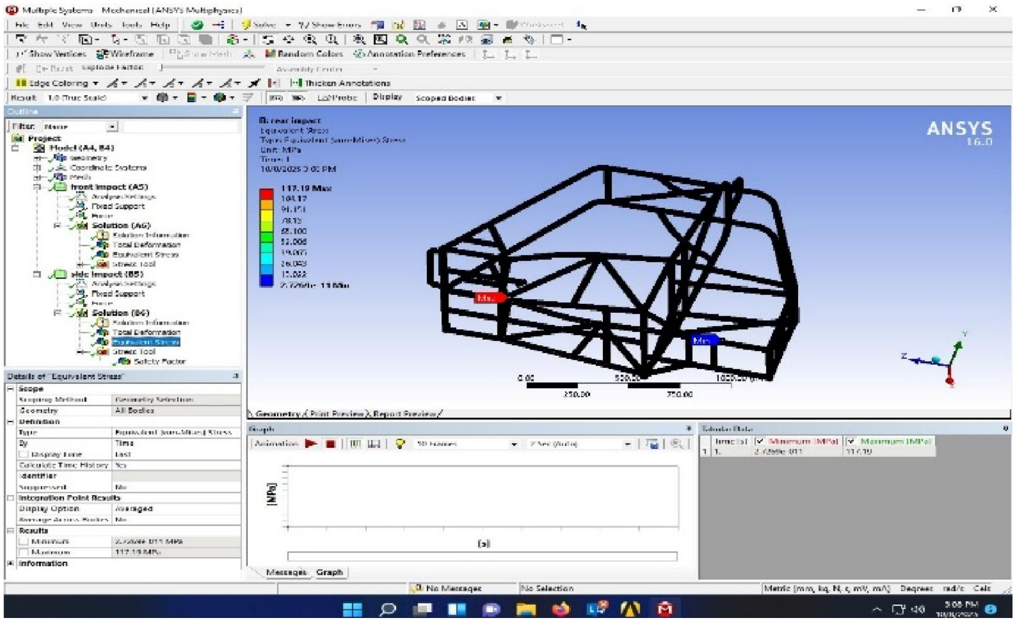

Figure 3. Side impact analysis

Rear impact test

For rear impact, the load is applied on the rear most member. And the fixed member is front member. The rear impact analysis image was shown in fig.4

Here we test how much stress the rear part of the roll cage can take.

Impact time (t) =0.30sec

v=16.67m/s

Work done is again calculated by same method and is

Work done=|- 0.5Mv^2|

=|-0.5x300x (16.67) ^2|

Work Done=41683.33N

d=t*v

d= 0.30×16.67

d=5.001m

F=work done/d

F= 41683.33 / 5.001

F=8335N

F≅9000N

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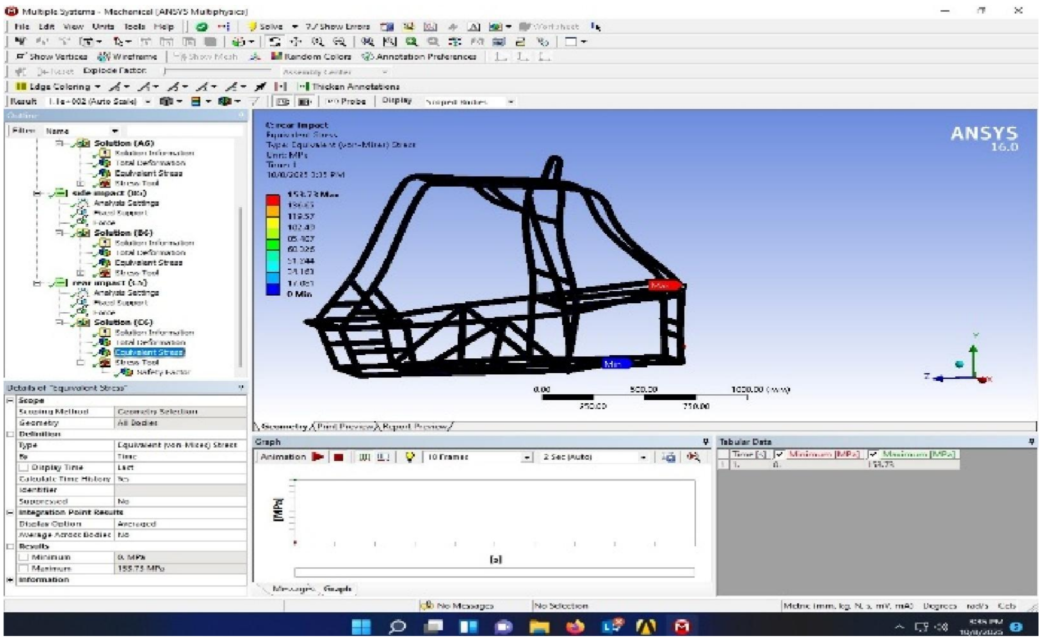

Figure 4. Rear impact analysis

Roll over test

During fall the overall potential Energy will be converted into kinetic energy hence;

M*g*h=0.5*M*(v^2)

$v=\sqrt{(g)}\ h \times 2$

Assuming the height of the fall to be 10 feet

10ft=3.048m

v=7.733m/s

Just substitute this v in the work done equation and find out Work done.

Work done=|- 0.5Mv^2|

=|-0.5x300x 7.733^2=8969.59J

Impact time (t) =0.13sec

d=t*v

$d=0.13 \times 7.733=1.005m$

F=work done/d

F=8969.59 / 1.005=8925.26

F≅9000N

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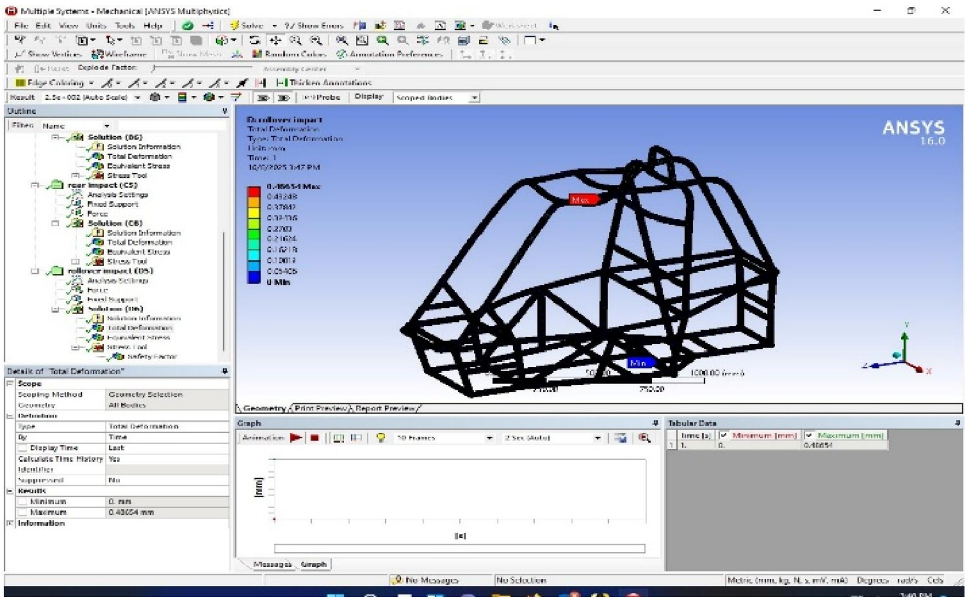
Figure 5. Roll over analysis

5.1 Result and discussion

Table 2.Results of different test

Aspects	Front impact test	Side impact test	Rear impact test	Rollover impact test
Impact (load),N	9000	9000	9000	9000
FOS	4.66	3.75	2.862	4.74
Total deformation, mm	0.16925	0.32812	1.1769	0.48654
Maximum stress, Mpa	94.405	117.19	153.73	92.827

The roll cage was analyzed under front, side, rear, and rollover impact conditions with an applied load of **9000 N**. The results show that all tests achieved a **factor of safety greater than 2**, indicating a safe design. The **rear impact test** produced the highest stress (**153.73 MPa**) and deformation (**1.1769 mm**), making it the most critical case. The **rollover test** showed the highest factor of safety (**4.74**). Overall, the stress and deformation values were within acceptable limits, confirming the structural integrity and safety of the roll cage design.[1, 4]

VI. FABRICATION OF ATV ROLL CAGE

Following the completion of the parametric modeling and computational optimization phases, physical manufacturing was executed. The fabrication workflow was systematically structured into discrete engineering operations—encompassing raw material processing, geometric contouring, and thermal joining—to preserve tight dimensional tolerances and maximize global structural stiffness.

The fabrication of the roll cage was carried out through cutting, notching, bending, and welding operations. AISI 4130 steel tubes were cut and fish-mouth notched according to the dimensions obtained from the CAD model to ensure accurate joint fitment. The tubes were then bent using a pipe-bending machine to achieve the required geometry while minimizing defects such as flattening and wrinkling. Following dimensional inspection and alignment verification, the members were assembled using Metal Inert Gas (MIG) welding. MIG welding was selected due to its high welding speed, ease of operation, good penetration characteristics, and ability to produce strong, defect-free joints. The completed structure was inspected to ensure dimensional accuracy and structural integrity.[2, 3]

VII. CONCLUSION

The design, structural analysis, and fabrication of an Electric ATV chassis were successfully completed. AISI 4130 Chromoly steel was selected due to its high strength-to-weight ratio, enabling the development of a lightweight yet robust structure. Finite Element Analysis (FEA) demonstrated that the chassis could safely withstand front, side, rear, and rollover impact loads, with all stress values remaining below the material yield strength and an acceptable factor of safety. The fabricated chassis satisfies the structural and safety requirements for off-road electric vehicle applications, providing a reliable platform for future vehicle development.

VII. FUTURE SCOPE

Future work may include dynamic and fatigue analysis, experimental validation of simulation results, optimization of chassis geometry for further weight reduction, and integration of the powertrain, battery pack, suspension, and steering systems. The use of advanced lightweight materials and topology optimization techniques can also be explored to enhance vehicle performance and efficiency.

REFERENCES

[1] V. B. Bhandari, *Design of Machine Elements*, 4th ed., McGraw Hill Education, 2017.
[2] S. Kalpakjian and S. R. Schmid, *Manufacturing Engineering and Technology*, 7th ed., Pearson Education, 2014.
[3] L. Jeffus, *Welding: Principles and Applications*, 9th ed., Cengage Learning, 2020.
[4] ANSYS Inc., *ANSYS Mechanical User's Guide*, 2024
[5] MEGA ATV CHAMPIONSHIP Rule book 2025