

# Design and Development of Mini-BAJA Chassis

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**Abstract** - The objective is to design and develop safe and rigid roll cage for all terrain vehicle which accommodates all Baja SAE rulebook. The purpose of the roll cage is to provide a minimal three-dimensional space surrounding the driver. The cage must be designed and fabricated to prevent any failure of the cages integrity. Before we started designing the roll cage, we had certain design parameters which we identified keeping in mind the application of the vehicle. The major parameters were High Ground clearance, Compact and light structure without compromising on the strength ergonomically and aesthetically sound Driver's safety. The vehicle has to travel in adverse condition so; the worst case damages needs to be taken into consideration. We started the design process by first making our driver sit in his preferred driving posture, converted this into a 3D sketch and determined the position of the driver's seat and the control pedals relative to each other. The position of driver was such that comfortable position is achieved considering 4 hours tough and dynamically versatile Endurance Race. The 3D modeling is done using creo software and analysis is done in hyperworks. As the results got in analysis, the changes have been made so as the factor of safety of the impact analysis of chassis is fulfilled.

**Keywords** - ATV, Mini-Baja, Hyperworks

## I. INTRODUCTION

The Main objective of the design was to build a sporty robust vehicle without compromising much on the performance in extreme terrains. Primary objective was that the vehicle should complete all the dynamic events without any breakdown. A core team was identified which overlooked, supervised and coordinated the different sub-teams responsible for design of identified major subsystems which was then integrated into a final design. The Main objective of the design was to build a sporty robust vehicle without compromising much on the performance in extreme terrains. Primary objective was that the vehicle should complete all the dynamic events without any breakdown. A core team was identified which overlooked, supervised and coordinated the different sub-teams responsible for design of identified major subsystems which was then integrated into a final design. Since the entire roll cage has been designed around our driver's driving posture ergonomics has been given topmost priority. The steering wheel and pedals have been placed so that hand

movement during is minimal. All foot pedals have been placed body roll ergonomically so that their operations are convenient over long period of time [1].

## II. MATERIAL AND TUBE SIZE SELECTION

Design considerations aside, the driving factor behind chassis material selection were the SAE competition vehicle regulations. Section 31.5 of the official 2016 Baja SAE Rule Book states that "the material used for the entire required roll cage members specified in 31.2.1 must, at minimum, be either circular steel tubing with an outside diameter of 2.5 cm (1 inch) and a wall thickness of 3.05 mm (.120 inch) and a carbon content of at least 0.18% OR steel members with at least equal bending stiffness and bending strength to 1018 steel having a circular cross section with a 2.54 cm (1 inch) outer diameter and a wall thickness of 3.05 mm (.120 inch). This ruling left the team with two options that were to either manufacture the roll cage from steel and the rest of the frame from aluminum or to make the entire chassis using steel. The slight increase in weight from an all steel chassis far outweighed the difficulty of reliably attaching a steel roll cage to an aluminum frame, thus the team chose to use steel. The steel chassis also has many other benefits including lower cost, higher safety factors, better manufacturability, and increased reliability. With this we have selected AISI 1018 Steel for our chassis. For primary members we have used 31.75 mm OD and 1.65 mm thick cross-sections and materials we have used is shown in following table with bending stiffness [1].

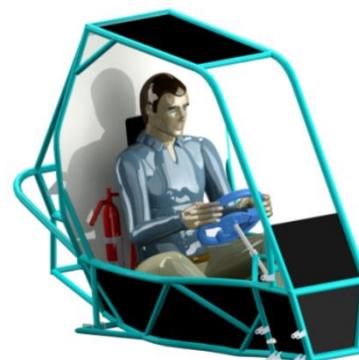


Fig. 1. Mini- Baja chassis

WEIGHT (kg)	Torsional Rigidity (Nm/deg)	Colour
30.32	1619.19	Blue
31.16	1873.82	Red
32.54	2158.48	Yellow
34.12	2391.25	Purple

In order to optimize the tubular structure, specific tubes or areas were focused on during each FEA simulation. The SAE rule book and driver envelope specifications (ergonomics) dictated the placement of many of the main structural tubes, so the bulk of refinement occurred with tube size, wall thickness, and location of bracing members. During each analysis, the areas of high stress were concentrated on and alleviated by adding bracing members to tune the stiffness and re-distribute load to other areas. Additionally, the tube size and wall thicknesses were adjusted until they were all uniformly stressed. This was a difficult process because as the chassis was optimized for one loading scenario, the changes made affected the stress distributions in the other load cases [2-3].

Table I  
Equivalency Calculations

Outer diameter (mm)	Inner diameter (mm)	Thickness (mm)	Moment of inertia 'I' (mm <sup>4</sup> )	Bending stiffness (EI) (N-mm <sup>2</sup> )	Bending Strength (N-mm/MPa)
25.4	19.4	3	13478.638	2.7631 x 10 <sup>9</sup>	1061.310
31.75	28.45	1.65	17723.373	3.633 x 10 <sup>9</sup>	1116.432
25.4	21.4	2	10136.744	2.078 x 10 <sup>9</sup>	798.1688
25.4	22.2	1.6	8508.815	1.744 x 10 <sup>9</sup>	669.985
25.4	23	1.2	6695.049	1.372 x 10 <sup>9</sup>	527.169

Elastic modulus: 205000N/mm<sup>2</sup>

We have done the Torsional Analysis in order to obtain desired torsional rigidity and the gusseting members are placed according to it.

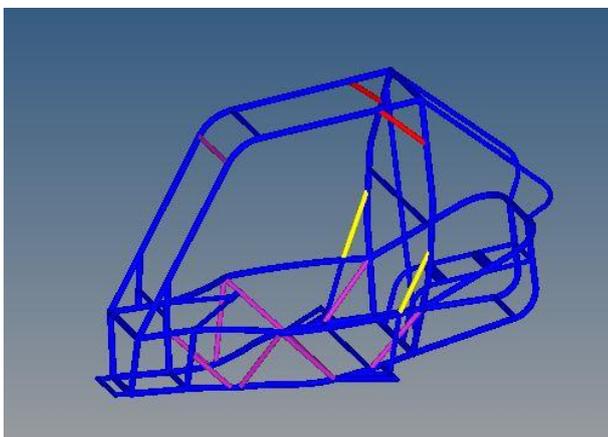


Fig. 2. Chassis after Torsional analysis

Table II  
Torsional Analysis

Total deformation in Y-direction =  $\Delta y_1 = 2.56\text{mm}$ .  
Total deformation in -Y-direction =  $\Delta y_2 = 2.56\text{mm}$ .  
We calculated torsional rigidity of the chassis by using following formula,

$$\text{Torsional Rigidity} = \frac{T}{\tan^{-1}\left(\frac{\Delta y_1 + \Delta y_2}{2 \cdot l}\right)}$$

Where, l = distance between Centre of car and suspension pickup points.

$$\text{Torsional Rigidity} = \frac{1252.54}{\tan^{-1}\left(\frac{0.00256 + 0.00256}{2 \cdot 0.28}\right)}$$

$$\text{Torsional Rigidity} = 2391.256 \text{ N.m/degree}$$

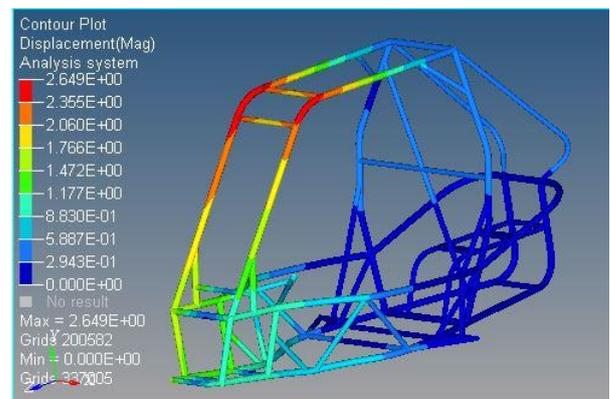


Fig. 3. Torsional Analysis

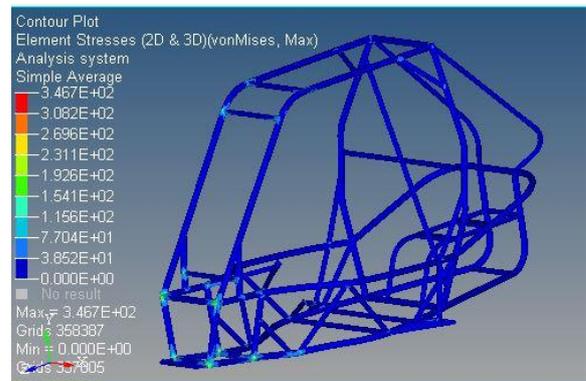


Fig. 4. Torsional Analysis

### III. DYNAMIC ANALYSIS

#### A. Front impact analysis (Car to wall)

In order to simulate the frontal impact crash, the vehicle was assumed to impact upon a stationary rigid mass with a speed of 50 Km/h [4].

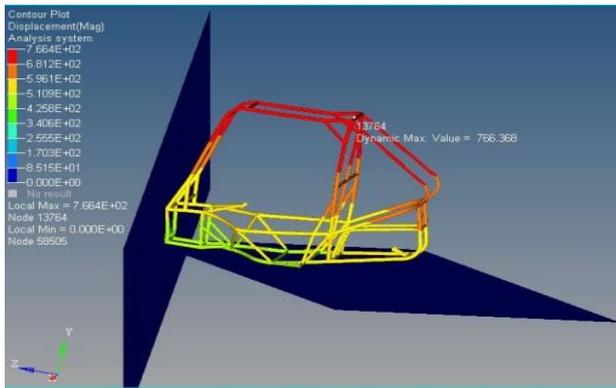


Fig. 5. Displacement

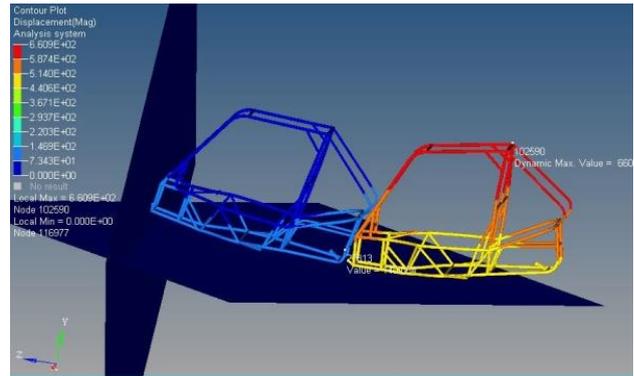


Fig. 8. Displacement

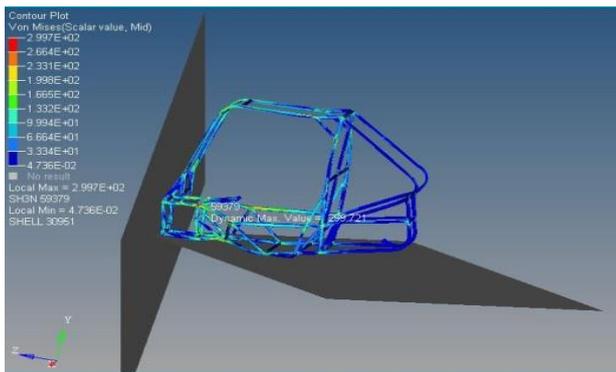


Fig. 6. Stress

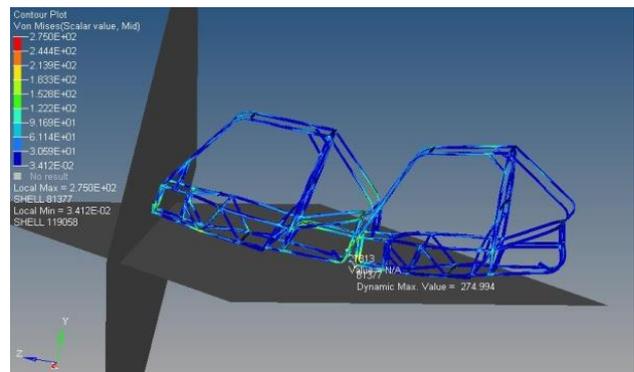


Fig. 9(a) Stress

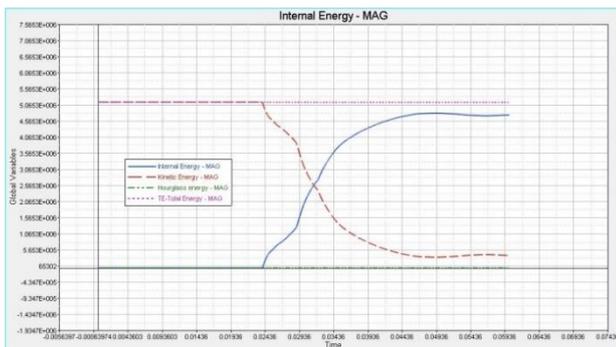


Fig. 7. Energy Conversion Graph

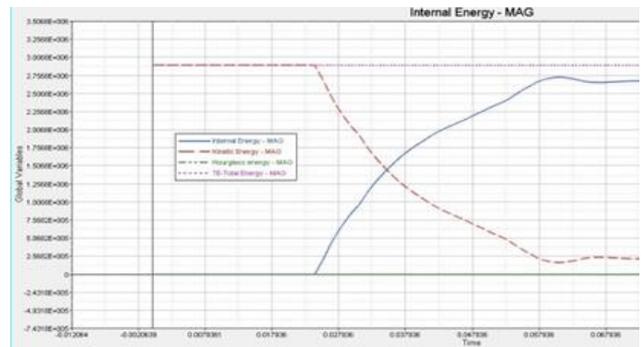


Fig. 9(b) Energy Conversion Graph

The deformation obtained clearly shows the driver is completely safe and the vehicle is safe.

### B. Front impact analysis (Car to Car)

In order to simulate the frontal impact crash, the vehicle was assumed to impact upon a stationary car with a speed of 50 Kmph. The car is placed in front of moving car and the results were checked.

### C. Rear impact analysis

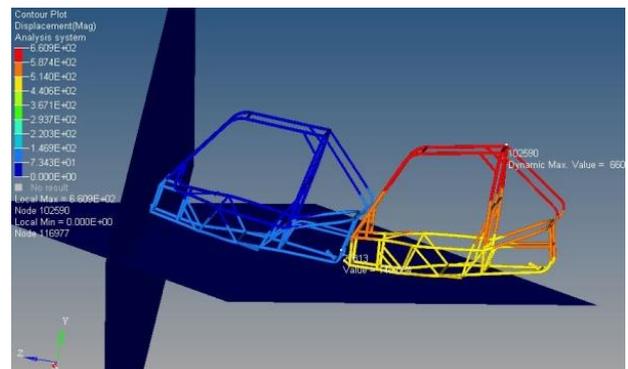


Fig. 10. Displacement

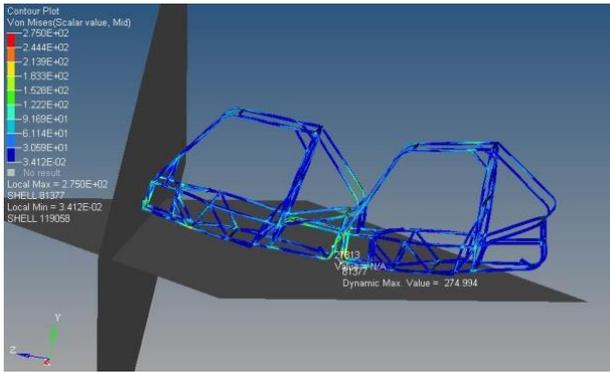


Fig. 11. Stress

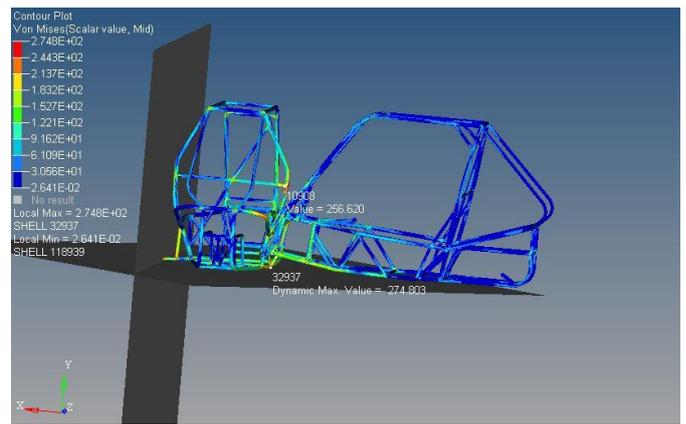


Fig. 14. Stress

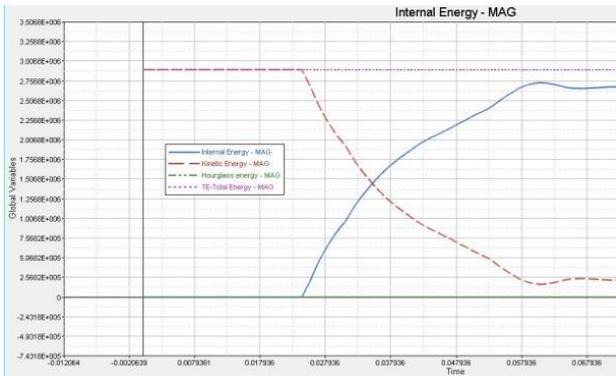


Fig. 12. Energy Conversion Graph

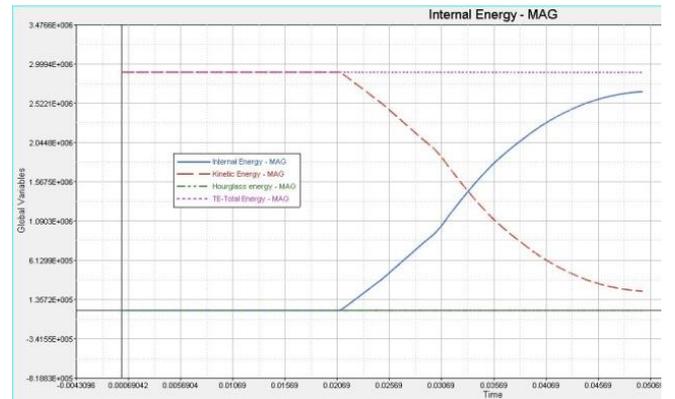


Fig. 15. Energy Conversion Graph

All results clearly show the chassis is very safe in impact load conditions.

#### D. Side impact

In order to simulate the side impact crash, it was assumed that vehicle running at speed of 40kmph makes an impact on one of the side of the roll cage.

The amount of impact at worst case scenarios in dynamics analysis shows the rigidity of the chassis.

#### E. Bending moment analysis

Bending stiffness of roll cage is calculated by using formula,

$$K = \frac{W}{d}$$

Where,

K = Bending stiffness of roll cage

W = Applied force

d = Displacement

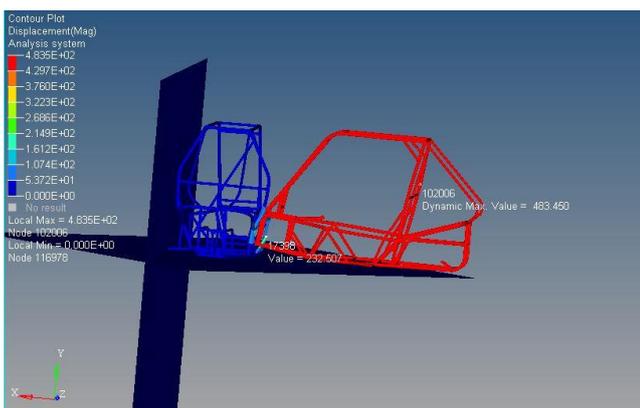


Fig. 13. Displacement

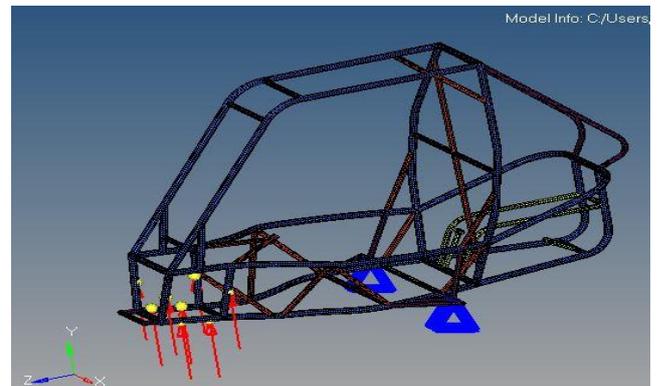


Fig. 16. Boundary Conditions

#### IV. RESULTS AND DISCUSSION

The weight of the chassis has been properly optimized by using torsional analysis and minimum gusseting members have been used. The dynamic analysis showed the vehicle is safe in either of the impact analysis and bending caused due to suspension impact on chassis.

#### V. CONCLUSION

The usage of finite element analysis was important to the design and analysis of the space frame. The analysis allowed the addition of important and key structural components to help the vehicle with stand front, side impacts as well as the rear impacts when in motion. While a viable solution to the stresses seen in a bending moment analysis shows the chassis is very rigid in dynamic and worst impact loading

#### VII. REFERENCES

- [1] Rulebook BAJA SAE INTERNATIONAL 2016.
- [2] Chris Bennett, Eric Lockwood, Anthony McClinton, Robin McRee and Colin Pemberton “SAE Mini Baja Frame Analysis”.
- [3] Mohd Hanif Mat, Amir Radzi Ab. Ghani “Design and Analysis of ‘Eco’ Car Chassis”, International Symposium on Robotics and Intelligent Sensors 2012 (IRIS 2012)
- [4] <http://users.tpg.com.au/users/mpaine/rollover.html>

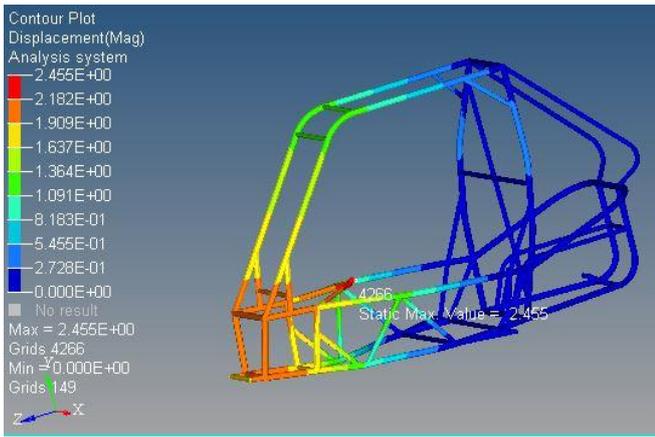


Fig. 17. Displacement

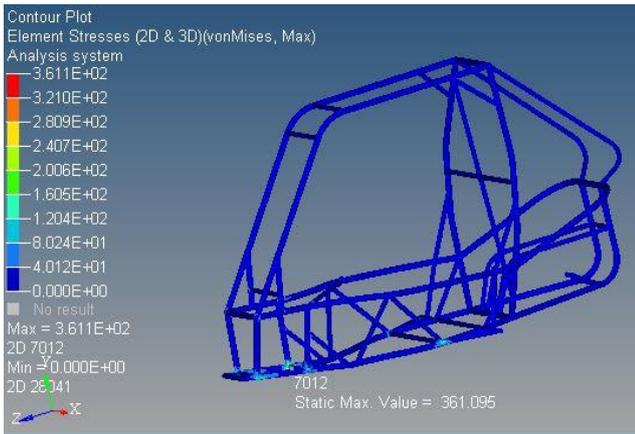


Fig. 18. Stress

$$K = \frac{W}{d}$$

$$= \frac{6867}{2.455}$$

$$K = 2797.14 \text{ N/mm}$$

$$\text{Bending Stiffness} = 2797.14 \text{ N/mm}$$

Table III

Bending stiffness

Weight (Kg)	Vertical bending stiffness (N/mm)	Lateral bending stiffness (N/mm)
30.32	952.33	2102.24
31.16	1156.96	2463.59
32.54	1312.35	2532.35
34.12	1642.82	2797.14