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Design and Analysis of Chassis for SAE BAJA Vehicle

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Abstract: *BAJA SAE is an intercollegiate competition organized by Society of Automotive Engineers (SAE) to design, build and race off-road vehicles. Chassis is an important part of the BAJA vehicle that supports body and other different parts of the vehicle. It also surrounds and protects the occupant in case of impact and roll over incidents and also gives the aesthetics of the vehicle. The paper deals with selection of material and cross section for the chassis and analyzing the frame design for different loading conditions to predict whether it will survive various impact scenarios using ANSYS workbench. The chassis design will be based on BAJA SAE India 2017 rule book taking safety and other aspects into account. The results from these simulations indicate that the frame is safe enough for the variety of worst-case scenarios tested.*
Keywords**:** *BAJA SAE, Chassis, ANSYS, AISI 4130, Von Misses Stress*

I. Introduction

The BAJA SAE is an event for the undergraduate students of engineering, organized by the Society of Automotive Engineers. The event organized in the name of Mini-BAJA competition. It serves as a platform for young engineering students to showcase their skills by designing, fabricating and validating a single seater off road vehicle and acquire a real-life experience while overcoming obstacle and challenges [2].

A vehicle chassis, also called as Rollcage is the main supporting structure of a BAJA SAE vehicle on which all other components are mounted. The main function of a chassis is to support the vehicle's mechanical components and deal with static and dynamic loads, without undue deflection or distortion. It should be designed in an ergonomic and strong effective manner at optimum cost and weight for rough terrain purposes. In current scenario available are overdesigned i.e. their structural rigidity and sturdiness are more than requirement. This leads to increase in weight and cost of manufacturing.

Jonathan Hastie’s [3] analysis allowed the addition of three important and key structural components to help the vehicle with stand front and side impacts as well as the forces due to the loading of the shock mounts. In this analysis it was found that design was failing in Roll Over, the findings from the finite element analysis and the actual failure have allowed us to integrate a solution to this problem into their design from the beginning. Chris Bennett et. al. [4] analyzed four iterations of the frame design. A simple loading case was applied to the different frame versions, and the frame design with the highest factor of safety was chosen for Front impact test, Rear Impact test, Side impact test and Drop test analysis. Deepak Raina et. al. [5] thoroughly dealt with various load analysis on chassis considerable Factor of Safety (FOS) applied to the roll cage design to minimize the risk of failure and possible resulting injury. This clearly reaffirms the vehicles ability to withstand extreme conditions. While some researchers [6,7,8,9] discuss about the finite element analysis of chassis in detail using ANSYS software.

The paper deals with one such design model of BAJA SAE chassis as per the guidelines of BAJA SAE India 2017. The work is discussed in the following sections include the Material selection, Cross-section selection, Design of a Chassis and Analysis of the Chassis.

II. Material Selection

Material selection for BAJA SAE vehicle is one of the key design decisions that has great influence on the safety, reliability and performance of the vehicle [10]. It also decides the weight of the vehicle, fabrication processes and cost. The qualities that were given due importance are yield strength, the strength to weight ratio and good weldability property. As per the guidelines of the SAE BAJA rule book [1] the minimum carbon content should be 0.18%. The materials selected for the study include AISI 1018, AISI 1020 and AISI 4130. Table 1&2 give the details of the chemical composition and Mechanical Properties of the materials.

Table 1: Chemical composition of AISI 1018, AISI 1020 & AISI 4130 steel

Element (%)	AISI 1018	AISI 1020	AISI 4130
Carbon, C	0.15 – 0.20	0.17 – 0.230	0.28 – 0.33
Iron, Fe	98.81 – 99.26	99.08 – 99.53	97.03 – 98.22
Manganese, Mn	0.60 – 0.90	0.30 – 0.60	0.40 – 0.60
Phosphorous, P	≤ 0.04	≤ 0.04	0.035
Sulfur, S	≤ 0.05	≤ 0.05	0.04
Chromium, Cr	–	–	0.80 – 1.10
Molybdenum, Mo	–	–	0.15 – 0.25

Table 2: Mechanical Properties of AISI 1018, AISI 1020 & AISI 4130 steel

Parameter	AISI 1018	AISI 1020	AISI 4130
Tensile Strength (MPa)	440	395	560
Yield Strength (MPa)	370	295	460
Poisson Ratio	0.290	0.290	0.295
% Elongation	15	36.50	21.50
Strength to Weight Ratio	55-70	65-85	90-120
Modulus of Elasticity (GPa)	205	200	210

The aforementioned materials have low carbon content, hence can be welded easily. However, AISI 4130 alloy steel is selected as it has high yield strength and strength to weight ratio than other materials. The AISI 4130 alloy steel also has very high tensile strength and corrosion resistance as it contains chromium and molybdenum as strengthening agents.

III. Cross Section Selection

Cross section of the tubing plays an important role in design of the frame. The bending strength and ease of fabrication are considered while deciding the pipe cross section [11]. It helps in reducing forces which are induced in the structure. Square and Circular are commonly used cross sections for BAJA SAE vehicle. The Primary members of the chassis must be of 25.4 mm (1 inch) outer size with 3 mm wall thickness. Also, the Secondary members must be of 25.4 mm outer diameter with minimum wall thickness of 0.89 mm. Bending, and shear are predominant in the chassis. To select a suitable cross section tubing an arbitrary bending load of 800 N is applied to study the bending characteristics

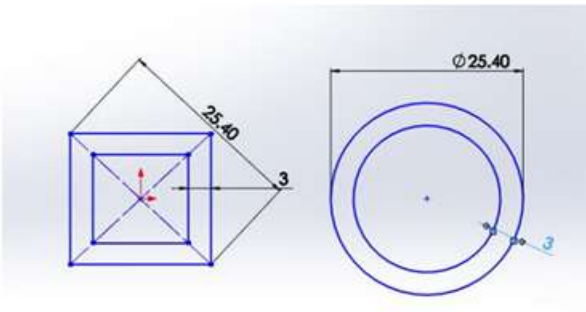


Fig 1: Square and Circular section

Table 3: Stress and Displacement analysis of section

	Square	Circular
Bending Stress (N/mm^2)	392.93	287.19
Deflection (mm)	10.372	5.375

Circular Cross-sectional diameter of 25.4 mm isselected as it has uniform distribution of forces and high torsional rigidity which resulted in improving strength of Roll Cage. as there is less stress concentration and deformation as compared to square.

IV. Design Of A Chassis

The preliminary design of a chassis is made using Solidworks 3D modelling software. A custom template of circular cross section for the roll cage member was created as per the design and it was applied to members and chassis structure was made using weldments.

The Rear Roll Hoop (RRH) defines the back side of the roll cage, it is a vertical member connected to rear Lateral Cross (LC) members on the top and bottom The RRH is a continuous tube and Lateral Diagonal

Bracing (LDB) members are used for providing more support. Two Side Impact Members (SIM) define a horizontal mid-plane within the roll cage. These members are joined to the RRH and extend generally forward

Two Lower Frame Side (LFS) members define the lower right and left edges of the roll cage. These members are joined to the bottom of the RRH and are extended forward. The forward ends of the LFS members are joined by the Front LC member. The LFS members are joined by the Under Seat Members (USM) that pass directly below the driver and is positioned in such a way to prevent the driver from passing through the plane of the LFS in the event of seat failure.

The Roll Hoop Overhead (RHO) members form the top plane of the roll cage provides safety to the driver in case of roll over. The RHO are made up of two continuous members running from the intersection of front LC till the top of RRH. The lower right and left edges of the roll cage are defined by two Lower Frame Side (LFS) members. These members are joined to the bottom of the RRH and extend generally forward. Front Bracing Members (FBM) are used to join the RHO, the SIM and the LFS.

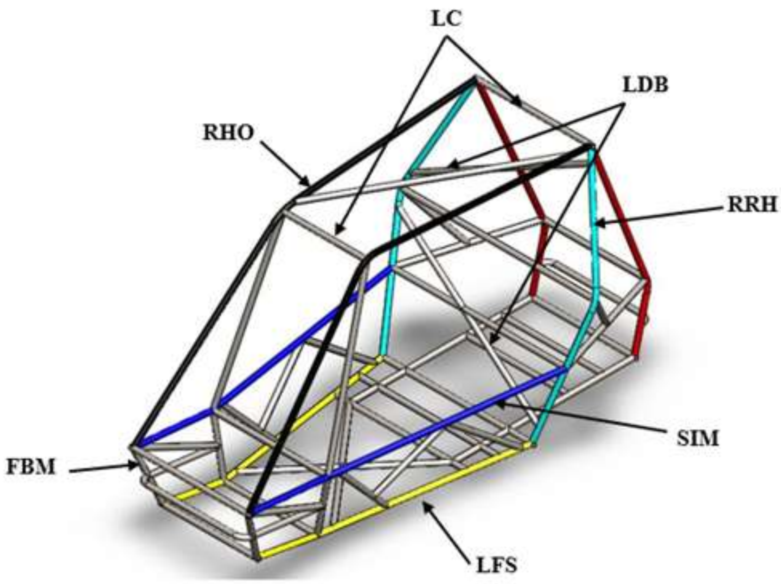


Fig 2: Chassis Design

V. Analysis Of The Chassis

The BAJA SAE vehicle chassis is analyzed using Ansys workbench for determining strength enough to sustain any impact and protect the driver and other vehicle components. In the analysis of frame, a quantity named G-Force is used to obtain the stress and deformation information in various impact scenarios [12]. G-Force is a measure of acceleration, when multiplied with the mass gives the magnitude of the dynamic force. The dynamic forces thus obtained are applied to the chassis to get stress and displacement values. The different tests performed are Front Impact, Rear Impact and Side Impact.

5.1 Meshing

Element size: 20 mm	Element Type: Beam
Solver Type: Direct Sparse Solver	Number of Elements: 4562
Analysis Type: Static	

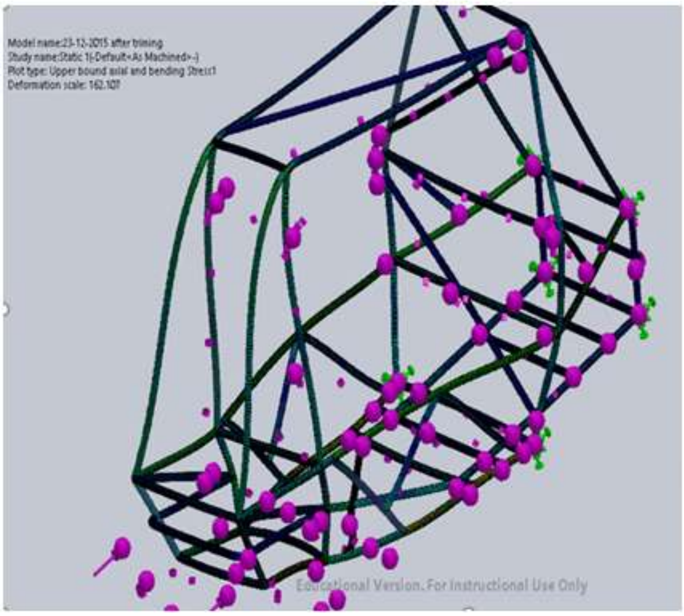


Fig 3: Boundary and Loading Conditions for front Impact

5.2 Front Impact Test

For Front impact test a G-Force of 10G is considered. Assuming mass of the vehicle (m) including the driver as 350 Kg the Front impact load (F1) is calculated

$$F_1 = \text{m} \times \text{a} \quad (1)$$
$$F_1 = 350 \times 10 \times 9.81 = 34335\ N$$

The rear section of the chassis is fixed and the impact load (F1) is applied on front junctions where FBM, SIM and LFS members join.

Name	Type	Min	Max
Stress1	TXY: Shear in Y Dir. on YZ Plane	0 N/m^2 Element: 157	2.2135e+008 N/m^2 Element: 1737

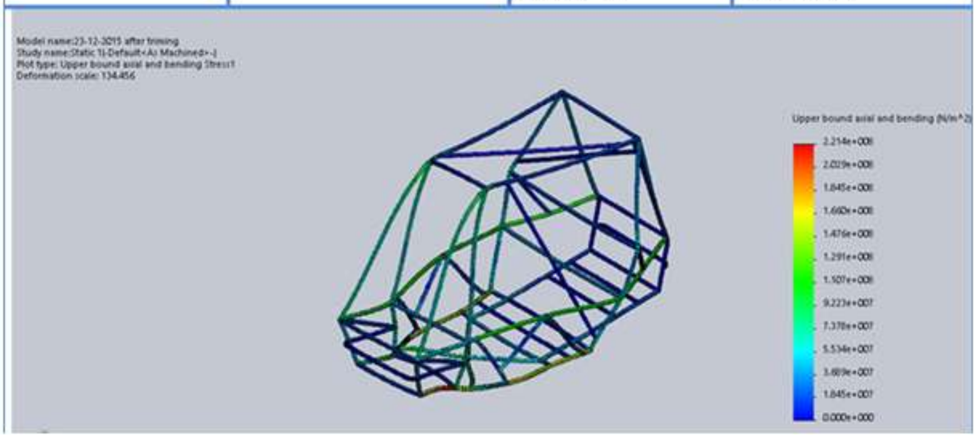


Fig 4: Von Mises Stress Pattern for Front Impact

Name	Type	Min	Max
Displacement1	URES: Resultant Displacement	0 mm Node: 159	1.77702 mm Node: 854

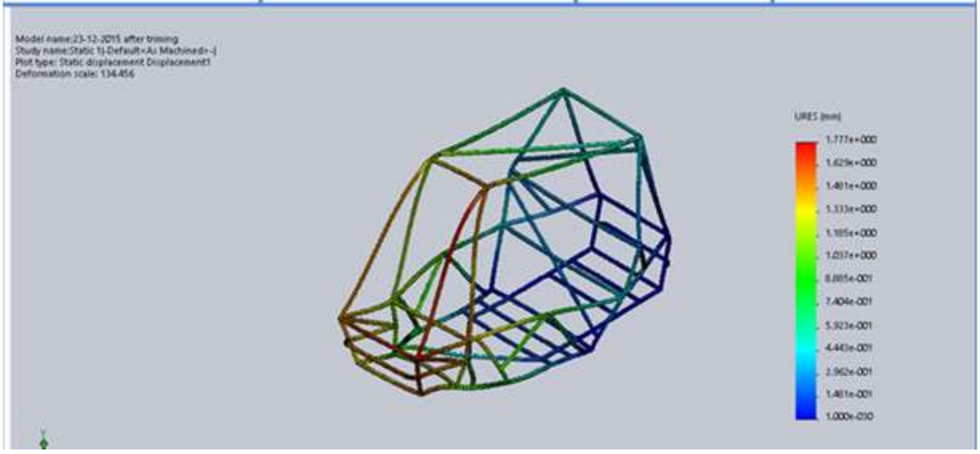


Fig 5: Displacement Pattern for Front Impact

Maximum Von Mises stress for Front Impact = 221.35 N/mm^2
Factor of Safety, $FOS = 460/221.35 = 2.07$

5.3 Rear and Side Impact Test:
For Rear and Side impact test, the G-Force of 4G is considered. Similar to Front impact test, the Rear and Side impact tests required sections were fixed and load was applied to obtain stress and displacement values.

Name	Type	Min	Max
Stress1	TXY: Shear in Y Dir. on YZ Plane	0 N/m^2 Element: 602	1.8807e+008 N/m^2 Element: 3473

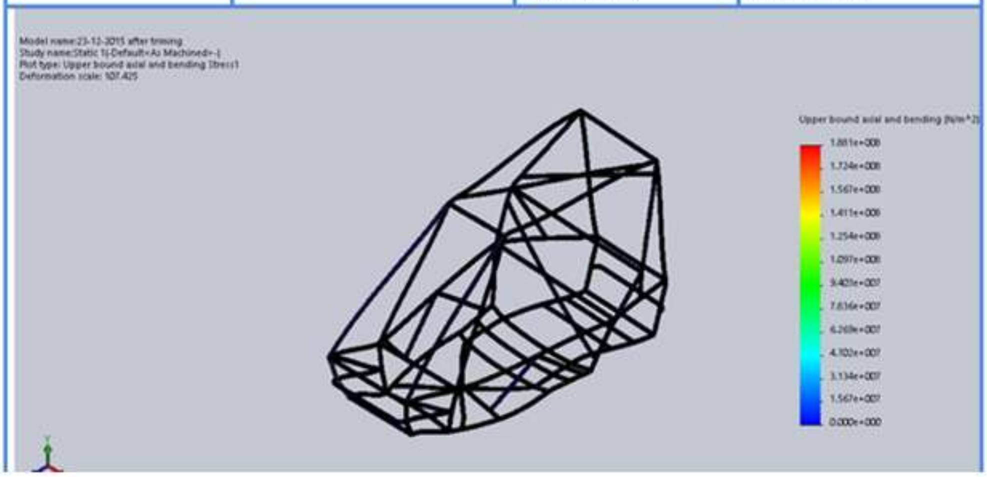
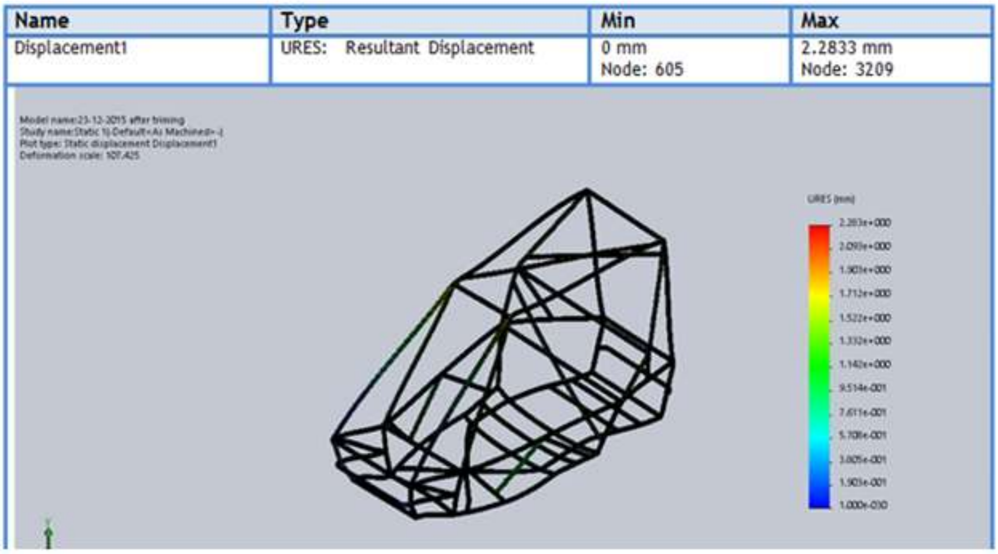
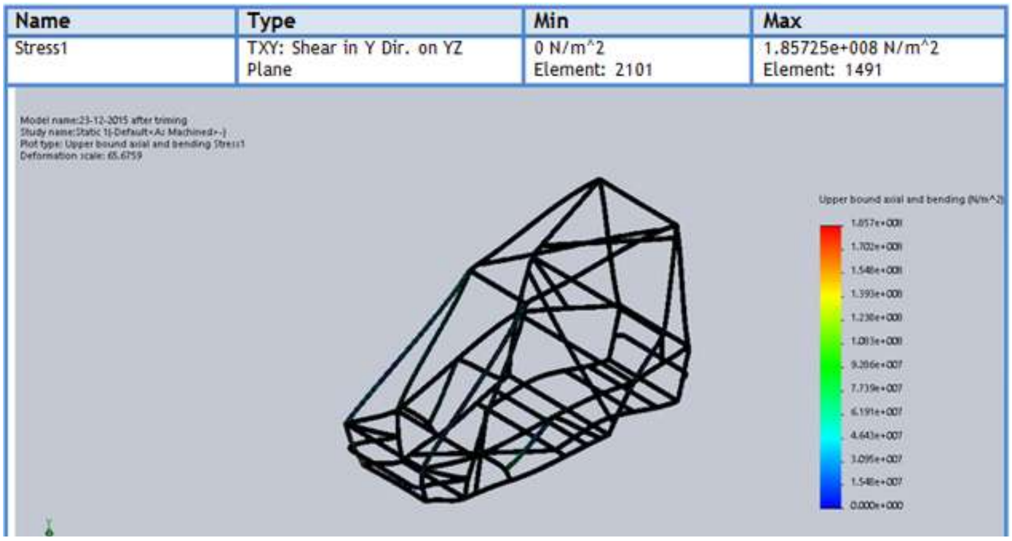


Fig 6: Von Mises Stress Pattern for Rear Impact



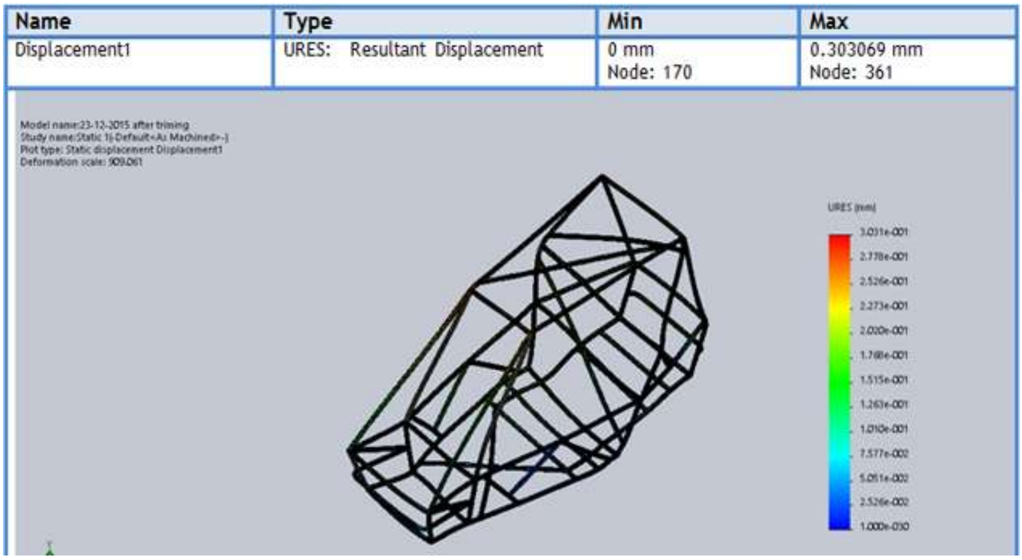
Name	Type	Min	Max
Displacement1	URES: Resultant Displacement	0 mm Node: 605	2.2833 mm Node: 3209

Fig 7: Displacement Pattern for Rear Impact



Name	Type	Min	Max
Stress1	TXY: Shear in Y Dir. on YZ Plane	0 N/m^2 Element: 2101	1.85725e+008 N/m^2 Element: 1491

Fig 8: Von Mises Stress Pattern for Side Impact



Name	Type	Min	Max
Displacement1	URES: Resultant Displacement	0 mm Node: 170	0.303069 mm Node: 361

Fig 9: Displacement Pattern for Side Impact

Table 4: Stress and displacement analysis of chassis

Test	G- Force	Load Applied (N)	Maximum Von Mises Stress (N/mm^2)	Maximum Displacement (mm)	FOS
Front	10G	34335	221.35	1.78	2.07
Rear	4G	13734	188.07	2.28	2.45
Side	4G	13734	185.72	0.303	2.48

VI. Conclusion

The chassis of BAJA vehicle is designed as per the specifications of BAJA SAE India 2017 rulebook. AISI 4130 material was selected for the chassis as it has high yield strength and strength to weight ratio as compared to others. Circular cross section was selected as it has very high torsional rigidity and uniform distribution of forces which results in improving strength of the chassis. A preliminary design of the chassis is made using SOLIDWORKS software. The stress analysis results and displacement pattern from ANSYS workbench indicate that the chassis is indeed safe enough to sustain the impact and protect the driver and other components.

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