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DESIGN AND ANALYSIS OF FORMULA CAR CHASSIS

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ABSTRACT:

Every year two competitions are held by Society of Automotive Engineers in India. The first being, FORMULA BHARAT and the second being SAE Supra. These two competitions primarily are based on design, safety and performance of the car that are built by various universities all over from India [5].

KEYWORD: Suspension geometry, FEA, Solid Works, Lotus, Torsional rigidity, Chassis frame, Deformation, Bending moment.

1.0 INTRODUCTION:

The Formula SAE competition attracts students from different universities and from different countries. The competition is divided into two main parts. The first one is static part and other one is dynamic part. Static event consist of technical inspection, Brake test, Tilt test, design event along with two presentation cost report and business presentation. Dynamic event consist of acceleration test, skid pad, autocross, fuel economy and endurance test. The ideal car should be of high performance, good fuel economy and should satisfy all the design safety rules mentioned in rulebook of FSAE international [1]. This paper corresponds to work carried out by team SCHNELL RACING to build and participate in FORMULA BHARAT in 2017. The team previously got rank 22nd in Formula Student India in 2016 and is expecting to perform well in FORMULA BHARAT 2017 event to be held at Kari motor speedway, Coimbatore.

A space frame chassis is used to manufacture FSAE car. By adding up small members in triangular pattern a truss bridge can be formed. These patterns are always in pure tension and compression. This concept is used behind the design of the space frame. The chassis should be easy to manufacture, repair and maintain. This paper will give idea about chassis design, material selection,and improvement in previous year's design, simulation and analysis of Chassis.

2.0 LITERATURE REVIEW:

To know the basic chassis design and different types of chassis those were used in the history. The book published by penguin book is titled by "the race car chassis" written by Forbes Arid.It mainly focuses on particular type of space frame chassis. The stresses induce in the space frame chassis. And how economical, less weight and readily available materials also easily manufactured [2].

Another piece of information by the same publisher but a bit older book named by "chassis engineering" written by Herb Adams . This focuses on how helpful the suspension geometry is while designing a space frame chassis. This book also gives large information about how useful the tire data is while designing the suspension geometry. About the tire characteristics and how we could tune the suspension setup[3].

Another main principle about chassis these are the primary information while designing the space frame is:

1. Cornering balance (neutral steering) under maximum lateral condition.
2. Compromise between cornering performance and drag on high speed tracks.

This principle helped us in designing the space frame and understanding the phenomenon of the wind resistance and the forces exerted on the uprights and suspension geometry [4].

3.0 METHODOLOGY:

The design of chassis should be such that it should satisfy following conditions:-

1. The chassis should be made according to SAE rules given in FSAE rulebook[1].
2. Aim for minimum weight.
3. Centre of gravity should be as low as possible.
4. Chassis should be designed for manufacturability and serviceability.
5. The chassis should be designed for maximum safety of driver.
6. There should be proper space for engine and drive train component.
7. It should be in accordance with suspension points.

3.1 GENERAL SPECIFICATION:

Table 1 General specification

Parameters	Value	Unit
Wheelbase	1650	mm
Trackwidth	1350	mm
Ground clearance	106	mm

During designing of chassis for main section, it should be looked upon, front roll hoop, main roll hoop, front bulk head and rear bulk head. By taking considerations of engine mounting points the position of main roll hoop has been fixed. Adequate space was given to engine and drivetrain components. Maximum space was given to cockpit area for better comfort. With the help of FSAE rulebook, the cockpit area was decided and larger amount of tolerance to 95th percentile rule was the main aim [1]. A good space in cockpit allowed the team to place battery and fuel tank. This resulted in the centralization of the mass and lowering of Centre of Gavity. The front hoop was at an angle for suspension points from linked between front bulk head and front hoop[6].

Static structural testing was done using SolidWorks. The weaker/effective links were obtained by analysis and modification was done to it.

3.2 MATERIAL SELECTION:

While designing the chassis the one of the most important criteria is the material selection. Material Selection plays a very important role while designing and manufacturing a vehicle because there are various types of forces and the frame should not undergo any kind of deformation. The material has to be stiff enough to absorb vibration, various shocks.

While selecting the material it has to be kept in mind that the manufacturing has to be done with ease and the availability of the material. The type of chassis was selected with the compliance of FSAE rulebook[1] and the team decided to go with Tubular Space Frame Chassis over the monocoque chassis due to cost effectiveness, ease of manufacturing and the unavailability of various sources and cost restrictions in spite of Space frame being heavier than monocoque.

SAE INTERNATIONAL MATERIAL REQUIREMENT:

MINIMUM MATERIAL REQUIREMENTS:

The primary structure of the car must be constructed of either round, mild or alloy, steel tubing (minimum 0.1% carbon) of the minimum dimensions specified in the following table

Table 2 Dimension requirements

ITEM or APPLICATION	OUTSIDE DIMENSION X WALL THICKNESS
Main & Front Hoops, Shoulder Harness Mounting Bar	Round 1.0 inch (25.4 mm) x 0.095 inch (2.4 mm) or Round 25.0 mm x 2.50 mm metric
Side Impact Structure, Front Bulkhead, Roll Hoop Bracing, Driver's Restraint Harness Attachment (except as noted above)	Round 1.0 inch (25.4 mm) x 0.065 inch (1.65 mm) or Round 25.0 mm x 1.75 mm metric or Round 25.4 mm x 1.60 mm metric or Square 1.00 inch x 1.00 inch x 0.047 inch or Square 25.0 mm x 25.0 mm x 1.20 mm metric
Front Bulkhead Support, Main Hoop Bracing Supports	Round 1.0 inch (25.4 mm) x 0.047 inch (1.20 mm) or Round 25.0 mm x 1.5 mm metric or Round 26.0 mm x 1.2 mm metric

Testing samples for their Tensile and its chemical properties:

CHEMICAL PROPERTIES:

Table 3 Chemical properties

Properties:	AISI 4130	AISI 1018	IS 1239
Carbon (c)%	0.310	0.35	0.17
Manganese (Mn)%	0.410	1.50	1.17
Silicon (Si)%	0.160	0.20	0.36
Sulphur (S)%	0.005	0.007	0.001
Phosphorous (P)%	0.015	0.016	0.013
Chromium (Cr)%	0.830	0.040	0.18
Nickel (Ni) %	0.010	0.058	0.004
Copper (Cu) %	0.005	0.001	0.008
Molybdenum (Mo)%	0.167	0.012	0.004

MECHANICAL PROPERTIES:

Table 4 Mechanical properties

Properties:	AISI 4130	AISI 1018	IS 1239
Yield Strength (MPa)	695.10	575.10	688.69
Ultimate Tensile Strength(MPa)	757.27	741.06	729.20
Elongation %	20	18.92	12

COST OF THE MATERIAL:

Table 5 cost of material

Sl. No.	Material Name	Primary (25.4*2.5) /Meter	Secondary(25.4*1.65) /Meter
1	AISI 4130	750	700
2	AISI 1018	300	275
3	IS 1239	150	90

These were the three material samples tested for its chemical composition, mechanical strength and also the cost of the material. After comparing all the three factors team decided to use AISI 4130 for the primary member such as Main Hoop, Front Hoop and the shoulder harness bar and IS 1239 for the secondary members due to easily availability and low cost.

3.3 ERGONOMICS:

Ergonomics [7] is the study of human and machine interaction. It is important to see how the machine behaves according to the human's comfort level. A machine should be easy to operate and user friendly without compromising with drivers comfort and safety. Ergonomics [7] helps to decide the driver's position with overall required width of the vehicle. In ergonomics team decides the position of driver's helmet, elbow location, steering wheel location, driver's foot location, etc. It helps to decide the driver's inclination hence ergonomics is one of the important factor while designing the chassis.

Fig.1 Ergonomics model (i)

Fig.2 Ergonomics model (ii)

After ergonomics the design of the chassis was started and the different locations were being set for the other important components of the vehicles such as Engine Position, Steering Position, Suspension Pickup points and Pedal Box Assembly. Once this was completed next objective was to concentrate on the various nodes and the triangulation as per the FSAE rules. After this a mock chassis was built to validate the design as per ergonomicsand in case of any change, redesigning is considered.

Fig.3 Ergonomics model (iii)

4.0 IMPACT ANALYSIS:

The analysis of the complete chassis was done using SOLIDWORKS Simulation software. For carrying out the impact analysis, 3D meshing was performed on the model and the subsequent analysis was done for different types of impact loads. Under different conditions the impact load on the vehicle is calculated as shown below:

At the time of analysis the weight of the vehicle(including the driver) was assumed to be 300kgs as the exact weight of the vehicle was not known.

4.1 FRONT IMPACT:

For front impact it is assumed that the vehicle is colliding into a rigid barrier from front.
The acceleration for front impact was taken to be 2G.
Force= Mass x Acceleration.
F= 300 x (2x10)
F= 6000 N.
This load is distributed uniformly on the front bulkhead.

4.2 SIDE IMPACT:

For side impact it is assumed that the direction of the impacting vehicle is considered perpendicular to the vehicle.
The acceleration for side impact is taken to be 1.5G
F=300 x(1.5x10)
F=4500 N.
This load is distributed uniformly on the side members.

4.3 TORSIONAL RIGIDITY ANALYSIS:

What is Torsional Rigidity:-When the vehicle is in motion, due to the roll rates of the suspension system a rolling moment is experienced on the chassis. This rolling moment results into development of a torsional effect whose force is experienced at the wheel center of the vehicle. The ability of the frame to resist this torsional effect is known as torsional rigidity of the frame.

As the exact value of the force experienced at the wheel center is unknown, it is assumed to be 1000N.

The load is applied on each side of the front suspension hard points, in vertically opposite direction.

4.4 ROLL OVER IMPACT LOAD:

The directions of the loads during rollover are at angle of 45 degree to the vertical plane of the vehicle. The load is divided at 2 points: 1 on the front hoop at the bracing point whiles the other on the main hoop at the bracing points. The force is assumed to be 3000N on each roll hoop.

The outcomes of the analysis of the frame using the above loads were obtained in SolidWorks. On the basis of the degree of severity of the impact, the factor of safety was found to be adequate.

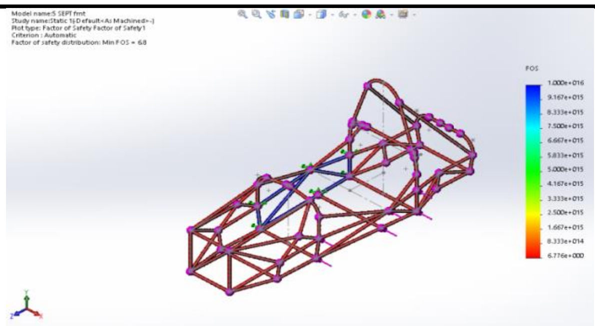

Fig7. Side impact FOS

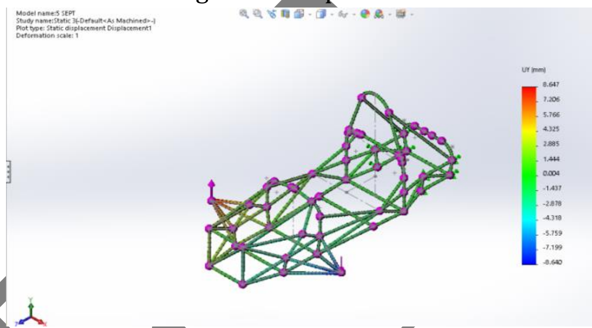

Fig.8 Displacement in vehicle during torsional impact

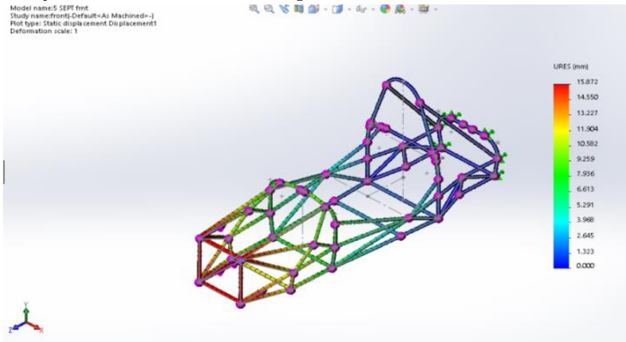

Fig.4 Displacement in vehicle duringfront impact

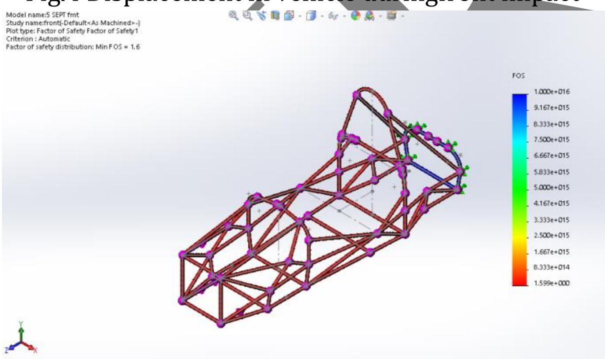

Fig.5 Front impact FOS

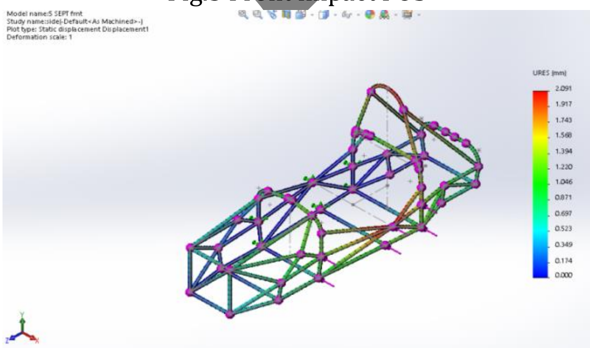

Fig.6 Displacement in vehicle during side impact

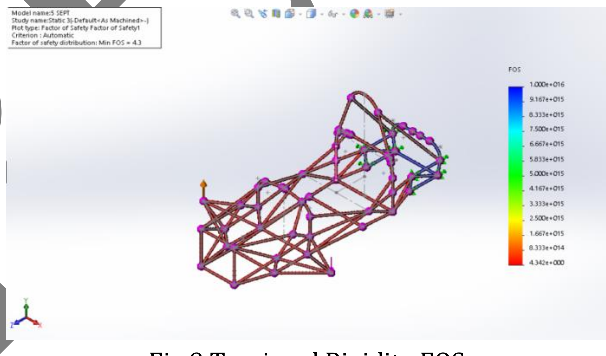

Fig.9 Torsional Rigidity FOS

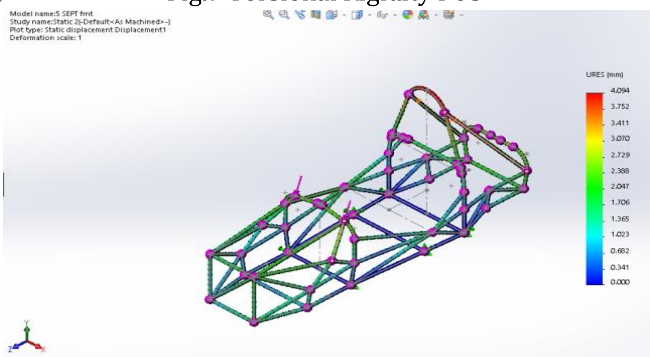

Fig10. Displacement in vehicle during rollover impact

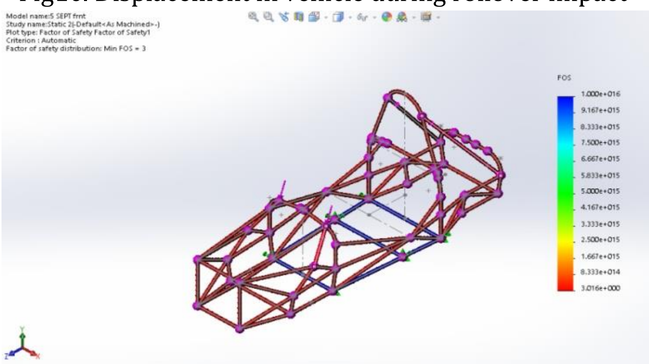

Fig.11 Roll over impact FOS

5.0 RESULT AND DISCUSSION:

Following results were obtained after the analysis.

Table 6 Results after analysis

Type of Load	Maximum Force (N)	Maximum Equivalent Stress (MPa)	Maximum Displacement (mm)	Factor of Safety
Front Impact	24000	370	15.8	1.6
Side Impact	6000	100	2.0	6
Torsional Rigidity	1000	160	8.6	4.3
Roll over Impact	6000	220	4.0	3

1. Results obtained in table no 5 it can be seen that the F.O.S in each of the analysis was enough for the chassis to be declared safe.
2. There has been no compromise with the safety of driver.
3. Also center of gravity has been lowered considerably.

6.0 CONCLUSION:

1. This paper consists of design and analysis of FSAE car. The chassis of the car made according to rules mentioned in SAE INTERNATIONAL rulebook and we tried to overcome all the flaws from previous year and fulfilled our objectives.
2. The welding techniques used are safe and will not undergo brittle failure.
3. The current weight of chassis is 38kg.
4. The material AISI 4130 was selected for main hoop, front hoop and shoulder bar and for secondary members of chassis IS 1239 is used.

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