Structural Optimization and Torsional Rigidity Analysis of an AISI 1018 Steel Space-Frame Chassis for SUPRA SAE Competitions.

1. ABSTRACT

Objective: The primary goal of this study was the structural validation and torsional optimization of a tubular space-frame chassis for SUPRA SAE competitions.

Methodology: Using Autodesk Fusion 360 for iterative CAD modeling and SimScale for cloud-native Finite Element Analysis (FEA), the design focused on integrating suspension hardpoints into a fully triangulated AISI 1018 steel structure.

Results: Ten design iterations were performed, transitioning from a rectangular to a pentagonal roll hoop geometry. Torsional rigidity was quantified by applying a 275 Nm torque couple, resulting in a maximum vertical displacement of 0.58204 mm. This corresponds to a final torsional stiffness of 2,267.63 Nm/deg—a 22.7% improvement over the initial design—while maintaining a constant chassis mass of approximately 35.48 kg.

Conclusion: Impact simulations (Front 6G, Side 4G, Rear 6G) confirmed structural integrity with a minimum Factor of Safety (FoS) of 1.602, ensuring compliance with global safety regulations.

2. INTRODUCTION

2.1 BACKGROUND & PROBLEM STATEMENT

In student-led motorsport competitions such as SUPRA SAE, the chassis serves as the dual-purpose safety cell and the primary datum for suspension kinematics. A critical engineering challenge is the "Stiffness Paradox": achieving high torsional rigidity to prevent mounting point deflection—which compromises camber and toe stability—without incurring a prohibitive mass penalty.

2.1.1 TECHNICAL GUIDELINES AND REGULATORY FRAMEWORK

To ensure the safety of the driver and to have a level playing field, the participants must adhere to a certain set of rules provided by the SUPRA SAE(Formula students) rule book. The following Primary guidelines to design a space-frame chassis :

- Main and Front Roll Hoop:- The Main and the front Main roll hoop must be made of a single continuous piece of tubing from one side of the lower frame to the other. It must be made of steel material with a minimum of 0.1% carbon content.
- Dimensional Clearance:- The design must accommodate the 95th percentile male template. Specifically, there must be a minimum of 50 mm of clearance between the

top of the driver's helmet and the line drawn between the top of the Main Loop and the front hoop.

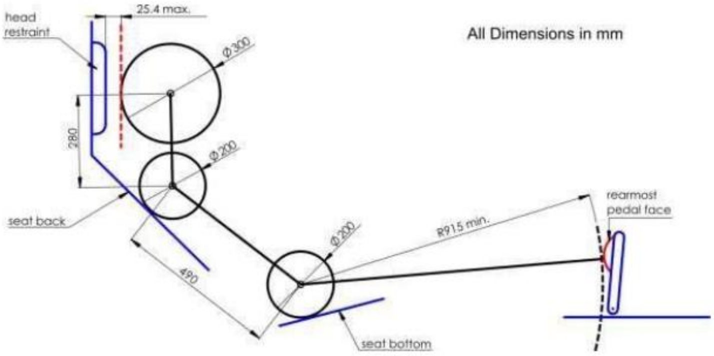

Fig 2.1 95th Percentile Male Template

- Triangulation and Load paths:- All members of the primary structure must be part of a fully triangulated truss system. This ensures that loads from the suspension and safety systems are transferred through axial tension and compression rather then bending moments.

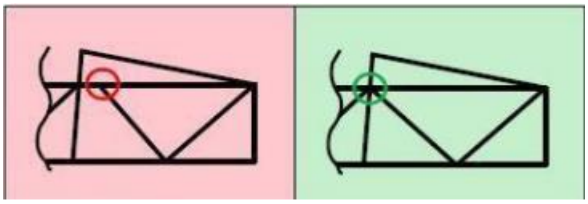

Fig 2.2 Triangulation and load path rule for Primary Structure

- Material Specifications:- The rules mandate a minimum wall thickness and outer diameter for "Primary Members" (like the main hoop and side impact structure). For AISI 1018 steel, the typical requirement are around 25.4 mm OD with a 2.4 mm wall thickness for the main hoop.

2.2 MATERIAL SELECTION

The selection of material for the SUPRA SAE chassis is a critical decision that balances structural stiffness, occupant safety, and fabrication feasibility. While various types of materials can be used to make a space-frame chassis, the selection process for this design is focused on a comparative analysis between AISI 1018 Steel and AISI 4130 Chromoly steel

2.2.1 COMPARATIVE ANALYSIS OF MECHANICAL PROPERTIES

the primary objective of a chassis design is to maintain a high factor of safety (FoS) while ensuring high torsional rigidity. The mechanical properties of the required materials are compared in the table below:

Table 2.1 Comparison of properties of AISI 1018 and AISI 4130 Steel

PROPERTY	AISI 1018 Steel	AISI 4130 (Chromoly)	Units/Metric
Yield Strength	~370	~435	MPa
Ultimate Tensile Strength	~440	~670	MPa
Modulus of Elasticity (E)	205	205	GPa
Density	7.87	7.85	$\frac{g}{cm^3}$

2.2.2 THE “STIFFNESS PARADOX” and Design Choice

In context of torsional rigidity (K), the material’s modulus of elasticity (E) is the governing factor rather than the yield strength. Since both AISI 1018 and AISI 4130 share nearly identical E value of approximately 205 GPa, a chassis constructed with identical tube diameter and wall thickness will exhibit same torsional stiffness regardless of the alloy chosen.

AISI 1018 was ultimately selected as the primary material for the space-frame chassis on the following justifications:

- Fabrication Feasibility: AISI 1018 offers superior weldability and less prone to brittleness in the Heat affected zone (HAZ) compared to AISI 4130, which often requires specialized TIG welding and post-weld heat treatment to maintain structural integrity.
- Cost-Effectiveness: Given that the stiffness remains constant between the two materials for the same geometry, AISI 1018 provides more economical solution without compromising the vehicle’s handling characteristics.
- Regulatory Compliance: The chosen material properties exceed the minimum requirements set by the SUPRA SAE rulebook for primary structural members.

2.2.3 STRUCTURAL INTEGRITY VALIDATION

To ensure the design is robust, the yield strength of AISI 1018 (370 MPa) is used as the baseline far all the subsequent FEA impact simulations. This ensures that the chassis can withstand front, side and rear impacts without undergoing catastrophic plastic deformation, maintaining a safe environment for the driver.

2.3 OBJECTIVE

The primary objective of this paper is to validate the structural integrity and performance of a student-designed SUPRA SAE chassis using a cloud-based FEA workflow. By moving from theoretical modelling to computational simulation, the study aims to ensure the vehicle is competition-ready and safe for high-performance operation

The specific objective of this study are:

- Geometric Design and rulebook Compliance: To develop a fully triangulated space-frame in Autodesk Fusion 360 that integrates the 95th percentile male template and meets all SUPRA SAE regulatory requirements for roll hoop heights and side impact structures.
- Structural Integration of Suspension Hardpoints: To accurately model and validate the placement of suspension control arm mounts and rocker arm points within the frame to ensure loads are transferred through primary nodes.
- Torsional Rigidity Quantification: To utilize the SimScale cloud-CAE platform to perform a simulated torsion test, calculating the chassis's stiffness in Nm/deg by applying a torque couple across a 550 mm loading width.
- Multi-Scenario Safety validation: To perform a suite of impact simulations-including front, rear, side impact analyses-using AISI 1018 material properties to determine the Factor of safety (FoS).

3. DESIGN METHODOLOGY

3.1 DESIGN CONSTRAINTS

The design of the chassis is strictly governed by the SUPRA SAE (Formula Students) regulatory framework, which prioritizes driver safety and structural standardization across all competing vehicles. These constraints act as the primary "hardpoints" around which the aerodynamics and mechanical systems must be packaged.

3.1.1 PRIMARY SAFETY CONSTRAINTS

- Main Hoop and the Front hoop Construction: The main Hoop must be a single, continuous piece of tubing from one side of the lower frame to other. It must be made of steel material with minimum of 0.1% carbon content to ensure structural integrity.
- Structural Continuity: All members of the primary structure must be part of a fully triangulated truss system, ensuring that loads from the suspension and safety systems are transferred through axial tension and compression rather than bending moments.
- Side impact structure: Chassis must include at least three longitudinal members on each side, connecting the front Hoop and Main Hoop, to protect the driver during a lateral collision Incident.

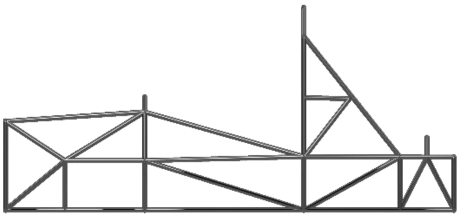

Fig 3.1 Space Frame Chassis Side Impact Structure Design

3.1.2 ERGONOMIC AND CLEARANCE CONSTRAINTS

- The 95th Percentile Male Template: The design must accommodate a standardized 95th percentile male template to ensure adequate cabin space for the driver.
- Percy template Clearance: There must be a minimum of 50 mm (2 inches) of clearance between the top of the driver's helmet and a line drawn between the top of the Main Hoop and the Front Hoop.
- Driver Egress: The cockpit opening must be large enough to allow the driver to exit the vehicle within the time limit specified in the safety rules.

3.1.3 MATERIAL AND SECTIONAL REQUIREMENTS

- Minimum wall thickness: The rules mandate specific minimum wall thickness and outer diameter of the primary structure members to prevent buckling during the impacts.
- Material Baseline: For this design, AISI 1018 was chosen as it meets the minimum carbon content and the mechanical property requirements set by the rulebook.

3.2 CAD MODELING AND INTEGRATION

The translation of the chassis space-frame requirements into a functional 3D model was performed using Autodesk Fusion 360. This phase focused on creating a high-fidelity digital twin of the chassis that integrates regulatory “hardpoints” with mechanical requirements.

3.2.1 WIREFRAME DEVELOPMENT AND NODE PLACEMENT

The modelling process began with a 3D wireframe sketch to establish the primary load paths of the space-frame.

- Node to Node Triangulation: Every structural member was aligned to ensure that multiple tubes converge at a single nodes. This strategy is critical for minimizing bending moments and ensuring that the chassis behaves as a true truss structure under load. The node to node triangulation must be done according to the rule book constraints just like the structure formed in the Fig. 2.2.
- Pentagonal and Hexagonal Roll Hoop Modelling: Moving away from traditional rectangular profiles, the Front Roll hoops was modelled with a tapered, pentagonal geometry, while the Main Roll Hoop followed a tapered Hexagonal geometry. This was achieved by defining specific width constraints at the shoulder level to enhance driver ergonomics while narrowing the footprint at the base for the aerodynamics packaging.

3.2.2 INTEGRATION OF SUSPENSION AND ROCKER HARDPOINTS

A key objective was to ensure that the suspension system does not act as a “floating load” on the chassis.

- Control arm mounts: The coordinates for the front and rear A-arm mounting points were imported into the CAD environment and used as “anchor nodes” for the frame. This ensures that cornering forces are fed directly into the most rigid section of the triangulated structure.
- Rocker Arm Reinforcement: Specific mounting points for the suspension rockers were integrated into the frame. Given the high concentrated loads experienced by rocker pivots, additional bracing was added to these nodes to prevent localized tube deformation.

3.2.3 COMPONENT PACKAGING AND CLEARANCE VALIDATION

Once the wireframe was established, the “Pipe” and “Sweep” tools were used to assign the AISI 1018 tube profiles.

- 95th Percentile Template: A virtual 95th percentile male template was placed within the cockpit to verify that the internal volume provided adequate room for the driver movement and safety egress.
- Roll Hoop Clearance: The 50 mm (2-inch) clearance rule was verified by drawing a plane between Front and Main hoops and measuring the distance to helmet of the digital driver model.
- Aerodynamics Readiness: The front bulkhead was specifically shaped to interface with a future nose cone design. The tapered geometry allows the nose cone to follow a smoother path, reducing the frontal area and improving the overall aerodynamic profile of the vehicle.

3.3 STRUCTURAL REFINEMENT AND ITERATIVE OPTIMIZATION

The final chassis geometry is a result of exhaustive design evolution consisting of ten distinct iterations. While the early stages involved exploring various space-frame topologies, the final phase focused on a comparative study between the two most viable designs. These two models share a similar primary structure but differ in their resolution of critical technical and performance challenges. The two models differ mainly to get more aerodynamic structure to the vehicle, while also looking forward to the chassis structure to be compliant with the SUPRA SAE rule book, while looking forward for the space-frame to be safe for the driver. The final space-frame design was designed while taking into consideration of the suspension system hardpoints which would affect the performance of the vehicle in high speed corners.

3.3.1 EVOLUTION OF SIDE IMPACT STRUCTURE (SIS)

A primary focus of iterative process was achieving full compliance with the SUPRA SAE safety standards.

- Design Audit: Early iterations failed to meet the mandatory 250 mm minimum height for the side impact members.
- Optimization: Through consecutive revisions, the SIS was relocated vertically. The final two design successfully placed these members at a height that ensures optimal driver protection in lateral collision scenarios while maintaining a favourable centre of gravity. The side view for the Initial iteration of the space frame chassis is been mentioned below, while the final chassis model side view can be referred from Fig. 3.1 above.

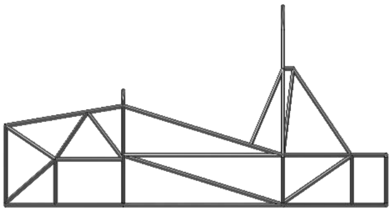

Fig 3.2 Side impact structure of Initial Iteration of the Space-frame chassis model

3.3.2 INTEGRATION OF SUSPENSION MOUNTING INTERFACE

Initial chassis versions focused primarily on the roll cage and lacked dedicated mounting points for the suspension system.

- Problem Identification: Without integrated hardpoints, suspension loads would have been applied to the centre of the tube members, inducing high bending moments at potential structural failure.
- Technical Solution: The final two iterations integrated specific reinforced nodes for the rocker arm pivots and A-arm mounts. This ensures that the dynamic loads from cornering and braking are fed directly into the primary triangulated nodes of the frame.

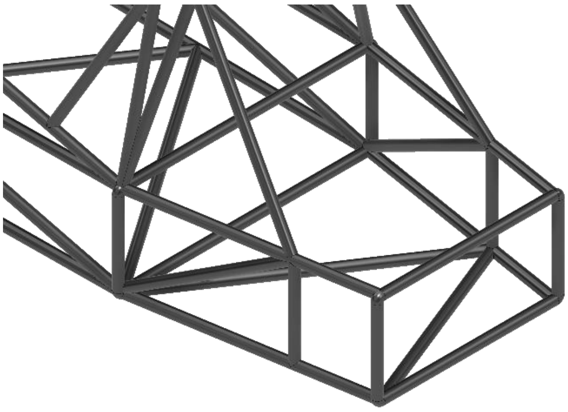

Fig 3.3.A Rear Suspension part of Initial iteration of chassis

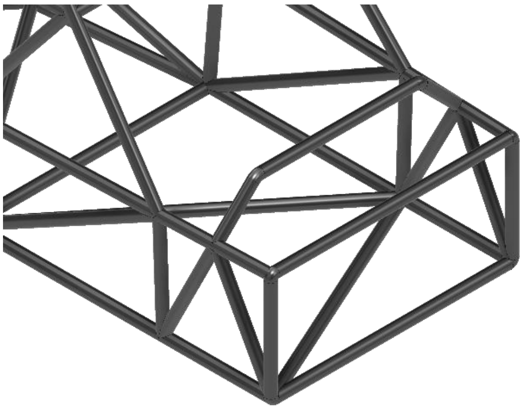

Fig 3.3.B Rear Suspension Hardpoint of Final model of the chassis

3.3.3 ROLL HOOP GEOMETRY AND AERODYNAMIC OPTIMIZATION

The transition from rectangular to pentagonal Roll Hoops was major breakthrough in the middle stages of the ten design cycle.

- Ergonomics & Aerodynamics: The initial rectangular hoops restricted driver manoeuvrability and created excessive frontal area.
- The Pentagonal Solution: Th optimized hoops are wider at the driver's shoulders for improves ergonomics but narrow at the base. This tapering allows for more streamlined integration of the nose cone, significantly reducing aerodynamic drag and saving space near ground for floor components.

3.3.4 MASS OPTIMIZATION AND SAFETY FACTOR (FoS) BALANCING

By analysing the results of the tenth iteration, a node-reduction study was performed to address "over-engineering".

- Weight Reduction: The initial side impact simulations yielded a factor of safety (FoS) between 3.48 and 4.0. By removing redundant nodes and strategically placing new diagonals-including the cockpit diagonal member-design achieved a balanced FoS.
- Results: This iteration maintained high torsional rigidity while reducing the overall chassis mass, leading to a superior stiffness-to-weight ratio compared to earlier prototypes.

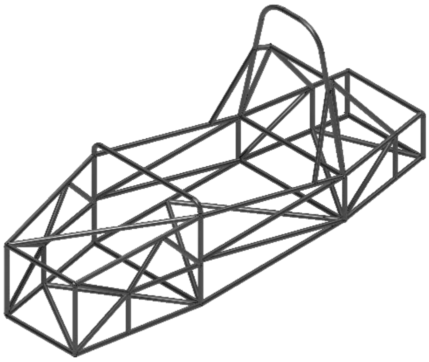

Fig 3.4 Isometric View of Initial Iteration of the Space-frame chassis

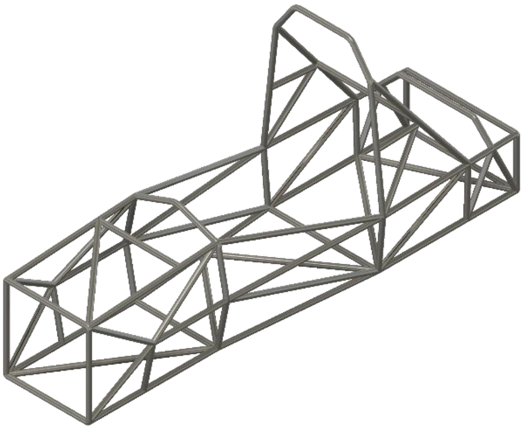

Fig 3.5 Isometric View of Final Iteration of the Space-frame chassis

4. FINITE ELEMENT ANALYSIS (FEA)

The structural validation of the chassis was performed using the SimScale cloud-native CAE platform. This allowed for high-fidelity linear static analysis to determine the frame's response to torsional and impact loads.

4.1 MATERIAL PROPERTIES

This chassis was assigned the properties of AISI 1018 Cold drawn Steel for the simulation. To justify this selection, a comparative study was conducted against AISI 4130 (Chromoly). This analysis focused on the relationship between mechanical properties, vehicle mass, and manufacturability.

4.1.1 THE MECHANICAL PARADOX: STIFFNESS VS. STRENGTH

A common misconception is that "stronger" material result in "stiffer" structures. However, in context of the space-frame chassis, the following engineering factors apply:

- Torsional Rigidity: Torsional stiffness (K) is a function of the Young's Modulus (E). Since both AISI .1018 and AISI 4130 possess an identical modulus of approximately 205 GPa, the displacement and rigidity results remain unchanged regardless of which alloy is selected, provided the tube Outer Diameter (OD) and wall thickness are identical.
- Mass Efficiency: The density of both materials is nearly equivalent. Therefore, using AISI 4130 provides no inherent weight saving unless the tube wall thickness is reduced- an option often limited by SUPRA SAE minimum thickness regulations.

- Fabrication Constraints: AISI 4130 is significantly more difficult to work with in a student environment. It requires specialized techniques and, in many cases, post-weld heat treatment to prevent brittleness in the Heat Affected Zone (HAZ). In contrast, AISI 1018 offer superior weldability and ease of fabrication, making it more reliable choice for manufacturing.

4.1.2 SUMMARY OF SIMULATION CONSTANTS

Based on the objective to achieve high torsional rigidity, the properties of AISI 1018 were utilized as the baseline for all FEA calculations in SimScale:

Table 4.1 AISI 1018 Properties used in the simulation Run for the Space frame chassis on SimScale

Property	Value	Unit
Young’s Modulus	205	GPa
Yield Strength	370	MPa
Density	7870	$\frac{kg}{m^3}$
Poisson’s Ratio	0.29	-

4.2 PRE-PROCESSING

The pre-processing phase involves preparing the digital model for the simulation solver. This step ensures that the geometry is correctly interpreted by SimScale and that the mathematical mesh is optimized for both accuracy and computational efficiency.

4.2.1 GEOMETRY PREPERATION AND CLEANUP

Before importing the model from Autodesk Fusion 360 to SimScale, the chassis underwent a geometry cleanup process:

- Structural Consolidation: All secondary components not contributing to the primary load path were removed to simplify the simulation.
- Node Verification: Every tube intersection was inspected to ensure perfect contact, allowing for a continuous mesh that accurately transfer axial loads between members.
- Hardpoint Identification: The specific coordinates for the suspension mounts and rocker arm pivots were marked as “Faced” or “Nodes” to allow precise boundary condition application.

4.2.2 MESHING STRATEGY

To discretize the tubular structure, a standard mesh was generated within the SimScale environment. The choice of mesh was balanced between capturing thin-walled nature of the AISI 1018 tubes and maintaining a reasonable calculation time:

- Element Type: Tetrahedral elements were utilized to capture the complex geometry of the weld joints and the pentagonal roll hoop curvatures.
- Global Fineness: A moderate to fine global refinement setting was applied to ensure the mesh was dense enough to capture high stress concentration at the nodes.
- Local Refinements: Specific refinements were applied to the front bulkhead and suspension hardpoints, where the 275 Nm torque couple is introduced, ensuring high fidelity displacement results.

4.3 SIMULATION SCENARIOS AND BOUNDARY CONDITIONS

To fully validate the chassis, four distinct simulation scenarios were conducted. While the torsional rigidity analysis serves as the primary performance metric, the impact simulations ensure the safety cell remains intact under extreme collision loads.

4.3.1 TORSIONAL RIGIDITY ANALYSIS

The torsional test was conducted to quantify the frame’s resistance to rotational displacement. The majority winning teams in the SUPRA SAE competition have a torsional rigidity of around 3000 Nm/deg, while the normal teams also show a value of around 1500-1800 Nm/deg. This design has been simulated and verified through that simulation to have a constant torsional rigidity value of around 2,267 Nm/deg, which is considered to be a gold standard value for a Student lead Formula type vehicle.

- Setup: The rear suspension hardpoints were fixed in all six degree of freedom.
- Loading: A torque couple was created by applying equal and opposite vertical forces of 500 N at the front suspension nodes across a 550 mm width.
- Convergence: A mesh convergence study was performed to ensure that the displacement results were independent of the element size, with the final mesh achieving a stable vertical displacement of 0.8048 mm.

4.3.2 IMPACT ANALYSIS SCENARIOS

The impact simulations were designed based on standardized G-load requirements for student competitions, using the AISI 1018 yield strength of 370 MPa as a failure threshold.

- Boundary Conditions: For impact tests, the chassis is typically constrained at the opposite end of the impact site to simulate the inertia of the vehicle mass.
- Safety Factor: The target was to maintain a Factor of Safety (FoS) > 1.5 in all scenarios ensuring that even under high-load iterations, the structure remains within the elastic region of the material.

5. RESULTS AND DISCUSSION

5.1 MESH CONVERGENCE ANALYSIS

Before finalizing the structural results, a mesh convergence study was conducted to ensure the independence of the FEA solution from the element size. The vertical displacement at the front bulkhead node was monitored across three levels of mesh refinements in SimScale. This study was conducted to rectify and prove that the vertical displacement at the front bulkhead node remained constant or almost constant irrespective of the size of the mesh elements or the number of mesh elements used in the simulation.

Table 5.1 Mesh Convergence For Max vertical Displacement (Torsional Rigidity)

Mesh Level	Element Count	Max Vertical Displacement (m)	% Variation
Coarse	~584,000	5.774e^-4	-
Medium	~787,000	5.7841e^-4	0.20%
Fine (Final)	~990,600	5.8204e^-4	0.62%

The variation between the medium and fine mesh is only 0.62%, confirming that the results are mathematically stable and suitable for final rigidity calculation.

5.2 FINAL TORSIONAL RIGIDITY CALCULATION

Using the converged vertical displacement and the specified torque couple parameters, the torsional rigidity was calculated:

The total Force (F) is considered by multiplying the value of G with the mass of 50 kg.

- Applied Torque (T): 275 Nm (derived from 500 N across a 550 mm width)

$$T = F * L$$

$$T = 500\ N * 0.55\ m$$

$$T = 275\ Nm$$

- Calculated Angle: 0.12127 degree

$$\theta = \frac{2 * 0.00058204}{0.55} * \frac{180}{3.14159}$$

$$\theta = 0.12127\,°$$

- Torsional Rigidity (K): 2,267.63 Nm/deg.

$$K = \frac{T}{\theta}$$

$$K = \frac{275\,Nm}{(0.12127°)}$$

K=2,267.63 Nm/deg

This result of 2,267.63 Nm/deg ensure that the chassis is stiff and also the stiffness is sufficient to ensure that the AISI 1018 frame acts as a rigid platform, preventing chassis flex from interfacing with the suspension kinematics—such as camber and toe stability—during high lateral load cornering manoeuvres.

5.3 IMPACT ANALYSIS AND SAFETY VALIDATION

The chassis safety was validated through front, side, and rear impact simulations. These tests ensured that the vehicle meets the structural safety requirements while maintaining an efficient weight to strength ratio.

5.3.1 SIDE IMPACT OPTIMIZATION

In the initial design stages, the side impact analysis yielded a Factor of Safety (FoS) between 3.48 and 4.0

- Analysis: An FoS of 4.0 indicated that the side structure was over-engineered, contributing unnecessary mass to the vehicle.
- Optimization Results: Through the iterative process of removing redundan nodes and integrating the cockpit diagonal, the final design achieved a more efficient FoS of 1.602 while remaining compliant with the 250 mm ground clearance rule. The pipes and the nodes removed from the side impact structure were added to the rear part of the chassis, to improve the FoS of the rear end of the chassis, resulting in not much reduction of weight of the chassis.

5.3.2 FRONT AND REAR IMPACT INTEGRITY

- Front Impact: The front bulkhead successfully managed the deceleration loads, ensuring the safety cell protected the driver’s lower extremities from intrusion. The total accelerated load applied on front impact is multiplication of 6 times the value of G and the total mass of vehicle including driver(Assumed to be 300 kg).
- Rear Impact: The rear structure demonstrated adequate rigidity to secure the powertrain assembly and maintain the integrity of the firewall during a rear-end collision scenario. The total accelerated load is equal to the product of 4 times the value of G and total mass of vehicle, i.e:- 300 kg.

Table 5.1 Impact test Scenario and results

Impact scenario	Impact Force/G-Force	Factor of safety (FoS)
Front Impact	6G	1.745
Side Impact	4G	1.6023
Rear Impact	6G	3.65

5.4 COMPARATIVE ANALYSIS OF DESIGN ITERATION

To quantify the effectiveness of the iteration design process, a comparative analysis was performed between the initial compliant design shown in Fig 3.4 and the final optimized design shown in Fig 3.5.

5.4.1 COMPARISON OF TORSIONAL PERFORMANCE

The simulation results for both designs under the 275 Nm torque load are compared in the table 5.2 below. Notably, despite addition of functional components in the final version, the total mass remained nearly constant.

Table 5.2 Comparative Structural Performance of Initial vs. Final Chassis Designs

Parameter	Initial Design	Final Design	Improvement (%)
Max Vertical Displacement	$7.142 * 10^{-4}$ m	$5.8204 * 10^{-4}\ m$	+18.5%
Torsional rigidity (K)	1,848.12 $\frac{Nm}{deg}$	2,267.63 $\frac{Nm}{deg}$	+22.7%
Chassis Mass	35.4 kg	35.48 kg	<1%

The Final design shows a torsional rigidity of about 2,267.63 Nm/deg which is 22.7 % improvement from the initial chassis design, which proves that the node triangulation structure functions better than the initial structural design. Hence, while suspension mounting are been attached to the chassis structure, while cornering the structure won't break down easily, help the vehicle to corner smoothly in high speed corners, resulting in better vehicle performance and also safety of the driver.

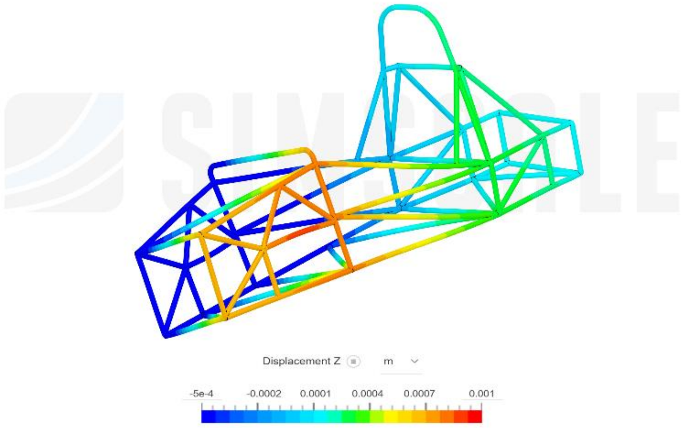

Fig 5.1 Initial Space-frame chassis design Max. Vertical displacement in metres.

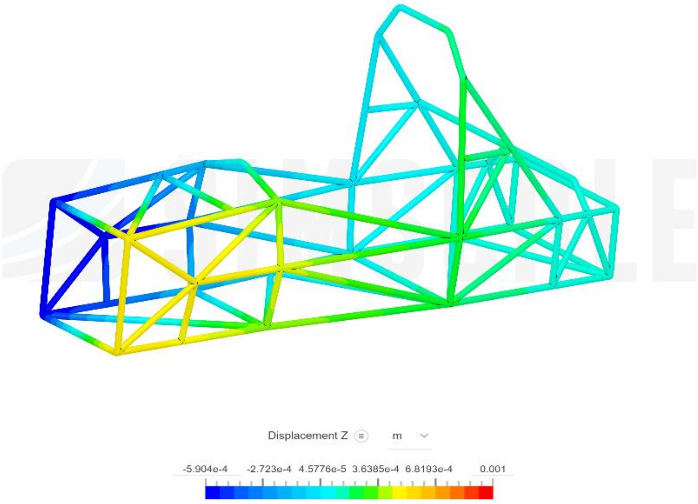

Fig 5.2 Final Space Frame chassis Design Max. Vertical displacement in metres.

5.5 SUMMARY OF DESIGN IMPROVEMENTS

The achieved of 2,267.63 Nm/deg validates several key design decision made across the ten iterations:

- Pentagonal Geometry: The transition from a rectangular to a pentagonal roll hoop provided superior structural load path while improving driver ergonomics and aerodynamic efficiency.
- Hardpoint Integration: Direct mounting of a suspension control arms and rockers into reinforced nodes eliminated localized bending moments, significantly boosting overall stiffness.
- Material Selection: The results confirm that AISI 1018 provides the necessary Young's modulus for High rigidity while remaining far easier to fabricate than high-alloy alternatives like AISI 4130.

6. CONCLUSION

The research and design process detailed in this study successfully developed a high performance space-frame chassis for the SUPRA SAE competition. Through a systematic evolution of over ten design iterations, the project transitioned from a preliminary compliant model to optimized structural solution that balanced aerodynamic efficiency, driver ergonomics and mechanical rigidity.

The final chassis performance and physical characteristics are summarized in the table below:

Table 6.1 Final result table of the chassis structure.

Parameter	Result	Unit/Metric
Total Chassis mass	35.48	Kg
Material	AISI 1018	Steel
Max Vertical Displacement	0.58204	mm
Torsional rigidity (K)	2,267.63	Nm/deg
Front Impact FoS	1.74	Safety Factor
Side Impact FoS	1.83	Safety Factor
Rear Impact FoS	3.65	Safety Factor

The SimScale results for the Front, side and rear impact are been mentioned in the Fig. below. The results in the Fig. are in form of Von Mises stress distribution legend scale, where the max stress value being 370 MPa, as the Yield Strength of the material AISI 1018 is around 370 MPa. From the Von mises stress distribution legend scale, the max. stress displaced is been calculated, which is further been used to find the FoS of the Space-frame chassis structure.

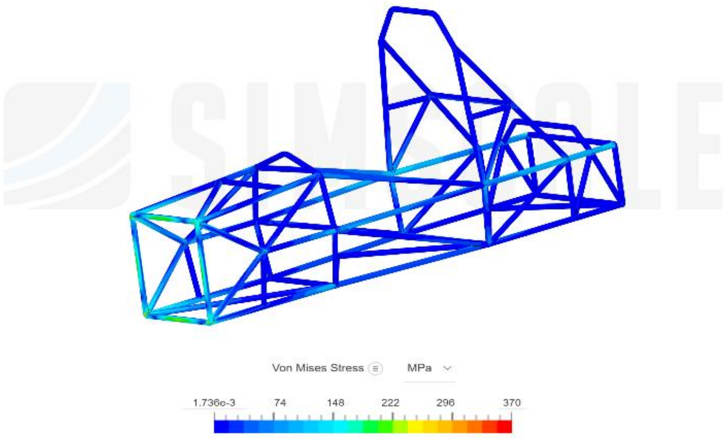

Fig. 6.1 Front Impact Von Mises Stress Distribution Test

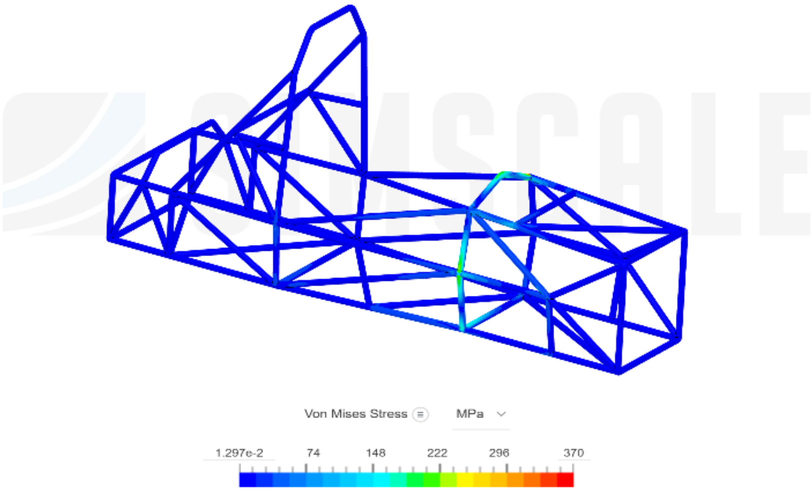

Fig. 6.2 Side Impact Von Mises Stress Distribution Test

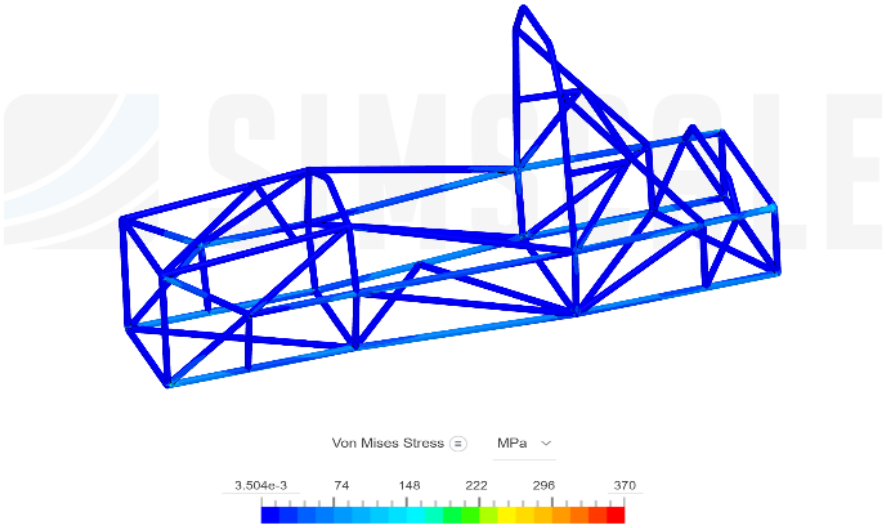

Fig 6.3 Rear Impact Von mises Stress Distribution Test

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7.1REGULATORY PRIMARY SOURCE

[1]SAE International, 2025 SUPRA SAE India Rulebook, 2025. [Online]. Available:

https://www.saeindia.org/.

7.2 SOFTWARE AND METHODOLOGY

- Autodesk Fusion 360: Used for the iterative 3D CAD modelling and wireframe development of the ten design stages.
- SimScale CAE: Utilized for all Finite Element Analysis (FEA) simulations, mesh convergence studies, and structural validation.
- AI Collaboration: This research was supported by AI-assisted analysis for structural optimization logic, mathematical verification of torsional rigidity, and technical documentation refinement.