

Chapter 4

FINAL CONCEPT AND DESIGN

After the concept development processes, a final concept had been selected due to its favourable characteristics with regards to weight, centre of gravity, torsional stiffness and structural strength. This chapter explains the third concept's development process and characterises it in detail and discusses the quantified properties and characteristics of the chassis.

4.1 DESIGN DISCUSSION

The third concept was selected as the design used for further application and research of this study. The choice was based on its low weight and its ability to transfer and resist applied loads more effectively. The key design feature to achieve this in any space frame design is to ensure that all the members are loaded axially as much as possible and to keep the bending stresses to a minimum. The chosen concept had good characteristics in terms of the way it handled axial loads and tended to avoid bending stresses.

4.2 DESIGN CHARACTERISTICS & PROPERTIES

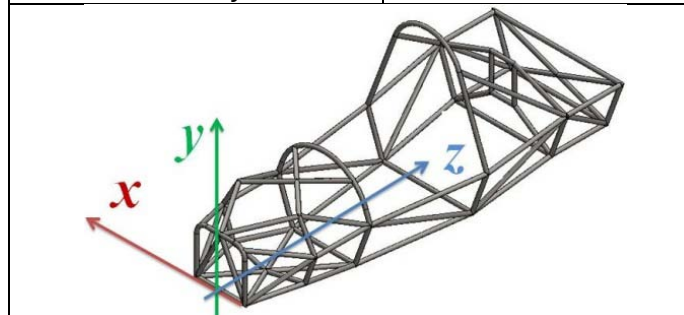
The chosen concept contributed well to the chassis stiffness and strength while using the minimum material. The three design objectives (torsional stiffness, weight and strength) of the chosen concept are the key design characteristics for a race car space frame.

4.2.1 CHASSIS WEIGHT AND MATERIAL

The weight and centre of gravity properties of the chosen concept were calculated with the help of the SolidWorks® finite element analysis (FEA) software and is presented in Figure 4-1. The y -coordinate of the centre of weight indicates the vertical distance from the bottom of the frame while the z -coordinate indicates the longitudinal distance from the front of the chassis frame. The x -coordinate will be zero as the chassis frame was designed to be laterally symmetric. The weight and centre of gravity position relative to the front, middle of the frame is given in Table 4-1. The z -coordinate is measured from the front of the chassis and the y -coordinate is measured from the bottom (Figure 4-1).

Table 4-1: Weight and centre of gravity coordinates

Weight	33.075 kg
Centre of Gravity – x	0 mm
Centre of Gravity – y	273.3 mm
Centre of Gravity – z	1269.5 mm



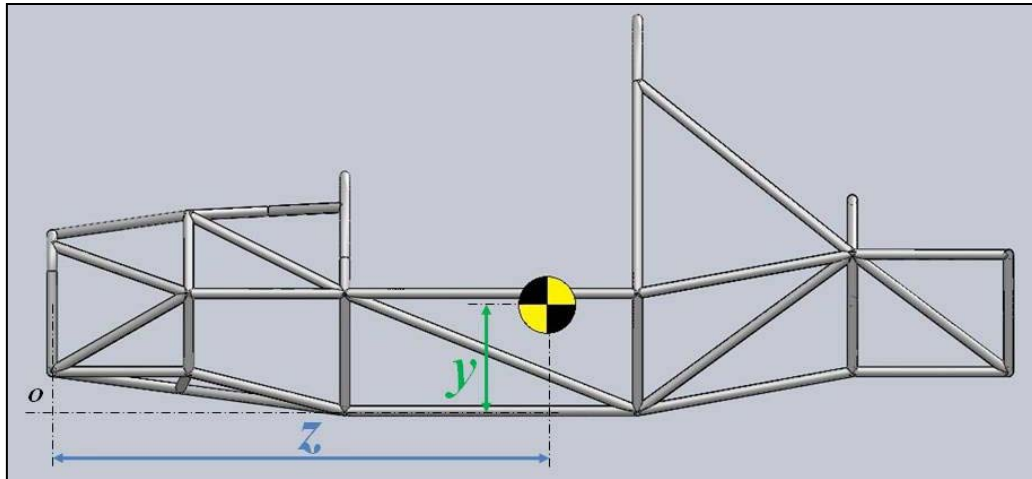


Figure 4-1: SolidWorks® representation of the chassis frame's centre of gravity

The chosen concept was designed to be constructed of SAE 1008 tubular mild steel. The material had the properties required by the Formula SAE (FSAE) rules. The material selection process was not considered as an opportunity to optimize the chassis material, but rather to ensure a satisfactory and reliable construction process. This material was considered adequate for the application due to its structural strength, mechanical properties, machine- and weldability together with its low cost and availability. Table 4-2 shows the material properties.

Table 4-2: Material properties of SAE 1008 tubular mild steel

Property	Value
Young's Modulus (E)	200 GPa
Yield Strength (S_y)	350 MPa
Tensile Strength (S_{ut})	650 MPa
Shear Modulus (G)	80 GPa
Poisson's Ratio	0.27 – 0.30 %
Density	7700 kg/m ³

4.2.2 CHASSIS TORSIONAL STIFFNESS

Torsional stiffness is the primary performance characteristic the chassis frame is designed for. Torsional stiffness is the structure's ability to resist torsional loads, a key characteristic for any race car chassis. The SolidWorks® FEA simulation software was used to design and evaluate the torsional stiffness of the chosen concept. The torsional stiffness of the entire frame was determined by considering the scenario where the structure will angularly deflect the most. It was represented by the scenario where the frame is anchored at the rear bulkhead while a torsional moment is exerted at the front bulkhead.

The torsional stiffness was determined by applying a known torsional moment to the front end of the structure while the chassis is fixed at the joint within the rear bulkhead. The torsional moment will cause deflections throughout the length of the frame. The translational deflections at the front two corners (y_1 and y_2) of the frame in the FEA were determined by using the SolidWorks® FEA probe function as shown in Figure 4-2. The values were used to calculate the rotational displacement. With the torsional moment as input and rotational displacement calculated from the values obtained from the FEA probes, the torsional stiffness could be calculated. The torsional stiffness was calculated for increased, generated cases in order to ensure accuracy and continuity.

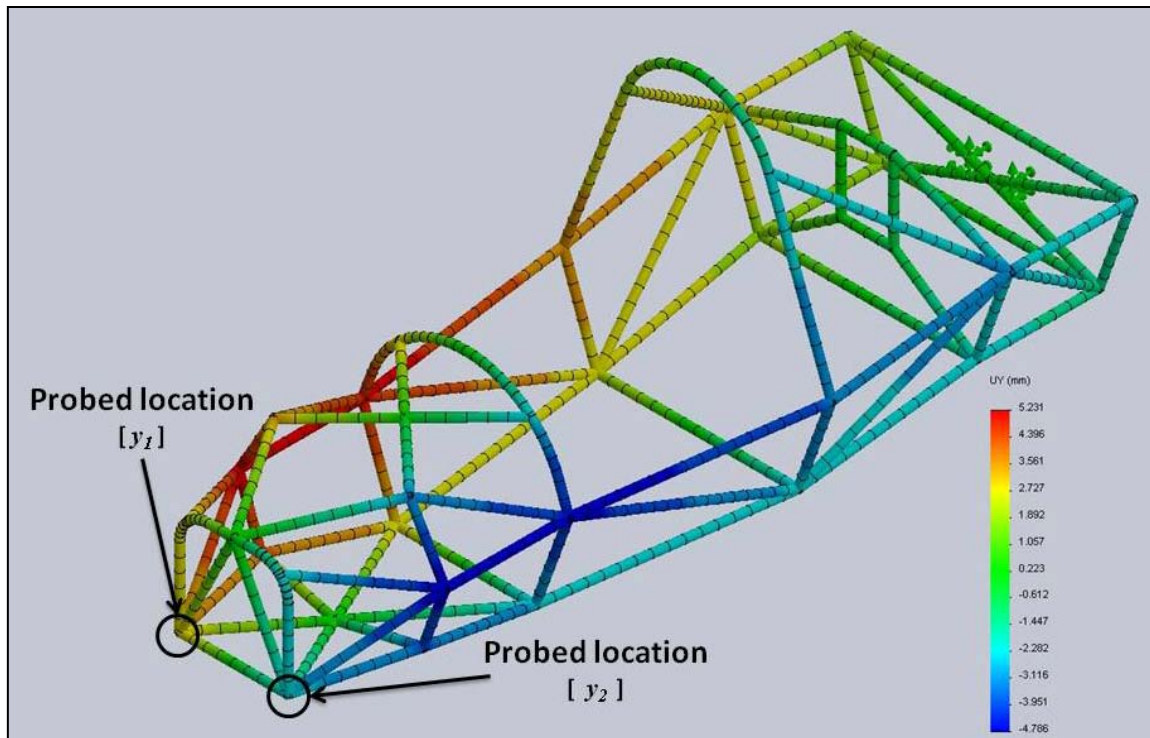


Figure 4-2: SolidWorks® FEA illustration of the simulated chassis displacements

Figure 4-3 shows a graph of the simulated values of the angular displacement at the front of the frame with the accompanying torsional moment inputs. The straight line corresponds to the theory that the structure is linearly elastic within the material's elastic region. The graph also indicates that the chosen chassis frame's torsional stiffness is continuous with increasing torsional load. The gradient indicates the frame has a torsional stiffness of 473 N.m / degree.

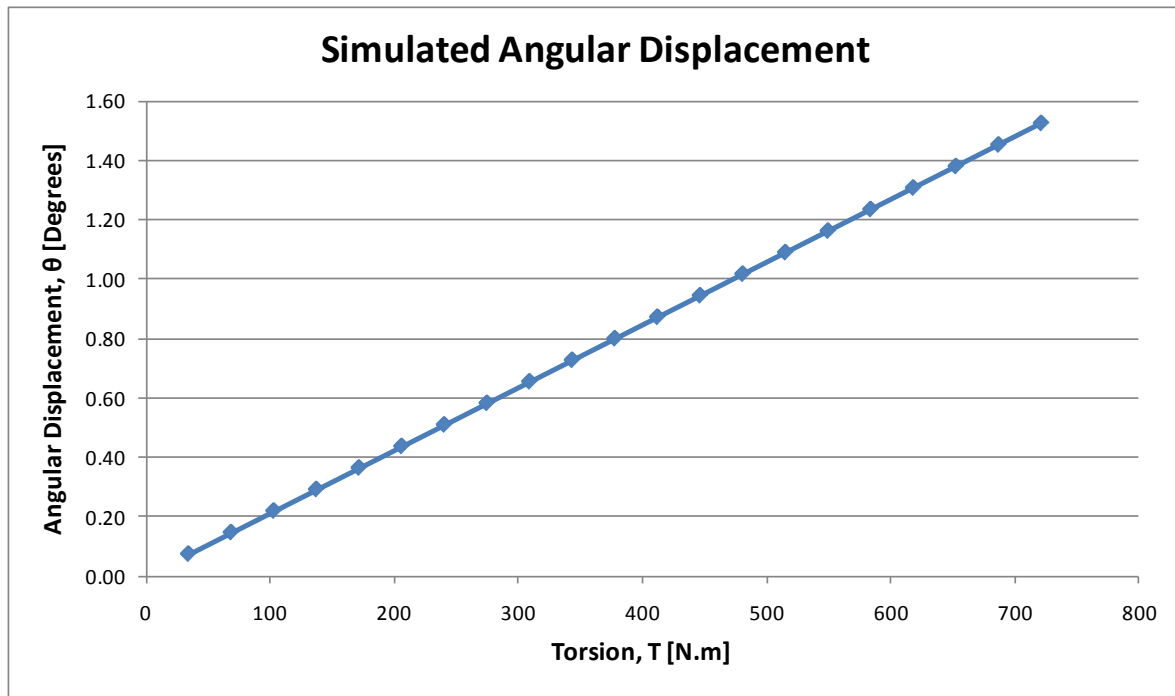


Figure 4-3: Graph of the angular displacement produced by the FEA results

4.2.3 CHASSIS STRESSES

The stresses were also analysed to study the strength and safety factor of the chassis frame. Space frames are ideally designed to transfer applied loads only in the axial directions of the various structural members the frame is made of. This phenomenon is rarely fully achieved in practice due to physical restraints of the vehicle components and all the other factors involved in the nature of a race environment.

The stresses of the chassis frame were obtained on selective members that make up the structural frame in the FEA simulation software. The stress values were also generated by using the SolidWorks® FEA probe function. The chassis frame was again fixed at the middle of the rear bulkhead's middle joint, with the torsional load applied the same way as in the deflections analysis. The torsional load was also increased progressively. The strain (ε) can be calculated from the stress (σ) and the elastic modulus (E) of the steel, using (4.1)

$$\sigma = E \cdot \varepsilon \quad (4.1)$$

Figure 4-4 shows the locations where the stresses were probed making use of the FEA software. The locations were selected on the basis of measurable stresses, practicality and their strategic importance within the structure itself. Three are located on the lower side impact structure of the cockpit structure, one on the front roll hoop brace of the front structure and on the main hoop brace on the rear structure.

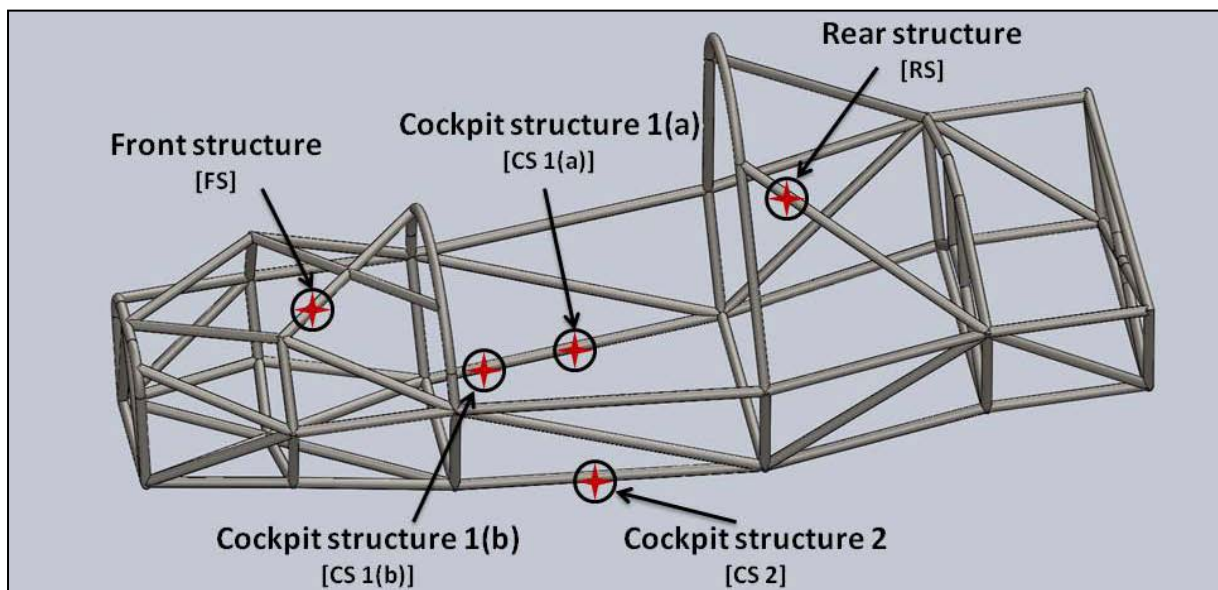


Figure 4-4: Probed locations on the chassis of the stresses

Figure 4-5 illustrates the relationships between the different stresses at the chosen points against a torsional input load. It is important to note that the stresses are defined by the SolidWorks® STR_{Max} stress result, which is defined as the upper bound axial and bending stress. It thus indicates the combined stress of axial and bending stresses in the particular member. The STR_{Max} is discussed in detail in Chapter 6.

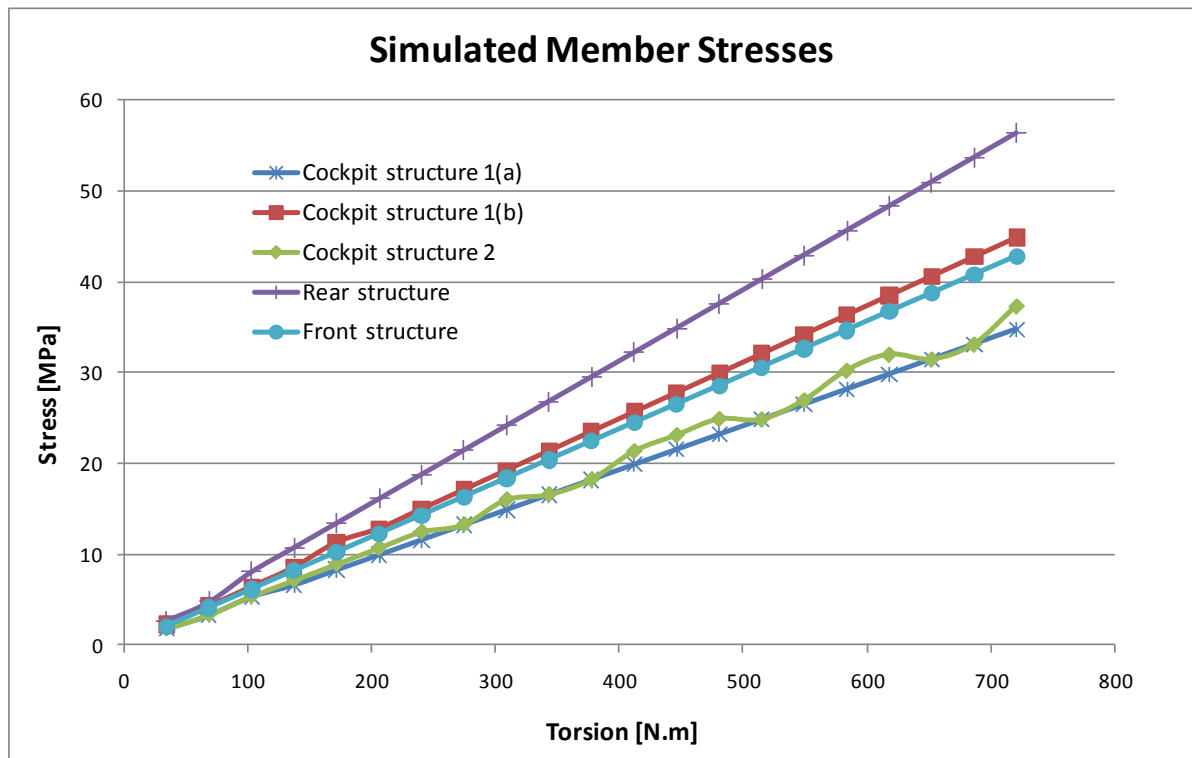


Figure 4-5: Graph of the member stress produced by the FEA results

The factor of safety (FOS) was also determined with the help of the FEA simulation software. The chassis frame will approach its breaking point at a torsional load of 833 N.m. The breaking point will be at the rear of the frame next to the fixtures of the model. The FEA indicated this as the breaking point due to the transfer of input torsional loads to this point. If the model was fixed differently, the FOS would be higher. The fixture setup in the simulation replicated the test setup scenario. Figure 4-6 is the FEA plot for the FOS. The plot represents the combined FOS of both axial and bending stresses, or, the SolidWorks® STR_{Max} stress at the frame's maximum torsional load before failure.

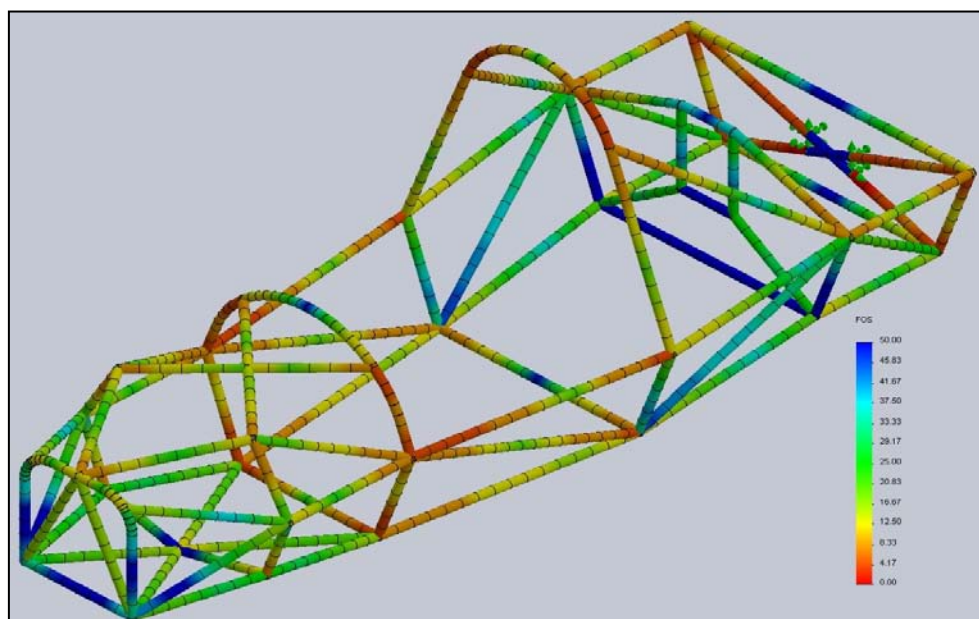


Figure 4-6: SolidWorks® FEA plot of the factor of safety at the maximum allowable stress

4.3 CHOSEN DESIGN SUMMARY

Table 4-3 is a summary of some of the characteristics of the chassis concept.

Table 4-3: Final design summary

Concept name	BRNOCHSS OCT (xi-a)
Weight	33.075 kg
Torsional stiffness	473 N.m/degree
Torsional efficiency	14.3 [N.m/degree]/kg
Maximum allowable torsion	833 N.m
Material	SAE 1008 Steel
Dimensions (L x W x H)	2450 mm x 870 mm x 1000 mm

4.4 CONCLUSION

The third chassis concept was chosen based on the performance characteristics it offered in a race environment. The third concept design was confirmed as the best of the three concepts developed. The chosen concept's development process together with its weight, centre of gravity, torsional stiffness, and strength properties were presented.

The next chapter discusses the manufacturing process of the chosen chassis. This includes all the preparation, procedures and techniques required for constructing the space frame of the designed chassis.