University of Southern Queensland

Faculty of Engineering and Surveying

Design and Manufacture of Scaled FSAE Chassis Using Generative Design and Topology Techniques

A dissertation Submitted by

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Abstract

This project aims to design an organic chassis for an autonomous FSAE vehicle. The project was scaled to allow for additive manufacturing capabilities and explores methods of manufacturing for the complex outcomes. Examining traditional chassis design methods and building upon the knowledge of generations of vehicle structure designers. The application of Generative design and Topology Optimisation into complex structures is proposed in this project. Design outcomes are inspected, Validated, and manufactured (prototyped) then further inspected for design defects and manufacturing quality. The process development through this project attempts to bridge the gap between traditional design and simulation, to modern design optimisation techniques.

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ENG4111 & ENG4112 Research Project

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____[redacted]____5/10/2022

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Gordon Drummond

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Chapter 1 – Introduction

1.1 Introduction

This study is to explore an organic chassis for a formula SAE vehicle. The processes utilised will apply Generative Design (GD) or Topology Optimisation (TO) to design and evaluate a chassis outcome. The study also aims to explore methods to apply advanced design optimisation to complex structures such as a vehicle chassis. Applying these methods to a simplified chassis design to allow ease of evaluation. The outcomes for a generative designed chassis are validated using FEA software. Although good results have been reached significant future work on the topic, this is required before the process can be implemented into industrial applications.

1.2 The Problem

Processes for evaluating complex designs for GD and TO are often coveted by the developer. Moreover, the individuality of each design contributed to the fact that there can be no hard and fast rule to using GD or TO. Developing knowledge around how algorithmic design works is primary to its application. The problem of optimising a chassis is the overwhelming number of unknowns, as well as the design constraints for components that will be attached to the chassis.

The secondary problem is the lack of theoretical process around the use of GD. Figure 1 shows a typically workflow for design, often a time-consuming process with little optimisation. This wastes resources and can delay projects, by implementing GD and potentially optimising this process and the outcome.

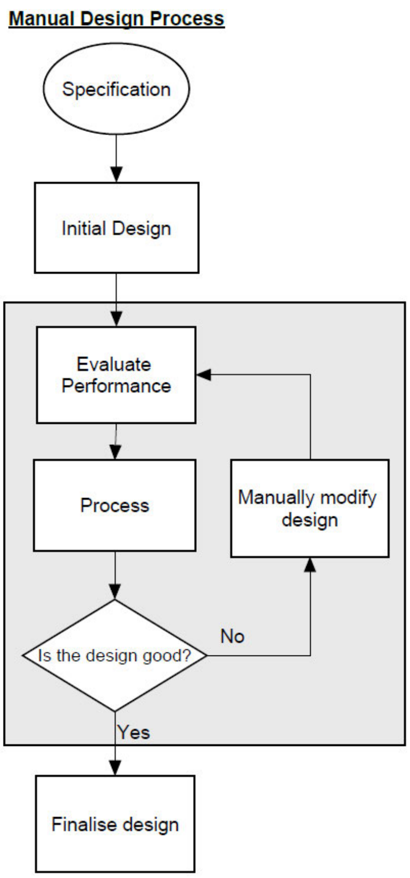


Figure 1; Typical manual design flow

1.3 Research objectives

The objective of this research project is to use Generative design (artificial intelligence) to model a scaled chassis for the USQ FSAE team. The CAD model will be accompanied with a mathematical model that can be used by the team to build their full-scale chassis. Scaling the project into a more manageable size for testing the vectorizing the automotive vehicle. Using this technology is very new to engineering and applying to a complex structure like a chassis will challenging. Another outcome of this research is to have a printable working model of a scaled FSAE vehicle for use by the team. The study will provide the groundwork for future work the team requires to compete at FSAE.

1.4 Summary

In summary the project will attempt to bridge the gap between current design strategies and strategies to apply Generative design. The implementation of these strategies can potentially decrease design time and ease optimising designs, in turn increasing productivity. Applying this technology to a complex structure such as a chassis is typically avoided due to the complexity of the calculations required to perform successful simulations.

Chapter 2 – Literature Review

2.1 Introduction

Chassis design is not a new concept in the automotive industry. The chassis is the primary structure for all mobile machinery not only in racing. Much of the research conducted for this project was completed as part of the literature review for ENG4110 – Research Methodology. This project was started during that time with intention to complete in November 2022. The explorations of design processes in generative design and topology optimisation have aided in the understanding of how the software operates.

2.2 Chassis Types

In the Automotive race industry, there has been much advancement over the years. Particularly in the material and design sections, vehicle chassis have also undergone many changes. These changes have made chassis design extremely complex systems that are highly effective in their performance. Many types of chassis have been designed over the years these include.

2.2.1 Function of the chassis

The primary function of the chassis is to combine all other components of the vehicle. It is the main contributing structure to the rigidity of the vehicle, giving it a ‘bone structure’. The chassis plays a highly significant role in how the vehicle will perform on the track (Hui 2012). Guiding factors for a chassis design are the characteristics of a chassis, some of these are more critical than others. Torsional stiffness is the resistance of torsion introduced to the vehicle by undulating road surface and cornering (Oshinibosi 2012). The importance of this characteristic is its contribution to the road performance of the vehicle (Leelakar & Krishnaraj 2021). Limiting the torsional rotation aids in the correct adjustment of the suspension characteristics of the vehicle.

2.2.2 Ladder chassis

This primitive chassis design is the oldest type of chassis and have been used in production vehicles since the 1950's (KALE 2016). The design consists of two main members which support the vehicles weight and cross members which tie them together. The design is cheap to manufacture and lends itself well to production vehicles.

2.2.3 Self-support chassis

Self-supporting chassis or Unibody chassis are dominate in production car chassis today. The design incorporates the body with supporting frame make one entire structure. Predominantly formed using pressed metal panels which are welded together. Due to the manufacturing process and the design requirements of this type of chassis it has good load distribution will being light weight. This chassis type is primarily utilised in production cars because of the high cost of press dies required to manufacture the panels.

2.2.4 Monocoque chassis

Monocoque chassis are a relatively new chassis concept. It incorporates one structure into the entire body and frame of the vehicle. Often made from carbon fibre the monocoque is very strong and very light, leading to better vehicle performances. Although the monocoque chassis has many advantages is also has significant disadvantages. Fibre composites are expensive to manufacture and are susceptible to fractures due to their brittle nature.

2.2.5 Space frame chassis

The Space Frame chassis is extensively used in the custom vehicle industry. Its strength comes from triangulation of steel or aluminium tubes, removing torsion in any one tube. The three dimensional structure removes any members exposed to twisting or bending (KALE 2016). The challenge of a space frame chassis design is achieving the required rigidity of the vehicle while reducing weight to its absolute limit. Manufacturing of these chassis designs is often cheap as materials used are readily available from supplies, although cheap good structural stiffness and minimum body deflection can be achieved.

2.3 Generative Design

Generative design is relatively new to industrial applications pioneered in the early 1970s as a way to approach complex design situations (Designing 2021). The term describes a process of designing typically using cloud based AI computing to evaluate algorithmic design (Wunner et al. 2020). Wunner et al. explains the potential of utilising algorithms to power design and the sophistication achievable using the GD process. It is important to mention that this tech does not replace experience in mechanical design it simply helps to quickly achieve an optimised design outcome for the given problem. However it is widely recognised there is a need for a theoretical framework to GD (Krish 2011). Shea et al. best describes GD as ‘‘generative design systems are aimed at creating new design processes that produce spatially novel yet efficient and buildable designs through exploitation of current computing and manufacturing capabilities’ (Shea et al. 2005). There are some down sides to GD its application to industry has been slow due to the lack of process theory. Generating many solutions presents more problems they solving the initial solution (Davis 2020). Davis explains that generative design has many flaws which need to be addressed before its fulling used in industry.

2.4 Topology Optimisation

Topology Optimization is relatively new and rapidly expanding field of structural mechanics (Rozvany 1997). The concept of Topology Optimisation (TO) was first published in an article in 1904 by Australia mechanical engineer Michell (Tyflopoulos et al. 2018). Tyflopoulos et al. explains the primary methods of TO are the solid isotropic material with penalization (SIMP) and the evolutionary structural optimization (ESO) or the bi-directional evolutionary structural optimization (BESO). To simplify this Sigmund &Maute suggest that a TO problem can be approached in two ways shape optimisation or as a density problem (Sigmund & Maute 2013). Shape optimisation can be view as LaGrangian (boundary following mesh) and Eulerian (fixed mesh). In the book Topology optimization in structural mechanics by Rozvany two-dimensional topology is described by the elimination of nonoptimal members. By doing so layout optimization of the grid by means of simultaneous selection of optimal topology, geometry, and cross-sectional dimensions. In Figure 2 this can be seen where (a) is the original (ground structure) and (d) is an optimised structure.

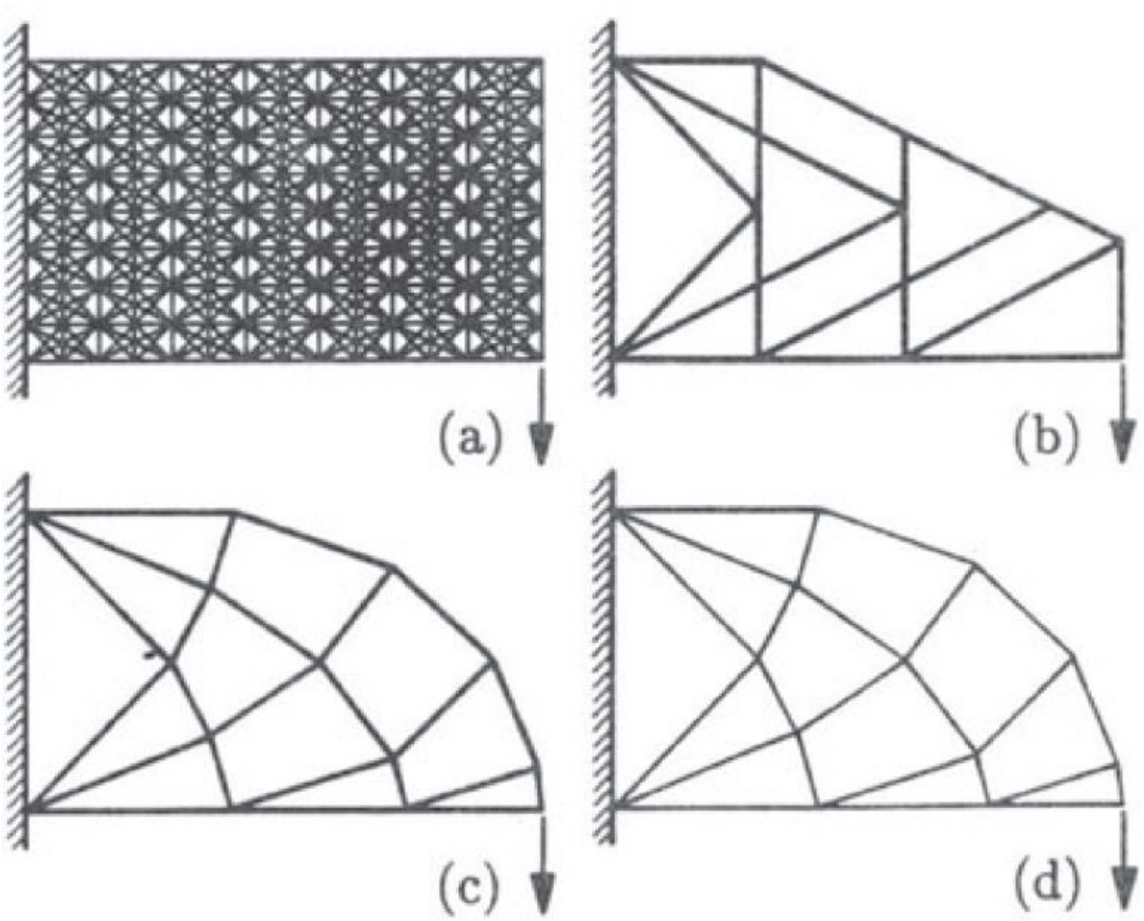


Figure 2; Layout optimization: (a) ground structure, identical topology in (b)-(d), identical geometry in (c)-(d), and different sizes in (c) and (d) (Rozvany 1997)

A problem in Topology optimization is dynamics. The book Topology Optimization: theory, methods, and applications by Bendsoe & Sigmund outlines how TO can account for vibrations and dynamic loading but due to complexity it has been removed from this project (Bendsoe & Sigmund 2003). There are many software tutorials online on the processes of TO, using Ansys FEA software presented by MT et al. shows how Ansys TO software works. It was able to identify and remove mass from the support bracket (MT et al.). The Creo demonstration by Ian Boulton appears to present better results with less post processing than the Ansys software.

2.6 Summary

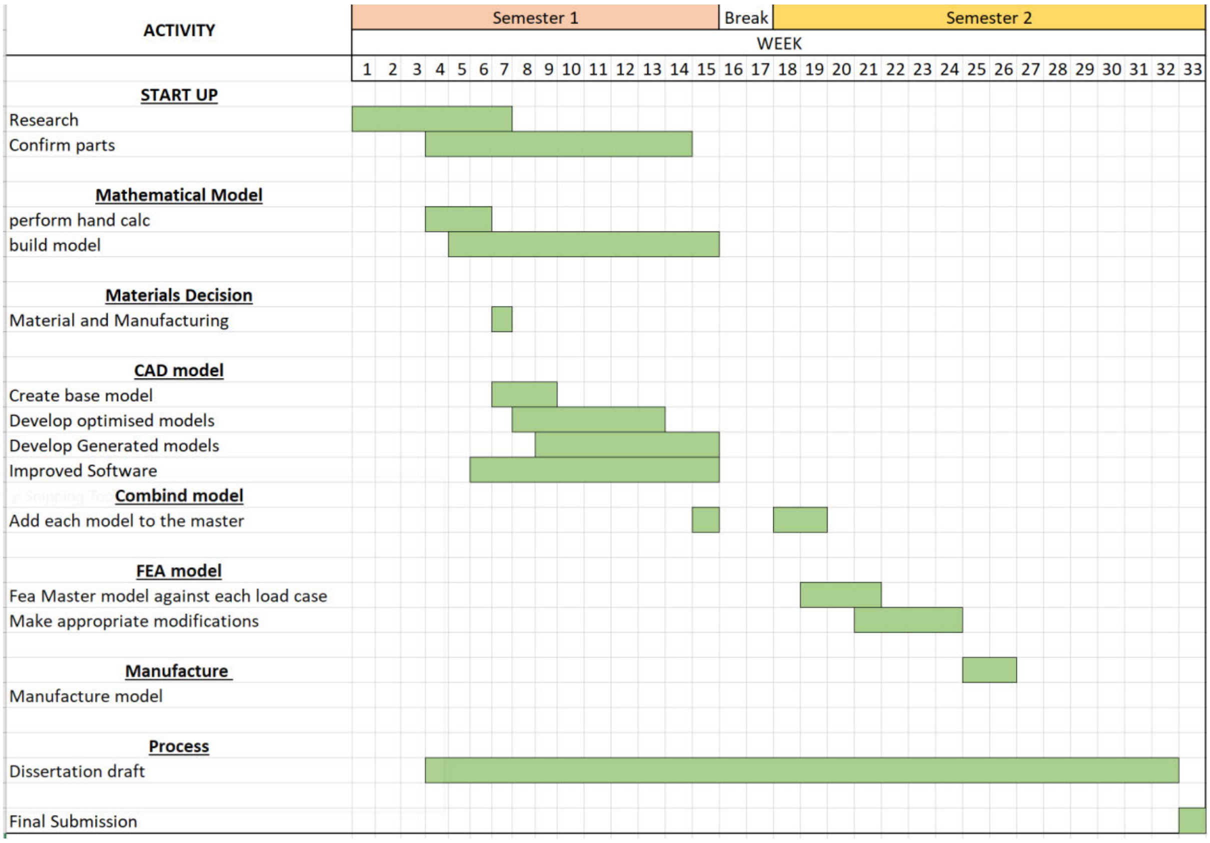
The use of GD or TO will undoubtedly create a new type of chassis, neither spaceframe or self-supporting. The organic shapes and integrated mounting points make this chassis type unique. The complexity of the analysis of the final design will prove difficult and consulting both the supervisor and possibly external experts may be required. The research shows that there is a gap in the design process, that many institutes are trying to resolve. As technology improves and the need for more refined structures increases these types of design processes will prove to be more valuable.

Chapter 3 – Resource Planning

3.1 Timeline

The timeline presented in Table 1 is a live document that has been updated a number of times throughout this research project. Some of the major changes include the confirmation of parts, this is taking longer than initially expected. Also, the model build is subsequently taking longer because of the component's specification. Changes to this document will continue to occur until the project is complete. The confirmation of parts was never achieved due to unforeseen constraints. The models produced would satisfy general design requirements but will need to be refined under future work.

Table 1; Timeline for Project



3.2 Manufacturing

The 3D print labs constraints include size of print and printable materials. This not only limits what design can be achieved but also the time frame of the manufacture. Utilizing personal connections to achieve high quality resin prints has proven to produce better quality results. The results of the manufacturing are presented in Chapter 5 – Materials and Manufacturing.

3.3 Limitations

The assessment of limitations has been conducted during ENG4110 and is applicable to the project. The limitations of this project are linked to software licensing. The expected licensing provided by the university may be adequate. Although the software is expected to be able to perform the requirements of this study if the case arises that it cannot other solutions will need to be explored. To date the work has been conducted using free software for students, it is somewhat lacking in the specifics for engineering applications and may not be adequate to complete this study. The analysis had was verified using other software that the university currently has licensing for.

3.4 Summary

The resources used in this project have been limited. The licensing and manufacture were sourced with minimum expense. Licensing of the TO software could have been supplied by the university but was deemed unnecessary. The GD software was freely available to students and no cloud expenses were incurred. Manufacture was partially done by the university and partially outsourced. Finally, the project was completed on these limited factors.

Chapter 4 – Research Design and Methodology

4.1 Introduction

The research project progressed through the generative design (GD) processes. This chapter presents the proposed design process and what is involved with application of GD to a complex structure. The software used to complete this work and the associated restrictions with the software. An initial model was created using known and unknown conditions, with some iteration successfully achieved a usable model. The design was then analysed and validated to the known constraints. The second part of the chapter is for future work where similar design inputs are simulated using different software to assess the problem using topology optimisation. This is expected to achieve better outcomes due to only have one model to analyse.

4.2 Generative design

4.2.1 Introduction

Generative design (GD) is a tool for designing objects that many human designers could not imagine. Applied typically at the start of the design process GD allows for many design outcomes, which need to be analysed by the designer. This section of the report explores the established process for GD and its application to chassis design. It presents the experimental work conducted using GD for a chassis design and its downsides.

4.2.2 Software

The Generative Design experiment of this project was conducted using Autodesk Fusion 360. This is a true cloud-based AI generative design, which took much longer than expected. The software has some nice features such as preloaded materials and limited design constraints. The latter of which come to be a downside as it afforded no control over the outcome. The instruction on the use of this software was followed from the Autodesk YouTube channel.

4.2.3 Process

The proposed process applied to chassis design was one that can be found on the Autodesk website. It involves having some specification, an initial design and as a design some idea of the outcome that should be achieved. Using Fusion 360 this can be achieved as an iterative process although somewhat limited the software did produce an organic chassis with some major flaws that do not satisfy the design parameters.

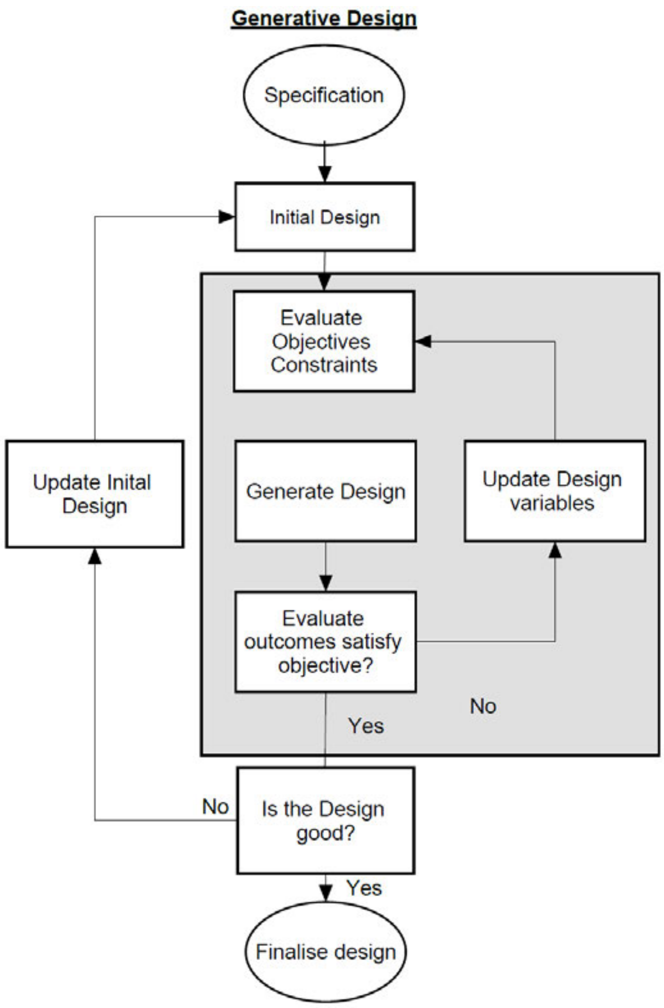


Figure 3; Proposed Generative design flow

It is important to note that this process worked, although not for such a complex structure as a chassis design. This workflow process is well adapted to simpler bodies and may be built upon in future work.

4.2.4 Specification

The specification for this project is based on many assumptions. The complexity of a vehicle chassis has been well established and as there is a lack of information on the other components for the chassis design. The project was simplified for include some basic suspension points and assumed weights. The forces needed for the GD was then calculated using excel. These were broken into assumed and what need to be calculated, from the research in Chapter 2 – Literature Review it was identified that vehicle chassis are assessed by a number of load cases. To design this chassis reversing this process is a viable way to streamline the process. Four primary load cases were the basis for the design specification, Forward impact, drop impact, acceleration and breaking.

4.2.4.1 Forward Impact

First the main forward impact could be calculated using Equation 1. The velocity of the vehicle was analysis if at the assumed top speed of the car 27.8 m/s hitting a solid object and instantly stopping. By setting d to a small number the force can be evaluated for a forward impact.

$$\boldsymbol{F = \frac{1}{2} m \frac{v^2}{d}}$$

Equation 1

Where m is the total mass of the vehicle, v is the velocity in m/s and d the distance it takes to stop.

4.2.4.2 Drop Impact

The drop impact specification was conducted as a worst-case scenario. For instance, if the vehicle was to jump in the air to a height of d and land hard. To simplify this no suspension was accounted for, although the force would be absorbed into the chassis through the suspension points. To calculate the time (t) it takes for the vehicle to fall Equation 2 was used. This value could be use in Equation 3 to find the velocity of the fall and subsequently the force of the drop impact.

$$t = [\frac{d}{(0.5 \times g)}]^{\frac{1}{2}}$$

Equation 2

Where t is the time of the fall in seconds, d the distance from start of drop to end in meters and g is gravity in m/s^2

$$V_f = V_i + g * t$$

Equation 3

Where Vf is the velocity of the fall in m/s and Vi the initial velocity in m/s, g is gravity in m/s^2 and t the time of fall calculated from Equation 2.

4.2.4.3 Acceleration

The acceleration force that the chassis will need to withstand is yet to be determined. This is because the tyre diameter has not been confirmed. The gearing ratio and torque output of the motors will also need to be confirmed to have the variables for the specification. The calculation for this can be finalised and easily implemented into the design once finalised.

4.2.4.4 Braking

The Braking force for the design is also yet to be determined. As the wheels and gear ratio will specify the top speed of the vehicle. The braking has been deemed to come from the motors the total weight can be assumed although the wheels and braking speed need to be calculated to get the braking force.

4.2.4.5 Components

This process relies heavily on having knowledge of the final structure. The number of unknowns that have been encountered to do this design makes it almost impossible to predict outcomes. The design method is based on what is required and without knowing how this car is to perform then the design that is produced will certainly perform to that standard. As very little design work was performed outside of this project only 3 other components were specified for the design of the chassis. This does not allow for a totally accurate chassis design and the results are purely to prove the process.

4.2.5 Initial Model

The initial model for this projected included many assumed geometries. The reason for this initially was to determine if Fusion 360 GD could process the geometry that was required for this project. The geometry consisted of two types, Obstacles and preserve regions. The forces calculated and assumed in 4.2.4 Specification was applied to the preserve bodies giving the chassis known operating forces that the chassis will need to withstand.

4.2.5.1 Obstacle Bodies

Obstacle bodies are the regions which the GD cannot generate into. In Figure 4 the first iteration of the initial design can be seen the red bodies are obstacles. The large box at the front of the vehicle adds an area that is forward of the front impact zone. In the middle of the model the general geometry of the inside of the vehicle is presented. As the design process progressed obstacles were added to build more detail into the final design.

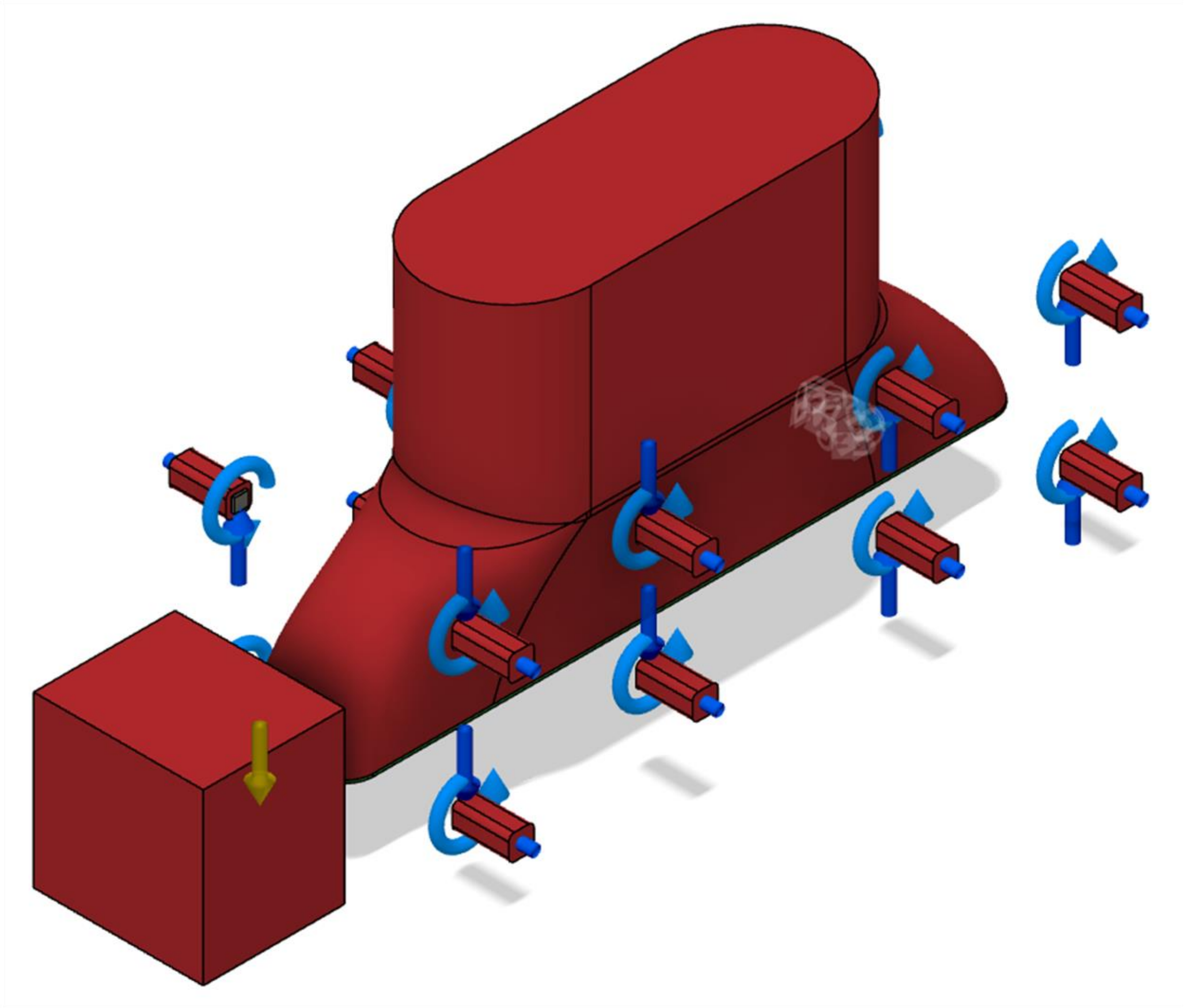


Figure 4; Obstacle bodies for initial design

The addition of steering into the specification came after the first iteration, in Figure 5 the body that cut perpendicular to the main vehicle is present for the steering connection rods.

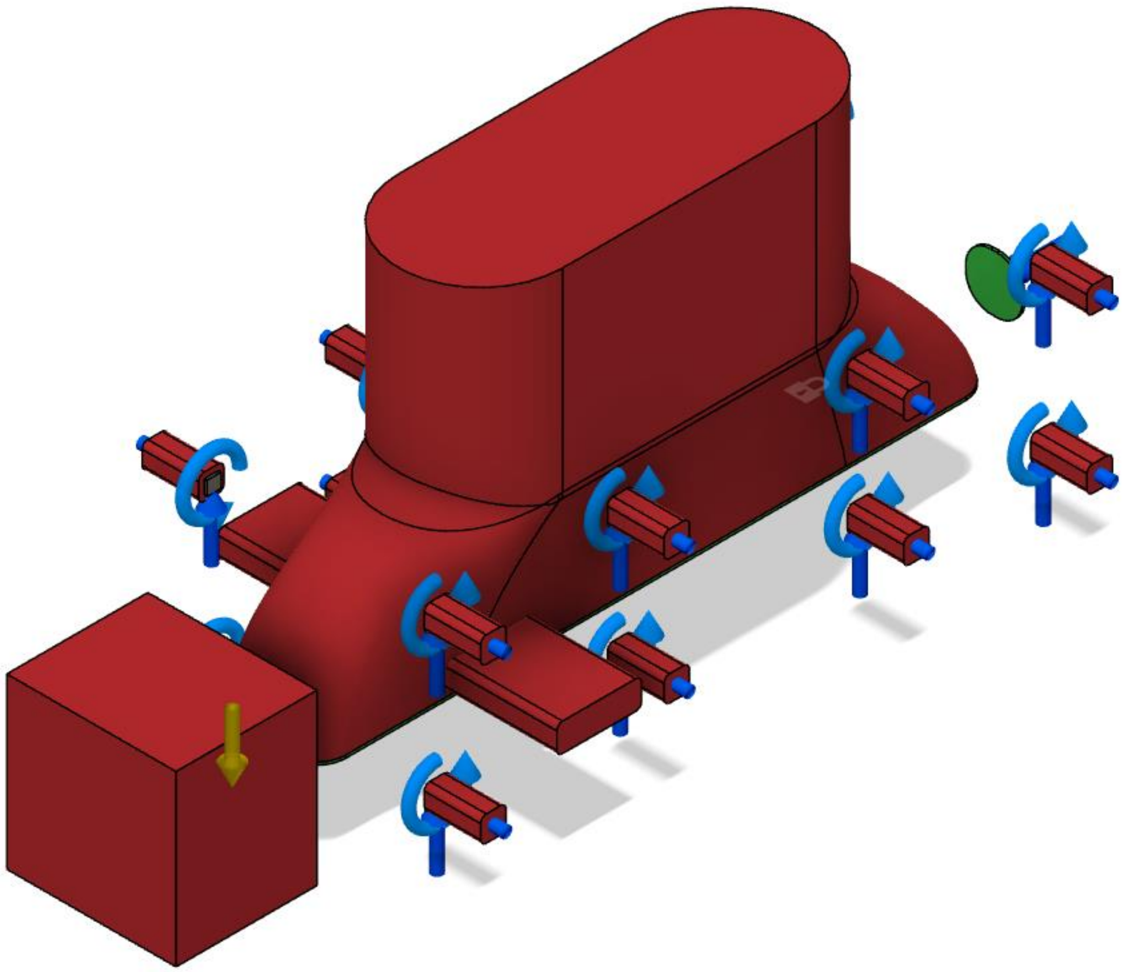


Figure 5; Obstacle bodies added steering clearance

Progressing through the project as components were added to the model more obstacle bodies need to be added. The first addition was location for the suspension shock to connect to the main structure. In Figure 6 the square preserve bodies at the top of the structure are the location and angle of the shock absorbers mounting point.

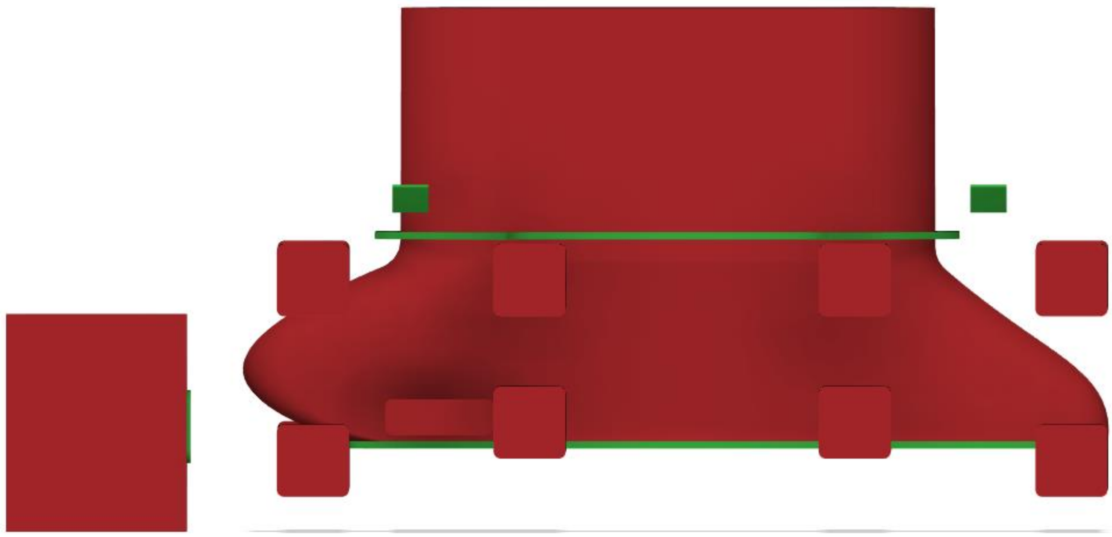


Figure 6; Addition of suspension points

These points then need to be unobstructed outboard of the chassis, addition of obstruction bodies solve this problem. Figure 7 shows the extrusion of these and ultimately where the shock absorbers are proposed to be located.

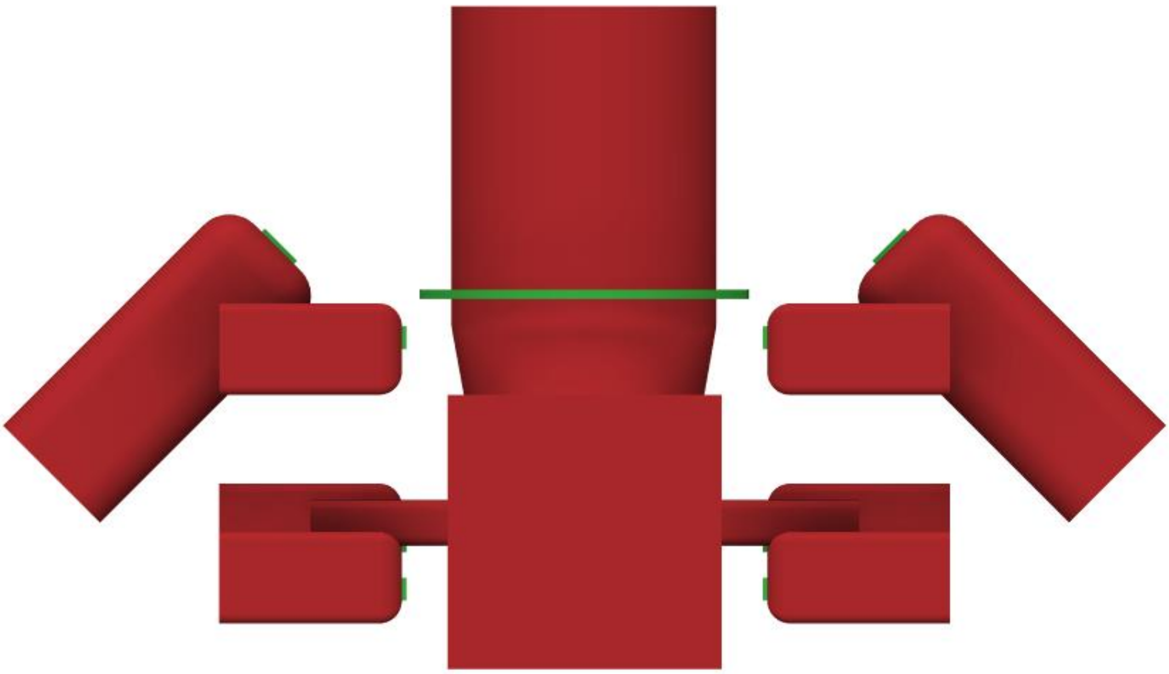


Figure 7; Suspension Obstruction bodies

When this design was run it produced results that had large ‘bridging” structures, this raised the centre of gravity of the chassis. To eliminate this problem the addition a body that produced nice curvature was added. Figure 8 shows the blue face that has been extruded across the top of the structure to remove the described problem.

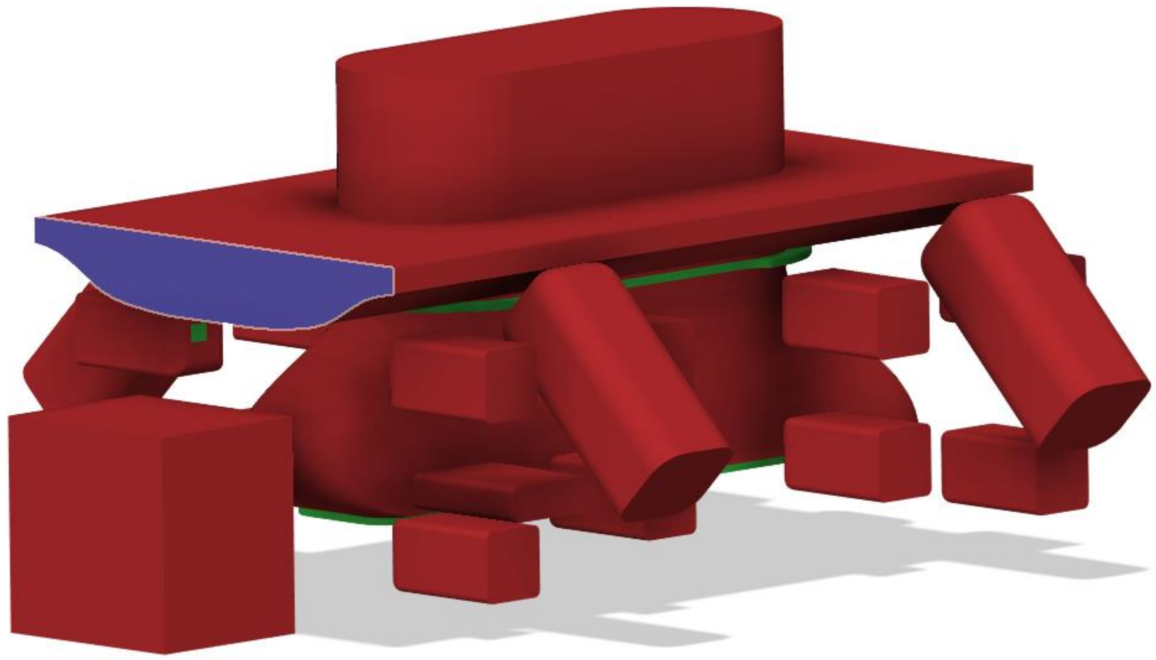


Figure 8; Obstacle to remove bridging structures.

When confirmation of the forward-facing camera and rear facing lighting came through the addition of mounting points was required. These also required areas for where the sensors would be located, so obstacle bodies were placed around them. In Figure 9 the forward and rearward bodies show where exactly the sensors are to be fixed.

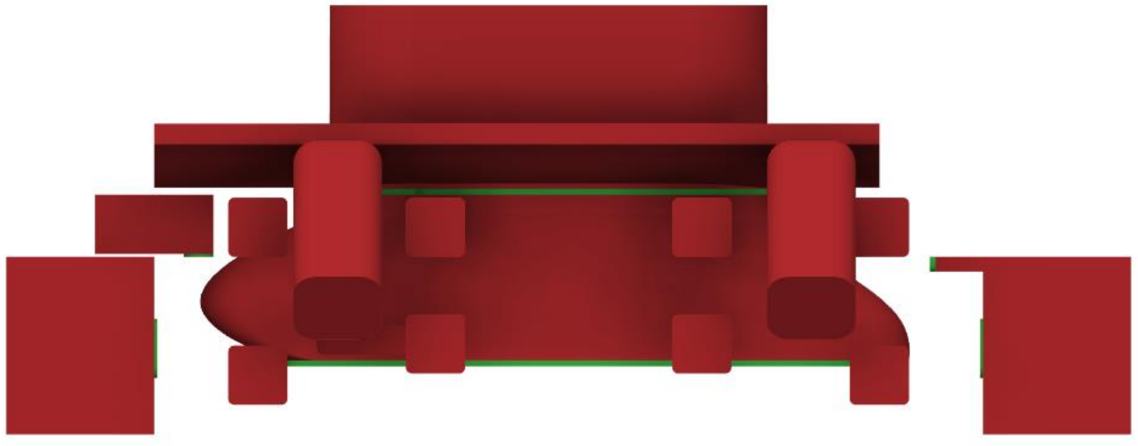


Figure 9; Addition of Sensor mounting

The final vehicle also requires forward and rear bumpers. These are to be mounted onto the points at the exterior of the vehicle. The square base of the bumpers needs to slide neatly into mounting points. During the initial print of the structure (V15) it was identified that there is obstruction for these bumpers, Figure 10 shows where the bumper mounting will slide through the mounting points.

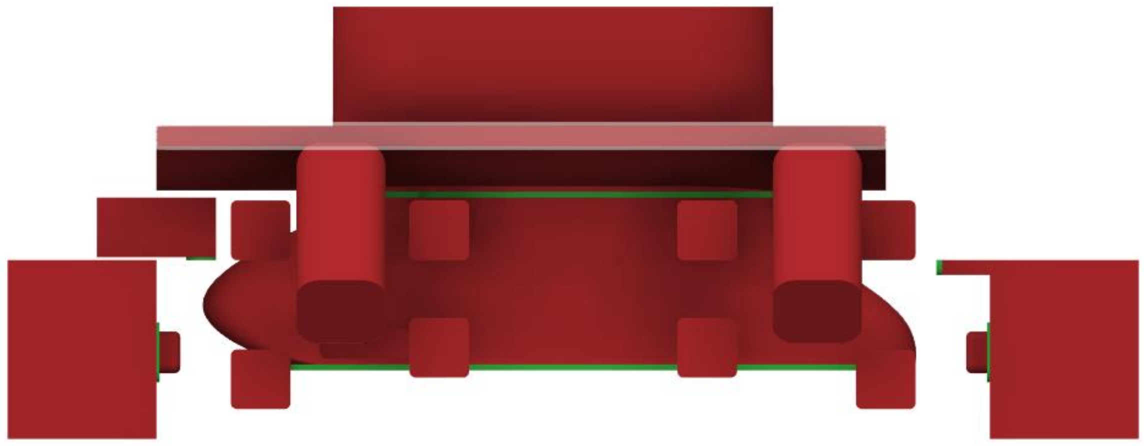


Figure 10; Obstruction for bumpers

During the final assembly some issues arose. The obstruction bodies that were added for the suspension upper posts appeared too not be large enough. The structure was inclosing the smaller body. This in turn did not allow area for the upper control arm to move and limited mounting options. Of course, the upper control arm could be designed around this, but an easier option is to enlarge the area of the obstacle. Allowing for room for the control arm movement.

After the initial print of the model, it was identified that some of the geometries had sharp edges. The GD then designed tight to these edges giving stress concentration into response to this. Adding large fillet/ radius to the contact edges elevated this problem. In doing this the stress concentration was removed and the final design flowed around these obstacles with smoother transitions.

4.2.5.2 Preserve Bodies

The other bodies required for the initial design are Preserve bodies. These are components of the final design that are required for mounting or fixing of other vehicle components.

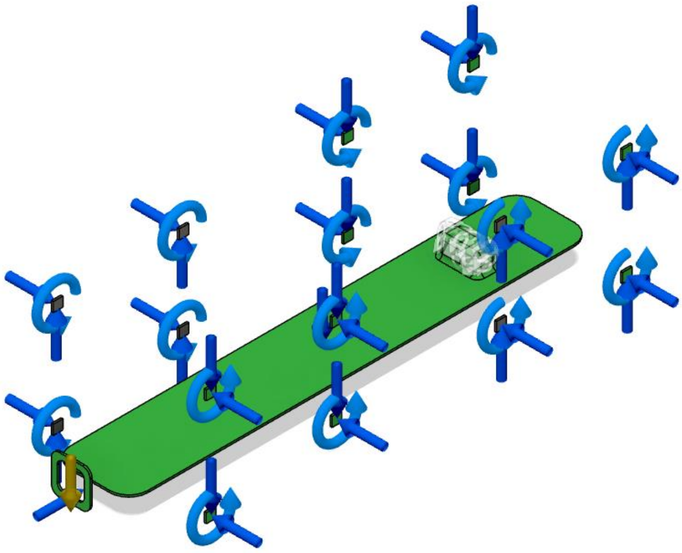


Figure 11 shows the green bodies that are preserve geometries. The small squares are fixing points for the suspension wishbones. The main bottom shape is the floor of the inside of the chassis this is included to mount electrical components. The square at the forward part of the model is the forward bumper of the vehicle.

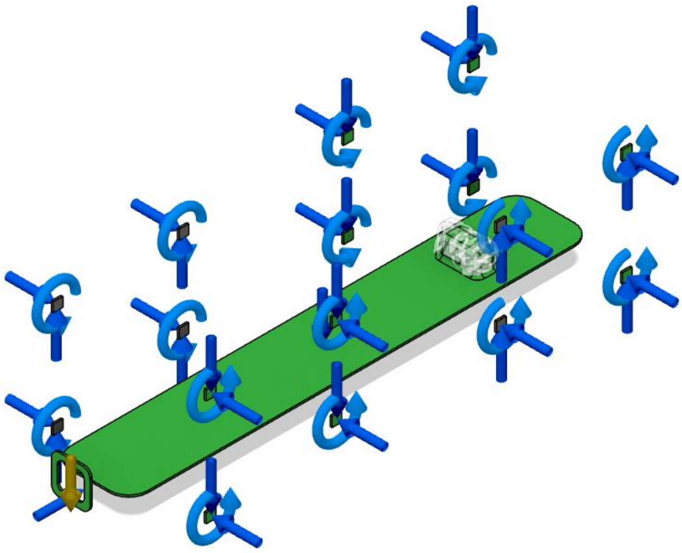


Figure 11; Preserve bodies for initial design

As the design progressed, features were added including a rear bumper. Figure 12 shows the included geometry of a rear bumper of the chassis. This was eventually added to both the front and rear of the model and can be seen in the final assembly Figure 60.

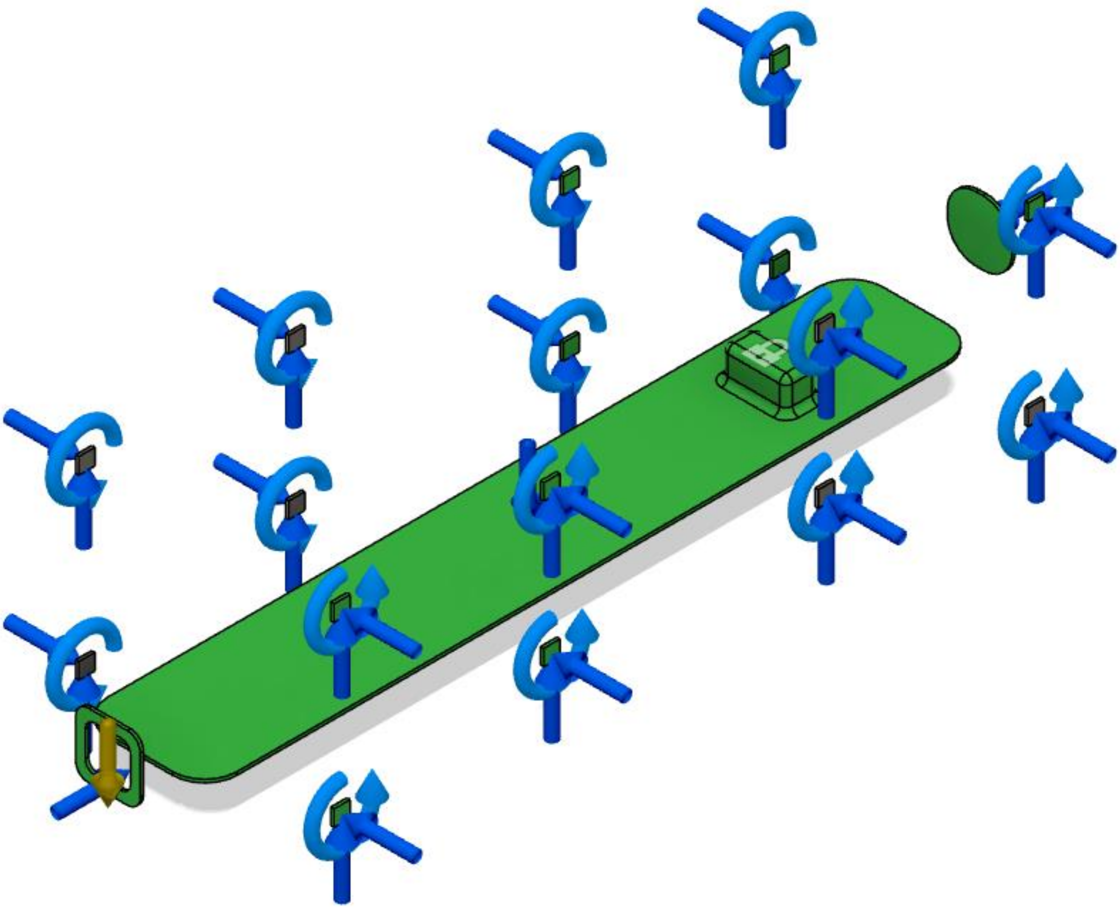


Figure 12; Preserve bodies, including rear bumper

The blue arrows that are present in figures in this section are the applied forces. They include a moment on the suspension points, this is assumed to be the maximum torque that the selected motors can produce. The yellow force at the front is gravity, seen in bottom left of Figure 12 this is added automatically by the software.

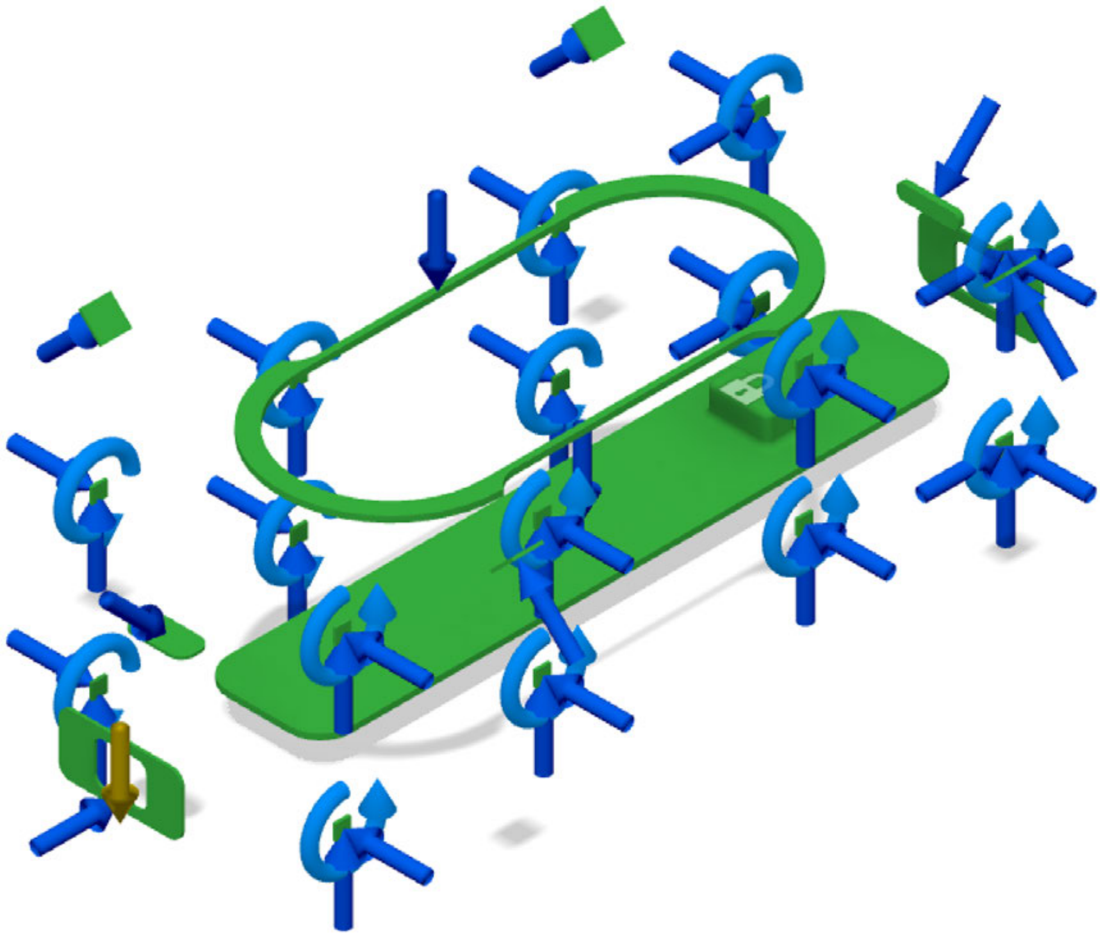


Figure 13; Final Design Preserve Geometry

The final design of preserve geometries is presented in Figure 13. The suspension hangers have been added for a space to mount the upper end of the shock absorbers. Also, the halo was included, this is the mating surface of the roof structure. These inclusions will be joined by many more preserve geometries as the final components are added. With each extra body added to the design the complexity of the outcomes will increase.

4.2.6 Materials and Manufacturing

As a research objective the final model will need to be manufactured using additive manufacturing. This limits the materials to be used to those that can be 3D printed, Figure 14 shows the materials selected from the preinstalled library of materials. Limiting the software to these materials reduces the number of outcomes possible. Although this still a possible 26 outcomes for the software to generate.

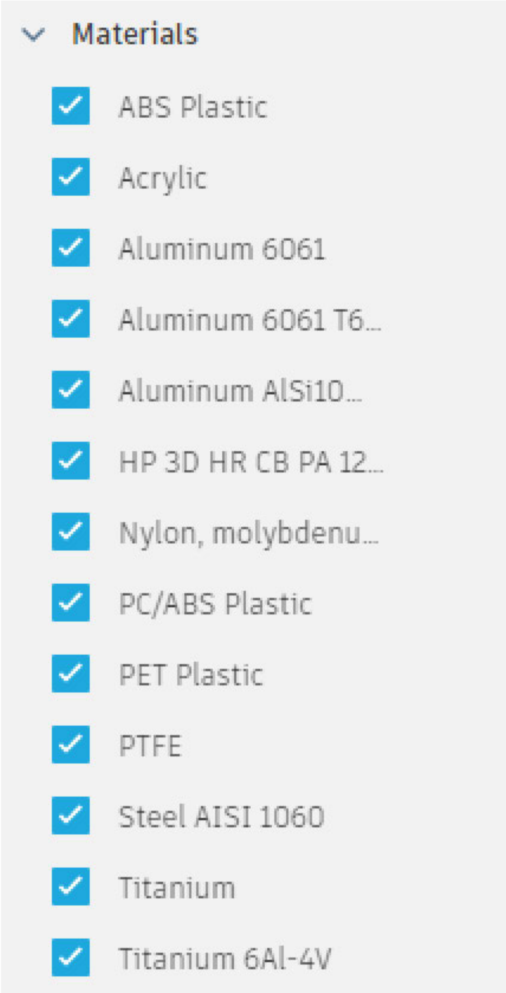


Figure 14; Materials selected for 3D printing

Changing the direction of print also changed the number of design outcomes. The initial variations of the design were done using x+ as the print direction. This often did not give good results, when changed to y+ and y- the results significantly improved. Adding this second direction also increase the number of results for 15 to 26 giving a better general idea of what was happening. The materials and manufacturing of the outcome are explored more in Chapter 5 – Materials and Manufacturing of this research paper.

4.2.7 Outcome Evaluation

4.2.7.1 Initial Outcomes

To reach a viable outcome, many iterations of the process is performed. These were often time-consuming averaging 4 hours per run time. The first visually pleasing design is shown in Figure 15 and Figure 16, although a nice design if fails to meet all the criteria of a chassis. There is not symmetry, and some potions are either too thin or too thick, this to lead to failure in service. Other issues were identified later, possible collisions with components that were not incorporated into the initial model, the steering clearance for example.

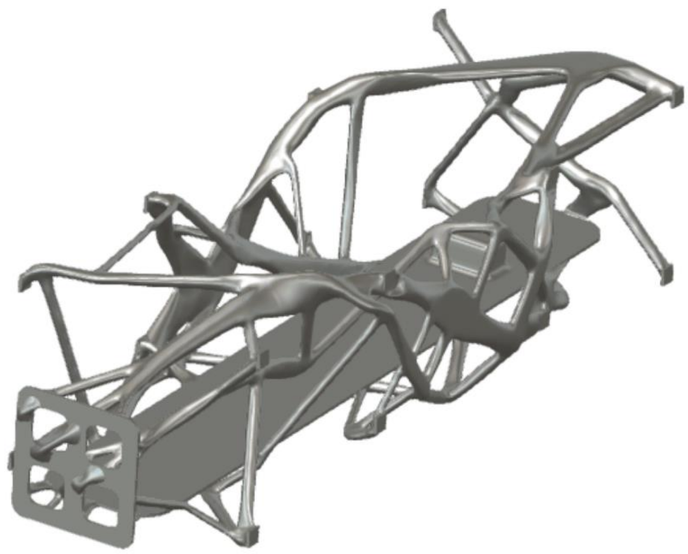


Figure 15; Isometric View, Aluminium AISi10Mg, 3D print

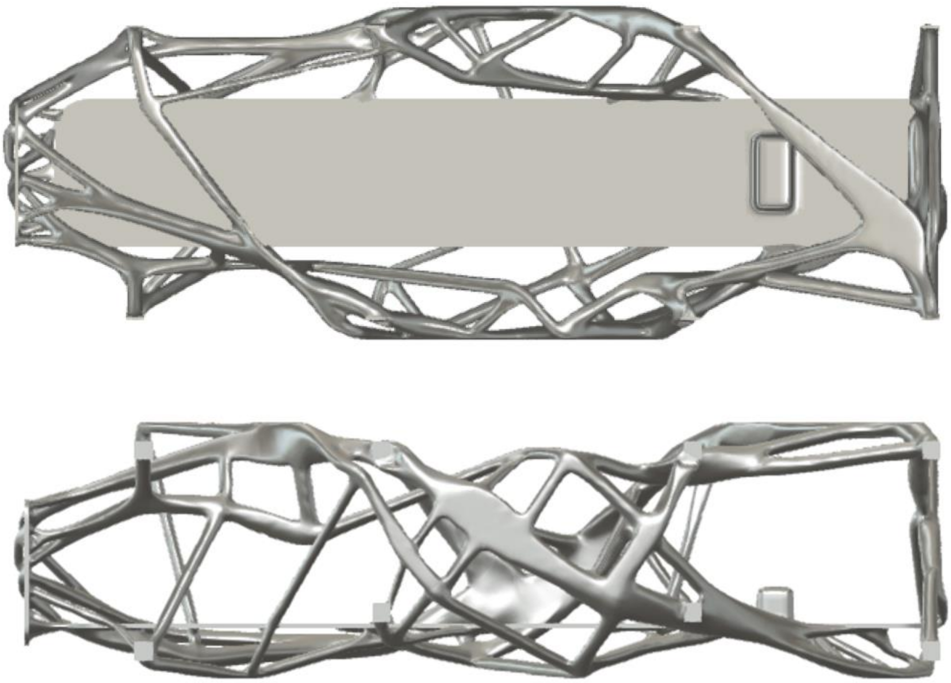


Figure 16; Top & Side View, Aluminium AISi10Mg, 3D print

The Design was reworked adding some more forces. The addition of forces was to balance the conditions put onto the chassis, once complete the final model can be analysed using FEA to validate its performance under more a-symmetrical conditions. Figure 17 through Figure 20 shows version 7 iteration of a titanium 3d printed chasses. This chassis is closer to symmetrical (not completely) and shows some promise. Inspecting this chassis its visible that the front and rear bumpers are slightly not supported correctly. This satisfies the conditions of the GD but once FEA would fail.

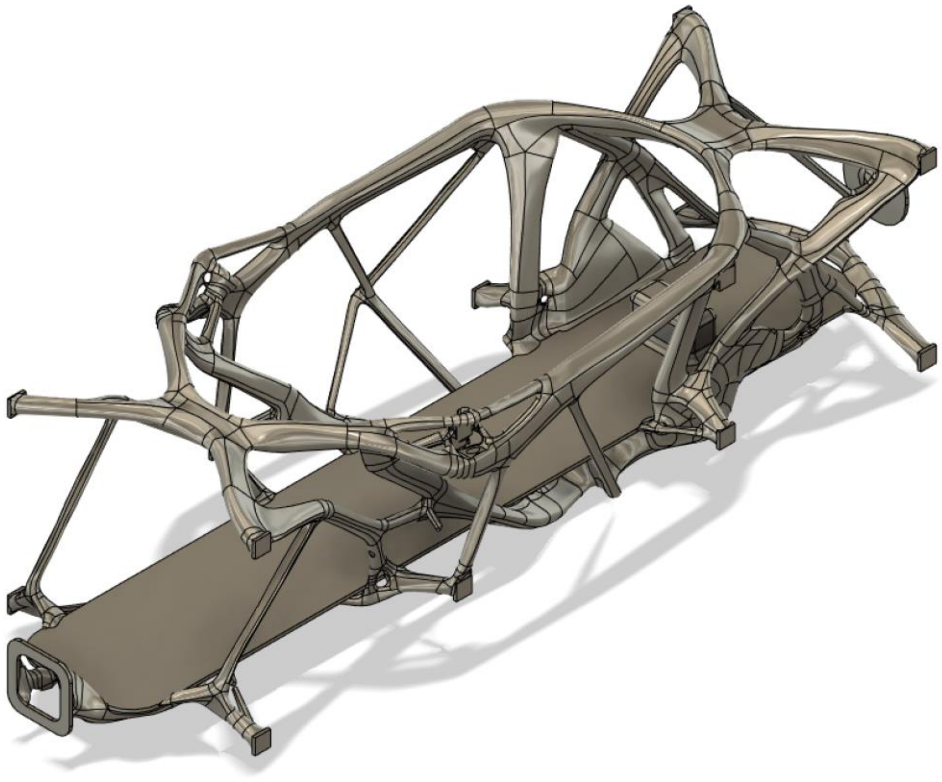


Figure 17; Isometric View, Titanium, 3D print

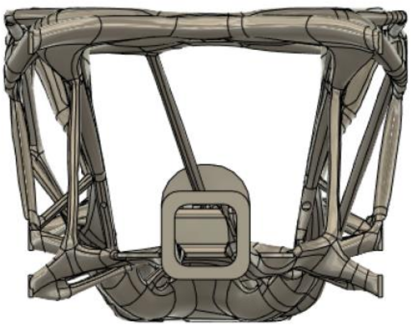


Figure 18; Front View, Titanium, 3D print

The front Figure 18 view reveals a nice, closed cross-section of the design. It has one bar running on a slight angle towards the rear, further iterations will try to limit these types of members.

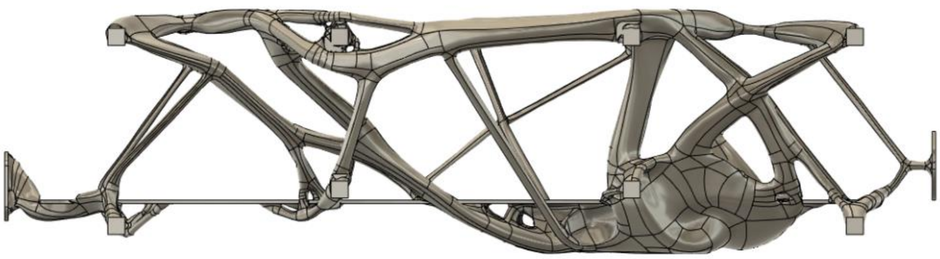


Figure 19; Right Side View, Titanium, 3D print

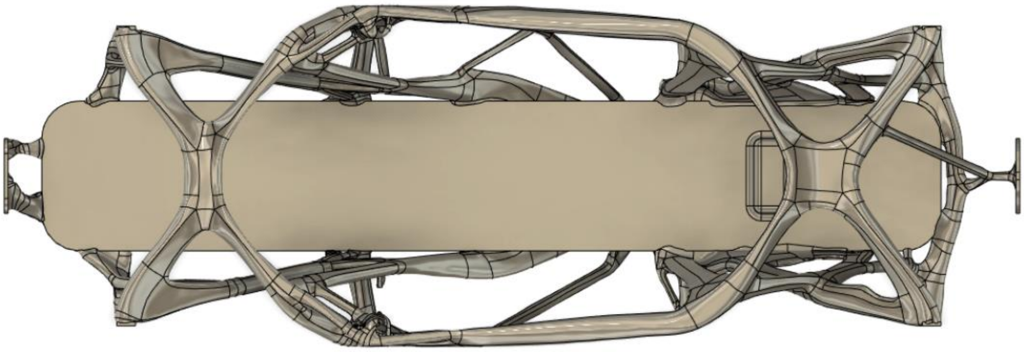


Figure 20; Top View, Titanium, 3D print

The top-down view in Figure 20 presents a nice structure with sold flooring and fixing structure. The rear bumper is less supported than the front, this would fail any further testing.

4.2.7.2 Final Outcome Evaluations

The 8th iteration bore significantly better options, shown in Figure 21 are the perceived top four options of this simulation. The defining difference between them is the materials used to construct them outcome 3 shown in the bottom left is ABS plastic, whereas the other three are non-ferrous metals. It is also important to note that outcome 5 (top right) is 34.5 Kg while outcome 3 is only 13 Kg. A significant reduction in weight for each design while both satisfy the problem posed to the GD in the initial design of this iteration.

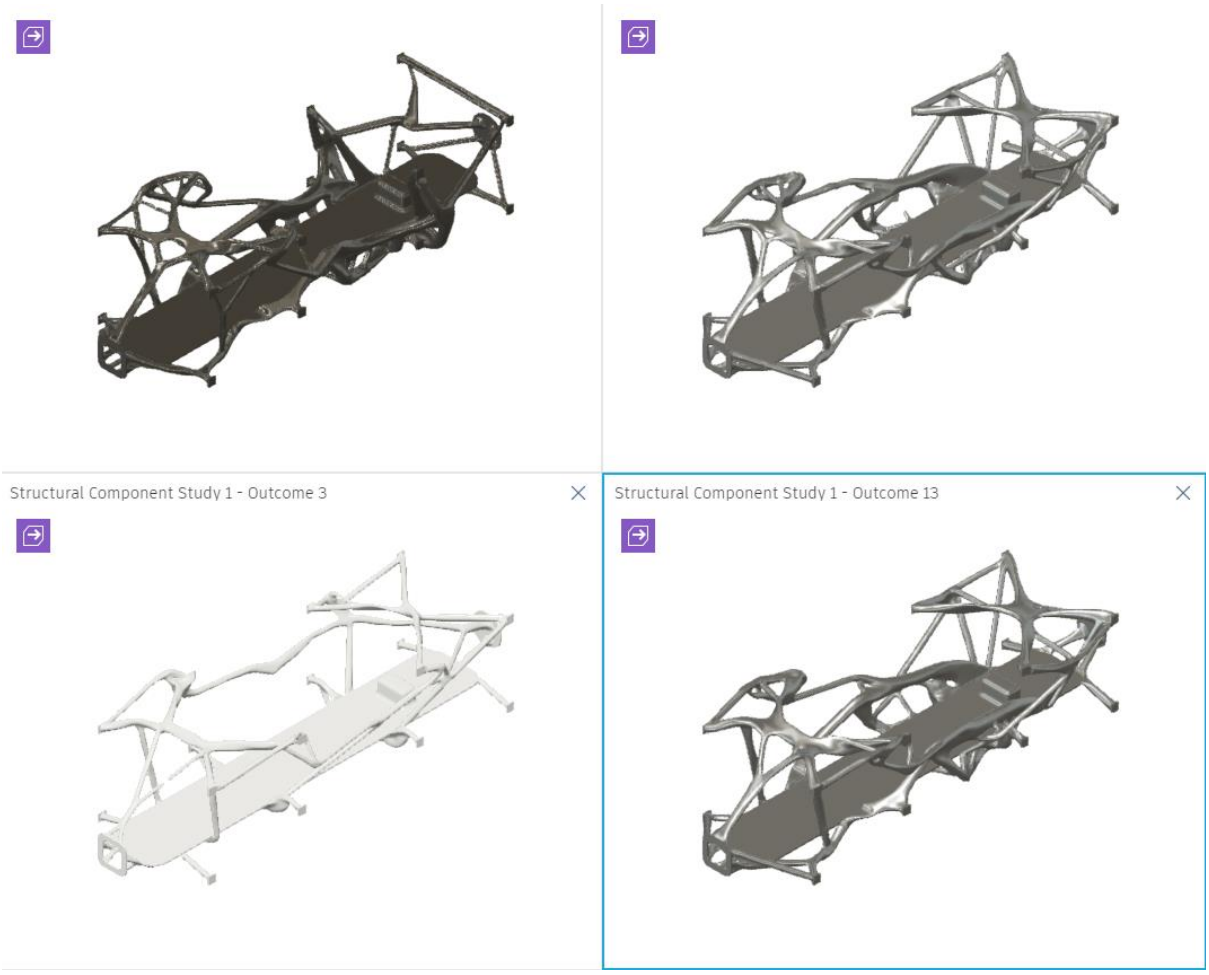


Figure 21; Four different designs for different materials.

From inspection Outcome 13 was selected for further analysis. Figure 22 to Figure 25 presents the design as a visually appealing chassis solution to the problem.

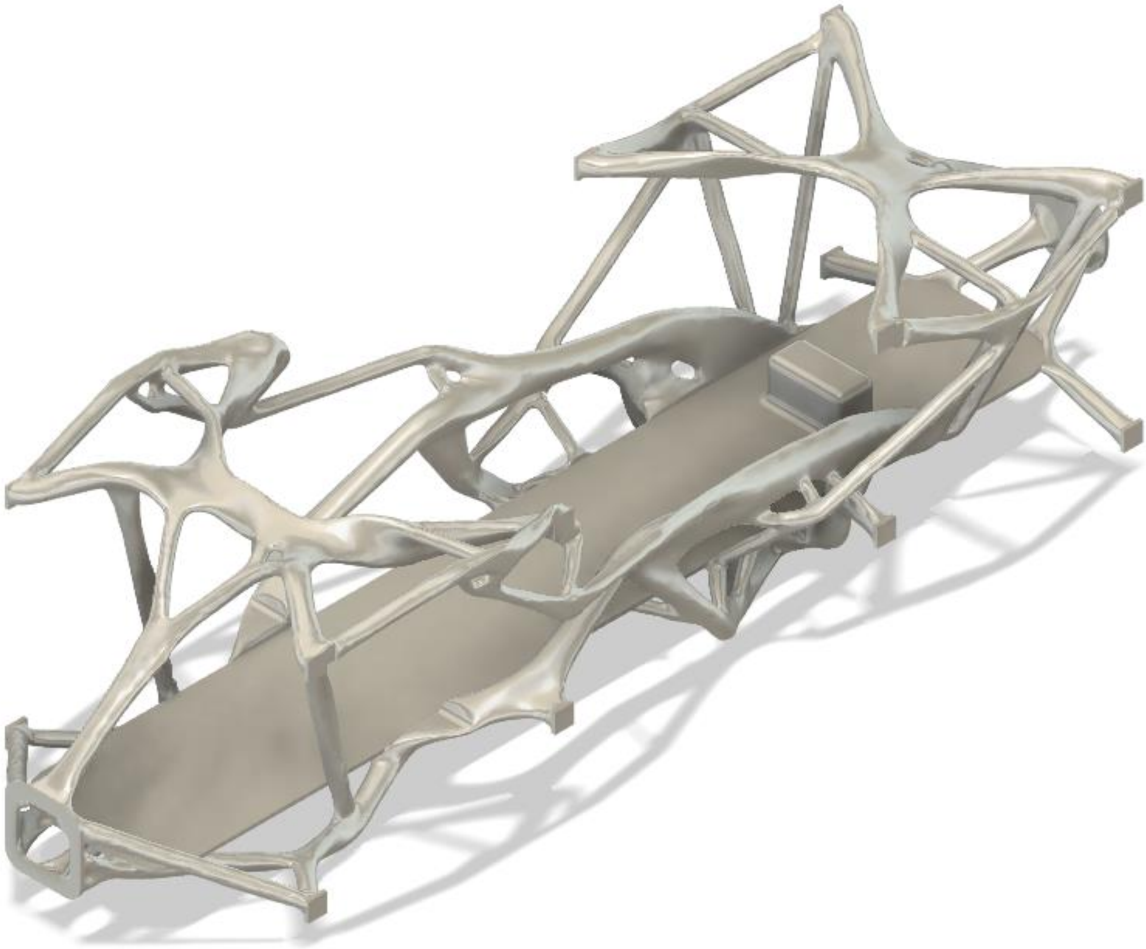


Figure 22; Isometric View, V8 outcome 13

Figure 22 shows the isometric view of the design from this angle it’s hard to see any asymmetric geometry. There is also a concern that the rear lower suspension mount is not braced by other members. This would need to be validated later in the design analysis.

Figure 23; Front View, V8 Outcome 13

Figure 23 presents the front view of the design, it has a tight overall geometric shape. The symmetry of the chassis from inspection looks good from this angle.

Figure 24; Right Side View, V8 Outcome 13

Figure 24 presents the right-side view of the design. From inspection of this design, it is clear that the flowing of members from the front of the chassis to the rear impact block. These members are thicker than the other members and is part of the main structure. The design is reasonably symmetric although some members are missing from the near side that are present on the far side.

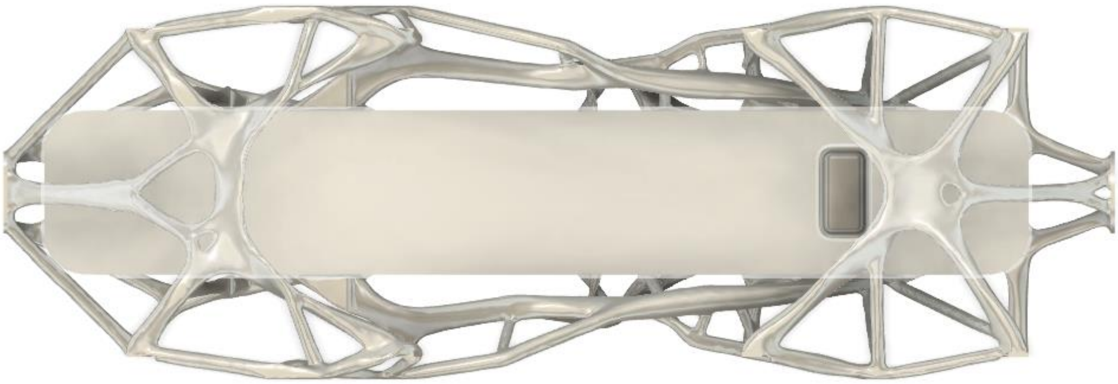


Figure 25; Top View, V8 Outcome 13

The top-down view shown in Figure 25 shows a nice flow shape of the chassis design. Although this is not a symmetric design from inspection alone. A quick analysis of the centre of mass Figure 26 and Figure 27 presents the centre of mass on the centre plane from the top view. From Figure 27 the centre of mass is slightly higher than expected, this is not a problem from a static analysis perspective but for vehicle handling lowering the centre of mass would be an advantage.

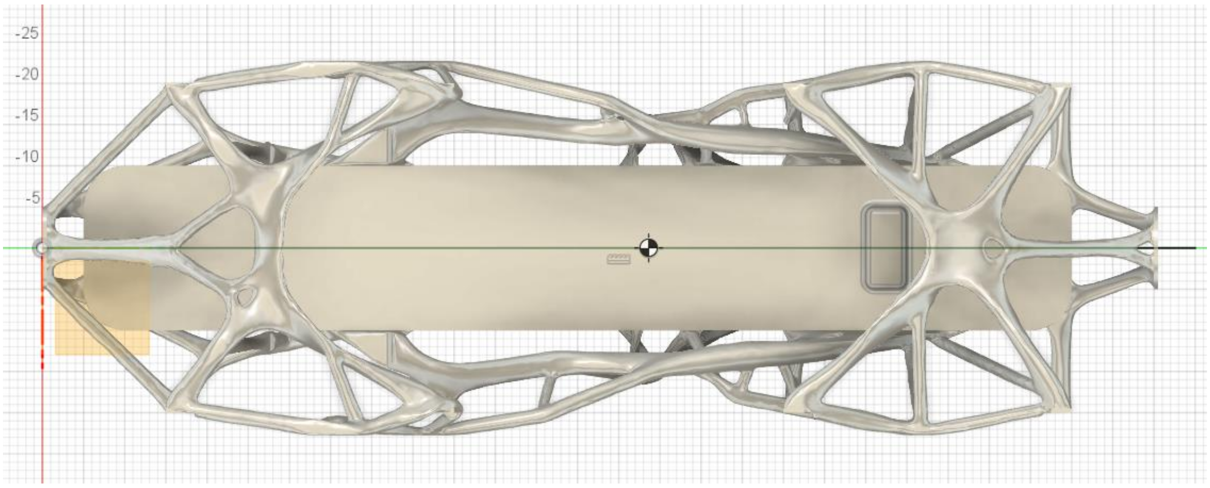


Figure 26; Top View, V8 Outcome 13, COM

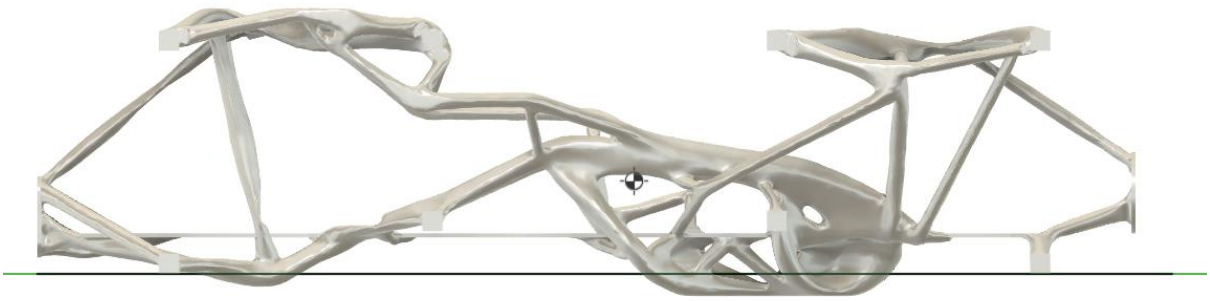


Figure 27; Right Side View, V8 Outcome 13, COM

Once the iterations were run several more times, an adiquite solution was found. In Figure 28 the final four designs are presented. Of these, two were chosen due to the major differences in design. The ones that were eleimated had mesh flaws and other had too heavy.

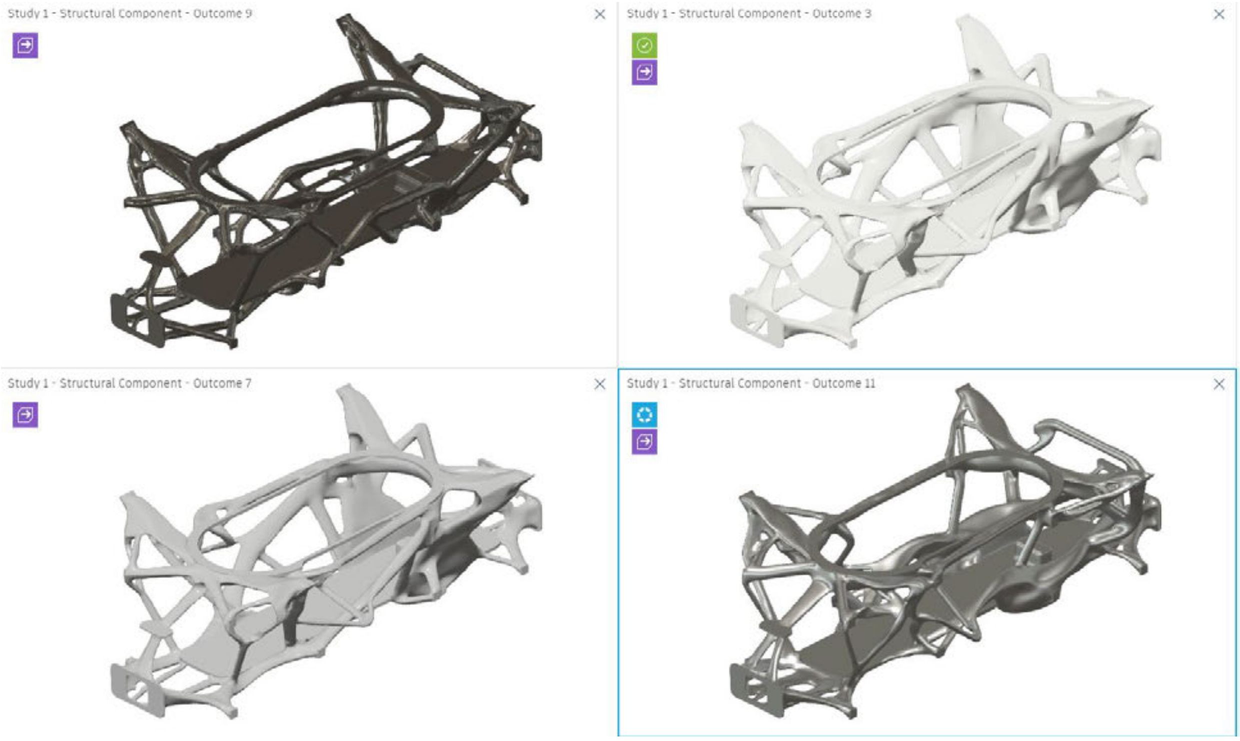


Figure 28; Comparison of final four designs.

The second-best outcome was Outcome 11. It has good structural completeness with no unfinished members. The front section was the most interesting it has arms that protrude from the from suspension mounts Figure 29 shows the top view where this is visible. From the side the model presented rather well with nice flowing structural bodies. This is what was expected from this final simulation. In Figure 30 the lower bodies show how the stress would flow through the lower section of the frame. It is interesting to note that the top rear most suspension mount has little forwards or rearwards support unlike all the others. Another downside to this design is the materials and manufacturing. It requires Aluminium 6061 and high-grade aluminium that is to be unrestricted in the manufacturing. This makes the model extremely expensive to manufacture. The weight of this design is significantly higher than the chosen optimal outcome 3. The details of both outcomes can be seen in Figure 31, It should also be mentioned that the factor of safety of this design is 79 that is far greater than the required 2 specified in the problem.

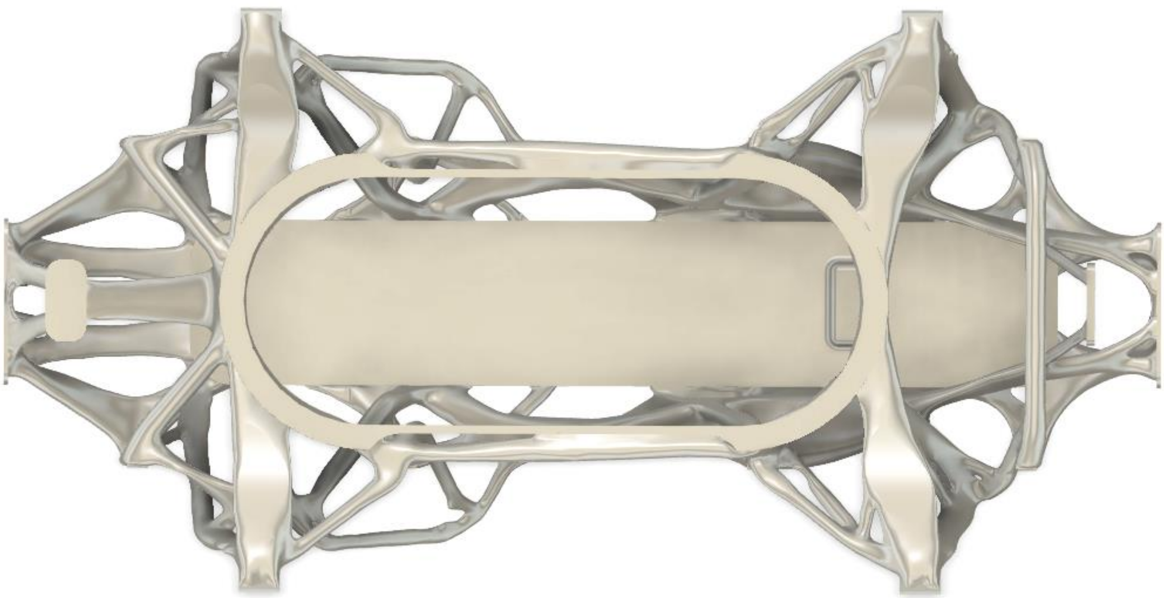


Figure 29; Top view V29 Outcome 11

Figure 30; Side view V29 Outcome 11

Study 1 - Structur... - Outcome 3
Iteration 45 (final)

Study 1 - Structu... - Outcome 11
Iteration 46 (final)

Properties	Outcome 3	Outcome 11
Status	Completed	Completed
Generative model	Generative Model 1	Generative Model 1
Material	ABS Plastic	Aluminum 6061 T6 0 Cold Formed
Orientation	Y+	-
Manufacturing method	Additive	Unrestricted
Visual similarity	Group 1	Group 2
Production volume (pcs.)	-	-
Piece part cost		
Range (USD)	-	-
Median (USD)	-	-
Fully burdened cost		
Range (USD)	-	-
Median (USD)	-	-
Volume (mm^3)	2.154e+7	1.944e+7
Mass (kg)	22.831	52.501
Max von Mises stress (MPa)	7.552	4.661
Factor of safety limit	2	2
Min factor of safety	2.648	79.163
Max displacement global (mm)	7.169	0.16

Figure 31; Outcome 3,11 Details

Although this design would satisfy the design problem the final design chosen was Outcome 3. This design is defined by its material and manufacturing method, being ABS plastic, printed in the Y positive direction (front to back). To assist the decision making a side by side comparison of the two designs is shown in Figure 31. In Figure 32 the side view of the final iteration can be inspected. It has nice flow from the bottom front section to the top rear, up the rear suspension hanger. This flowing member will help with the torsional stiffness of the chassis.

Figure 32; Side View V29 Outcome 3

The top-down view shown in Figure 33, shows the footprint of the chassis. It has similar thickening bodies along the ‘belly’ of the chassis. The size and shape of these sections are critical to its ability to withstand side impacts. They also add to the structural rigidity of the design, like the forward bracing. In Figure 32 and Figure 33 the front bumper mount is braced by a solid structure that extends back to the main floor body. This structure will protect the design from track spray and debris, as well as incorporating the bottom front suspension mount.

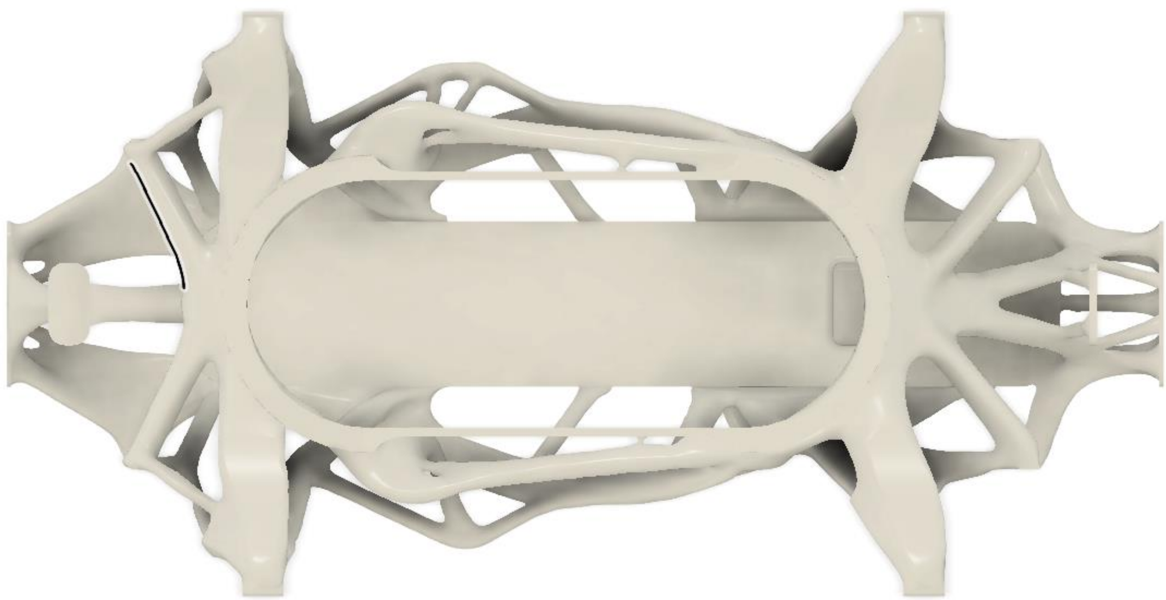


Figure 33; Top View V29 Outcome 3

The front view of the design shown in Figure 34 shows the thickness of this member and its smooth transiting. It also shows the belly members protruding from the sides of the chassis.

Figure 34; Front View V29 Outcome 3

Figure 35; Isometric View V29 Outcome 3

The overall chassis design shown in Figure 35 presents well. From visual inspection there is a few areas which need improvement. Where the main floor of the structure meets any vertical connecting members there is a sharp almost 90˚ angle, this will prove to be a stress concentration. Removing it will require the addition of a fillet to smooth the transition. Additionally, where the halo meets the upper side member there is a thin connecting member. Removing this will allow an increase in flexibility of the halo without the roof structure, but with it will not add anything to the combination of the structures. It also becomes a stress concentration during simulation moving attention from possible critical areas of the design.

4.2.8 Analysis

To validate the design a separate FEA analysis was conducted. Using the same load conditions from the GD, the design outcomes could be analysed. Figure 36 shows the displace to be a maximum of 0.1325 mm at the front impact zone. This very minimum considering the force that was applied at that point. Although this load case is used it would be highly unlikely that these loads will be applied to the chassis simultaneously.

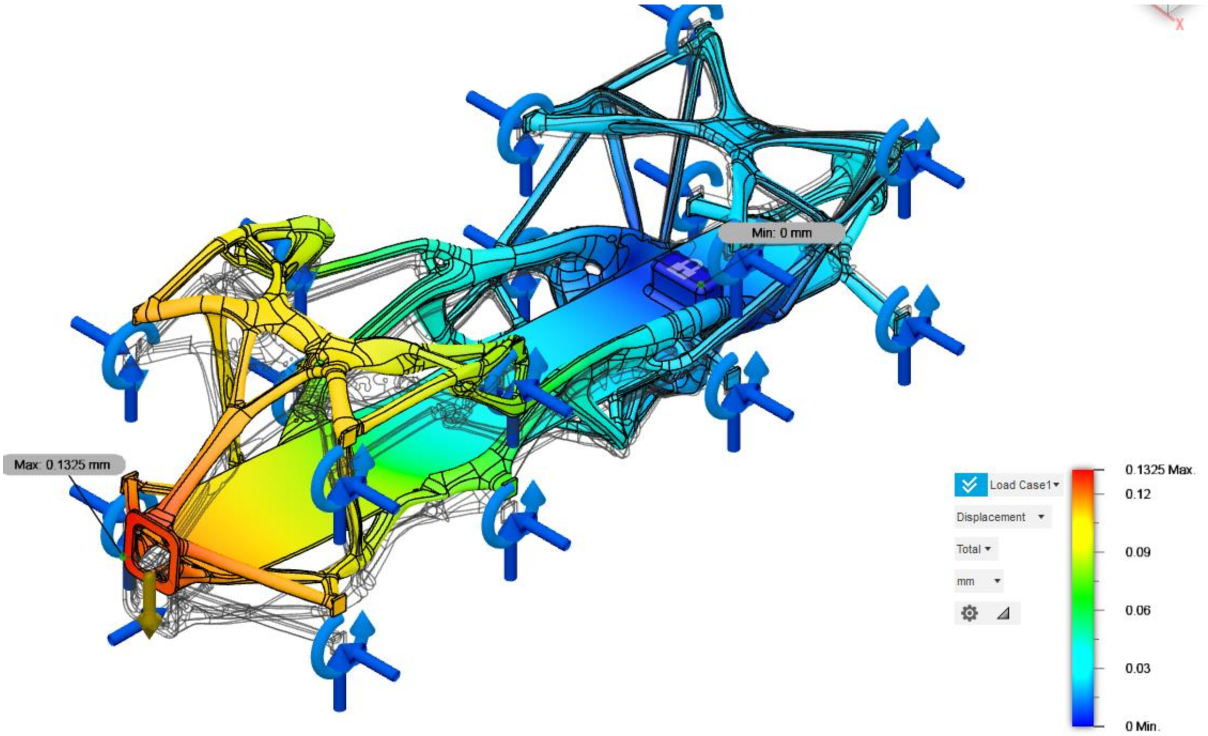


Figure 36; Displacement Plot, V8 Outcome 13

The Von Mises stress plot shown in Figure 37 shows that the maximum stress experienced under these load conditions is 4.998 MPa, very low compared to the design strength of the material.

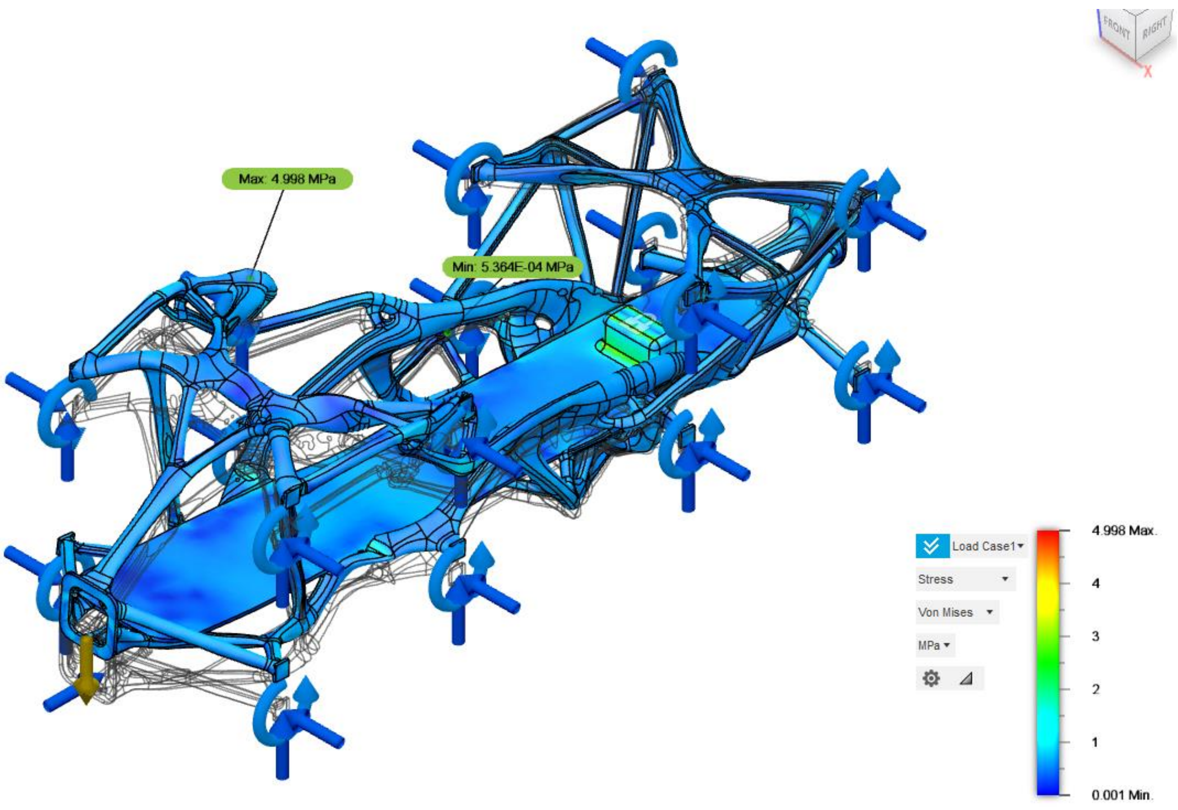


Figure 37; Stress Plot, V8 Outcome 13

The FEA analysis of the V29 chassis was conducted under four load cases. These were assessed as the most likely situations for the chassis to be in. The first being the load case that the GD was run under, using a second simulation to assess how much displacement and stress' the chassis is under during service is critical to is acceptance as a valid design. Using the Von Mises stress plot and Displacement plot as the two assessment conditions. Analysis of these plots were as follows.

4.2.8.1 Generative Design Case

The initial load case that the generative design was run under presents some interesting plots. The Von Mises stress plot presented in Figure 38 are low with a max of 11.06 MPa in the fixed block, this force is reaction force and could be considered irrelevant. This is because it would be highly unlikely that the chassis will wall from 1m onto one corner and impact a barrier straight on simultaneously. It is interesting to note that the remained of the structure is in the range of 0 – 2.5 MPa an exceptionally low stress value.

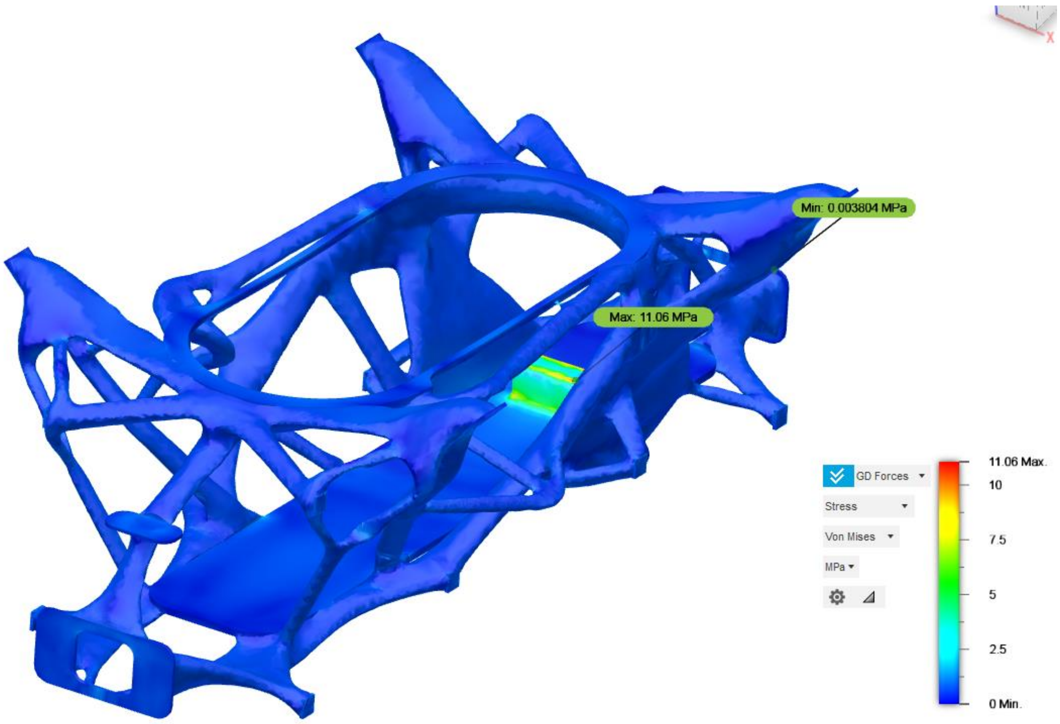


Figure 38; Von Mises stress Plot

The displacement for this case load is higher than expected. Figure 39 shows the displacement plot of V29 chassis, 6.3 mm is higher than the original simulations shown in Figure 36. Although this would be more likely to occur in a real-life situation, the 6.3 mm is not too much to damage the ABS structure in a permanent way.

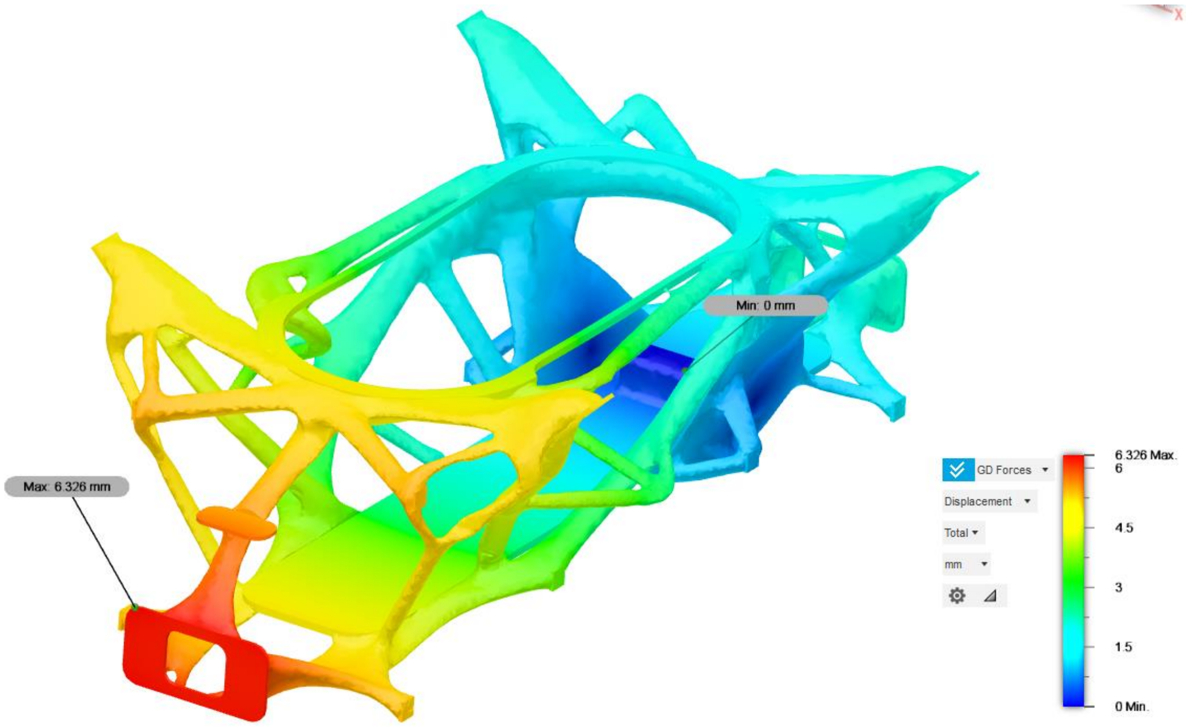


Figure 39; Displacement Plot

4.2.8.2 Torsional Case

The Torsional case was conducted to test the torsional rigidity of V29 chassis. locking down the from suspension points and applying force to the rear suspension points applies twisting stresses to the frame. The resulting stresses appeared to be extreme, although on more in-depth inspection it can be disregarded as a stress concentration in the locked surface. At the rear of the structure in Figure 40 a minimum stress of 3.68 MPa is present, a low figure that would be expected from this structure. The rest of the design is in the region of 0-10 MPa so minimum stress is applied under this load case.

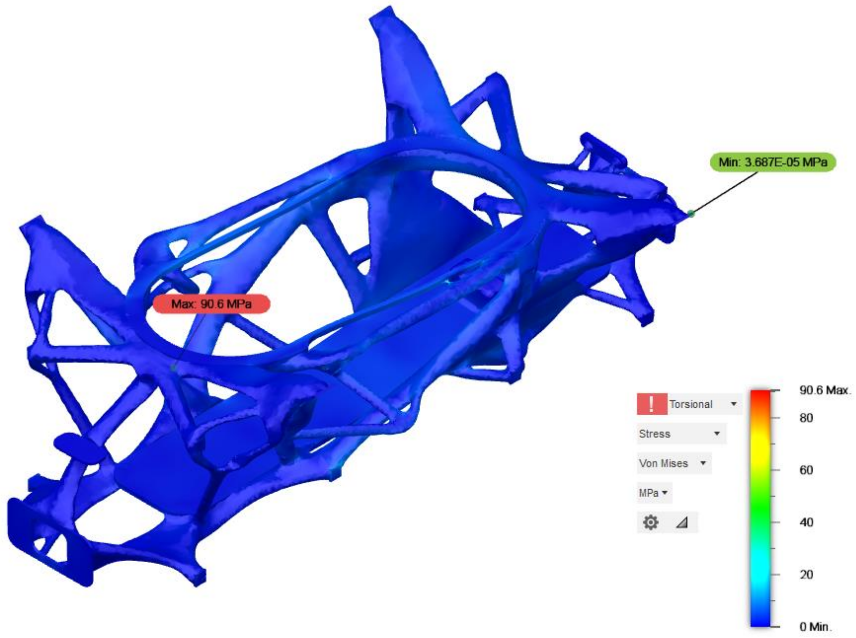


Figure 40; Von Mises stress Plot

A displacement of 4.28 mm shown in Figure 41 is a little more concerning. This load case can be cyclic in nature, as the vehicle turns at speed chassis are known to flex. Transitioning into dynamic loading studies is outside the scope and will not be further examined.

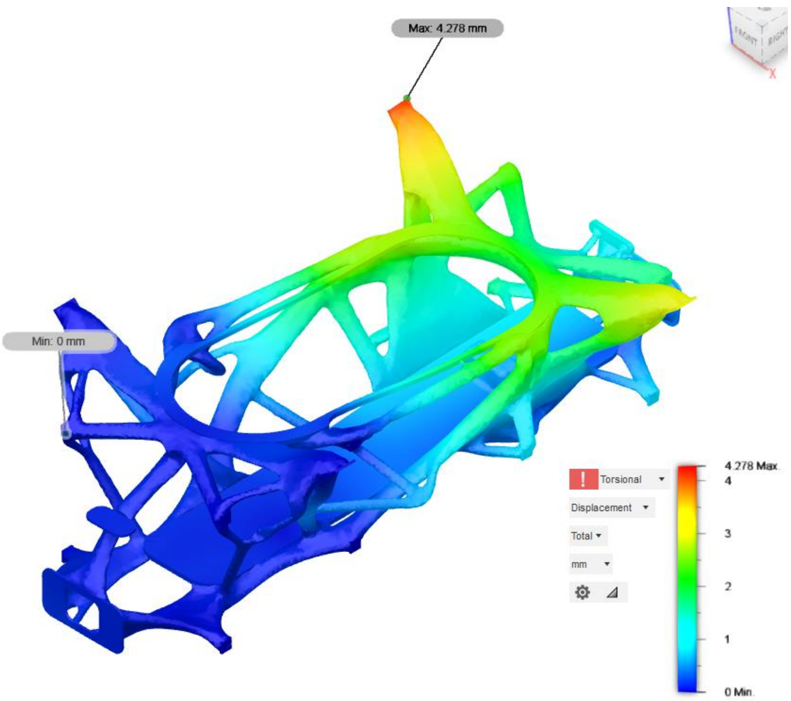


Figure 41; Displacement Plot

4.2.8.3 Front Impact Case

The front impact case presents some valid data on the design. Applying forces 2x that of which the design was initially subjected too. The Von Mises plot in Figure 42 shows that even under extreme conditions the maximum stress is 7.304 MPa. This is present in the rear of the frame where the frame was constrained with an all DOF lock. It was interesting to see that the force flowed along the bottom structure as well across the top. Some member joins are slightly lighter colour indicating that the stress is in these areas.

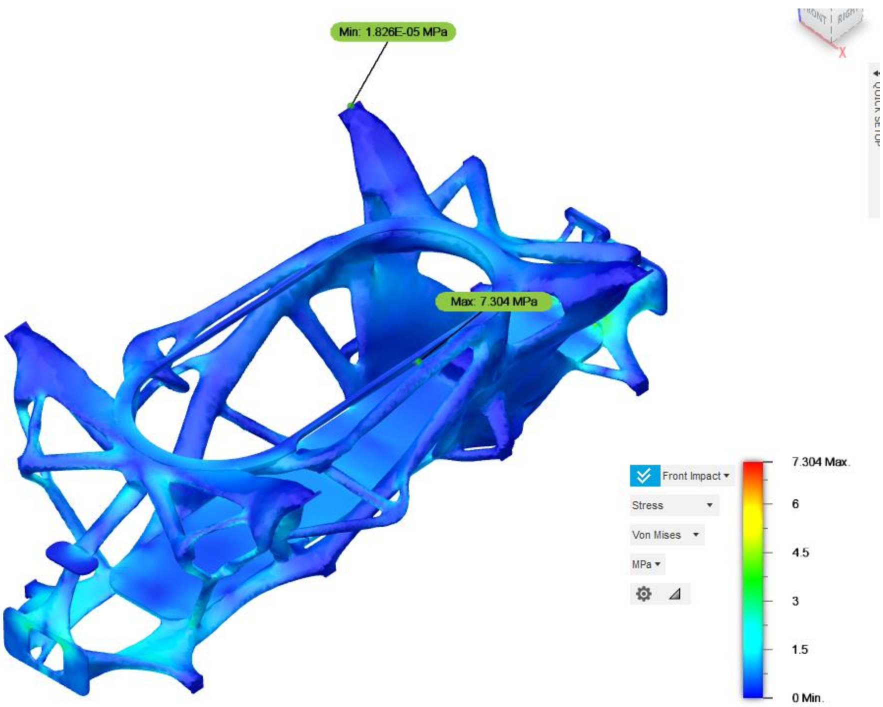


Figure 42; Von Mises stress Plot

The displacement is high for this case load. The displacement plot in Figure 43 shows the maximum displacement of 9 mm at the front section of the chassis. This is where the force was applied, although expected it can be contributed to materials. The displacement is gradual along the body from rear to front, meaning that the material is not deforming it is compressing. It is unlikely that the structure would deform, meaning that the entire body will absorb the impact. Naturally further studies should be conducted to verify the dynamic loading of this case, but that is outside the scope of this project.

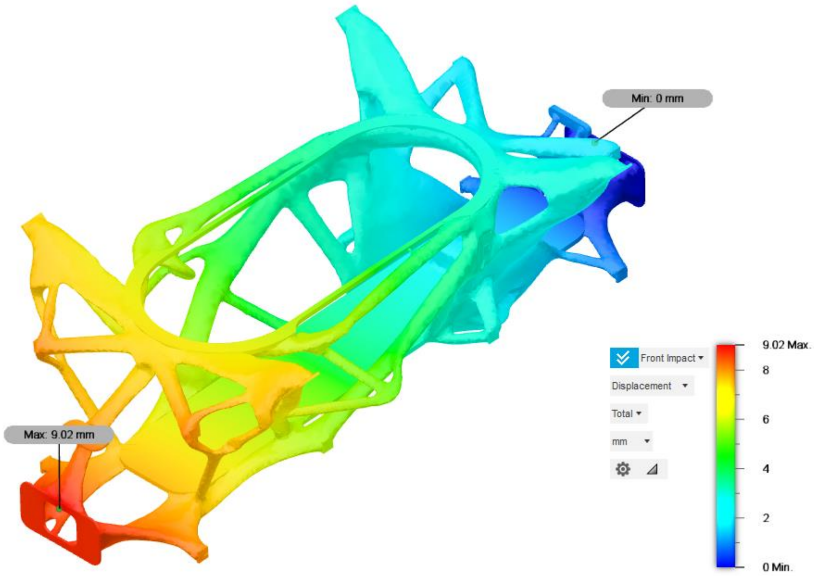


Figure 43; Displacement Plot

4.2.8.4 Side Impact Case

The side impact study was conducted as part of the specification by FSAE. A chassis should be impact resistant from a side impact, to conduct this study the impact force from the forward case was applied to the side structures of the body. The Von Mises plot shown in Figure 44 shows the resulting stress in the chassis. A maximum of 16.7 MPa was identified at the bottom of the design. This was identified as a stress concentration of a sharp corner easily removed by the addition of a radius to that area of the design. The remainder of the design showed limited amount of stress in the range of 0 - 3.4 MPa a safe area for the design material.

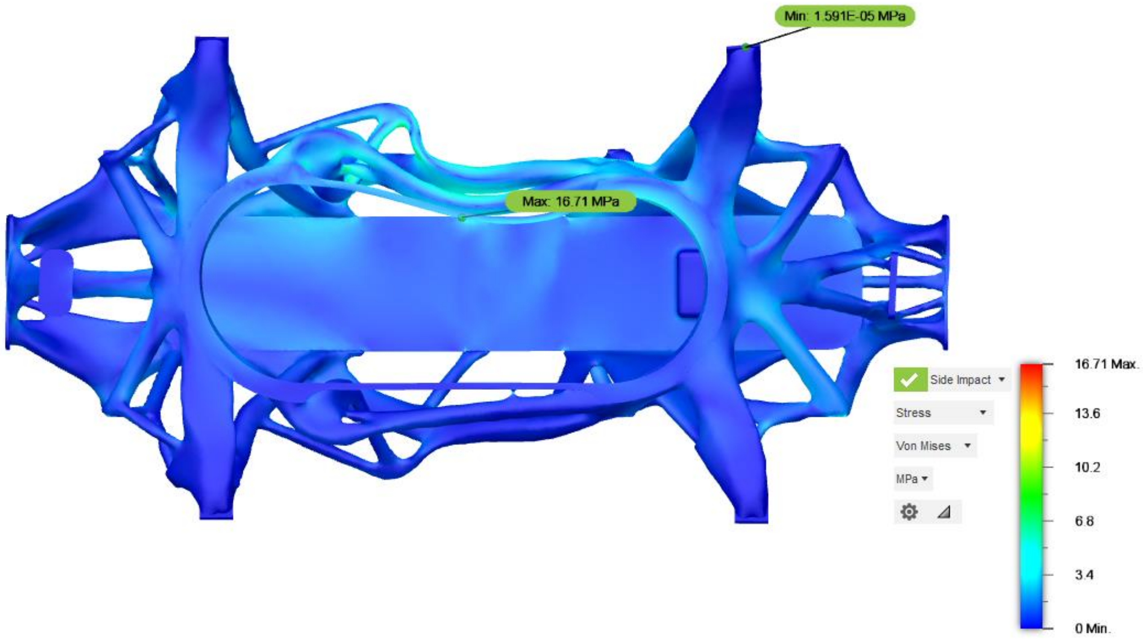


Figure 44; Von Mises Plot

The displacement of the side impact is shown in Figure 45 it shows how the upper and lower members deform. The displacement is measured at 2.1 mm this is significantly lower than expected. Although this analysis is not a true representation of what the chassis will do under this condition. A multi-interactions study would need to be conducted; this type of study is performed using advanced simulation software that is outside the capacity of this project.

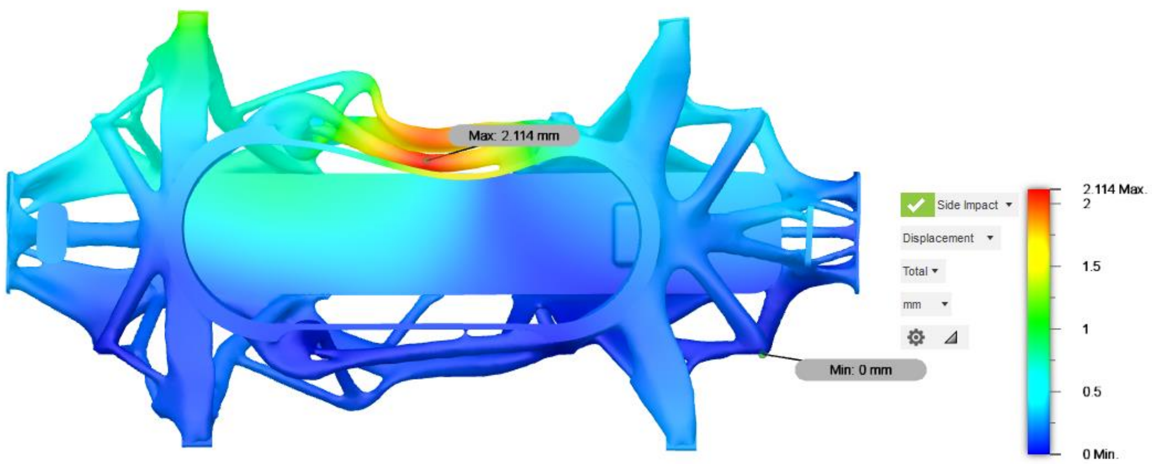


Figure 45; Displacement Plot

4.2.9 Conclusion

To conclude the Generative design process and evaluation is adequate for the design of a vehicle chassis. Although work was conducted around the validation of the chassis using four main load cases it is possible to do much more in this area. The inclusion of more final components and load condition evaluation will aid in this process. The design outcomes can be refined as more details are included in the specification and many more simulations run to analyse the performance of the vehicle. Using generative design is slightly less time consuming then traditional design processes it simply moves the design time to analysis time. Although similar timeframes are taken the design outcomes are far superior to those of traditional manual design. The organic structures produced by GD are visually pleasing and will become more prevalent in the future.

4.3 Topology Optimisation

4.3.1 Introduction

Topology Optimisation (TO) is a more controllable way of getting an organic chassis design. Using a stable platform like Creo could theoretically produce good results to solve the problem. The methodology proposed in this chapter has been assembled to theoretically assess if the TO and PTC Creo would be a viable option for this project. Although this software is proposed to be used from the beginning, limitations have restricted its use and anything presented in this chapter is for theoretical evaluation only and is yet to be tested.

4.3.2 Process

The process of Topology Optimisation is more basic than that of Generative design. It requires an initial geometry which is to be optimised. The simplification comes from removing obstacle geometries, if the external surface is already a preserve geometry, then it will stay that way. The control over the outcome is also a nice feature of this process. In Figure 46 the flow chart of the process it can be seen that the loop is simplified, and less iteration is need. There is also only one outcome, so no time is needed to evaluate many differing design outcomes. The outcome can easily be modified if the designer requires it later. This process has been adapted from the tutorial by Ian Boulton of the optimisation of a bracket for an aircraft.

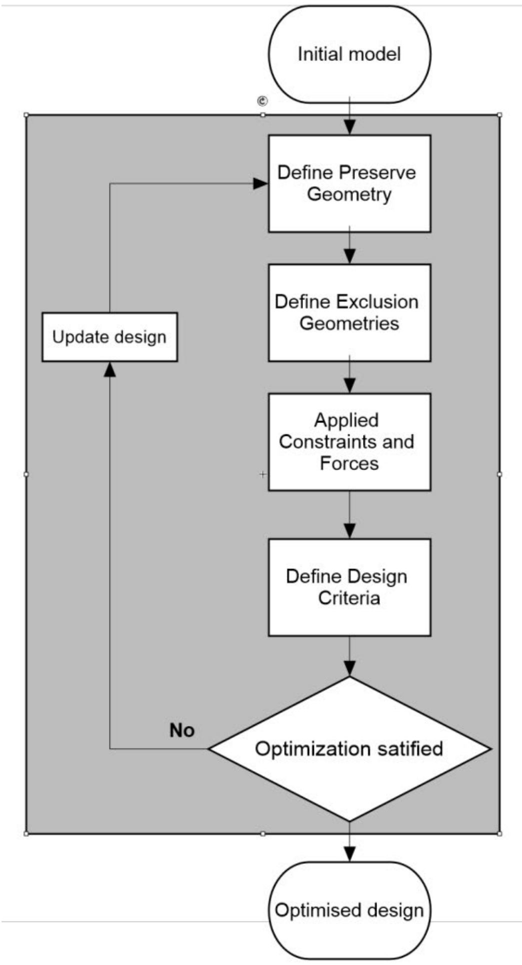


Figure 46; Proposed Process Flow Chart

4.3.3 Specification

The specification for the project is the same as that which is presented in 4.2.4 Specification. Using the same specification makes the comparison between the two technologies equal. As more information about the final project becomes available it can be added to the section. The using Creo being a professional software package allows for modifications without having to completely resolve the simulation. A great advantage of TO used in Creo is that the initial design can have a weight applied to it. In the case that the design needed to be 25% lighter then that can easily be added as a design criterion and designed for this constraint.

4.3.4 Initial Model

The initial model for TO is less complex than that required for generative design. A solid body the entire size that is required, or an initial design. This design is typically an old design that has been previously analysis with known specification. The tutorial by Ian Boulton shows the process of optimising. Figure 47 shows the initial geometry of the bracket being optimised.

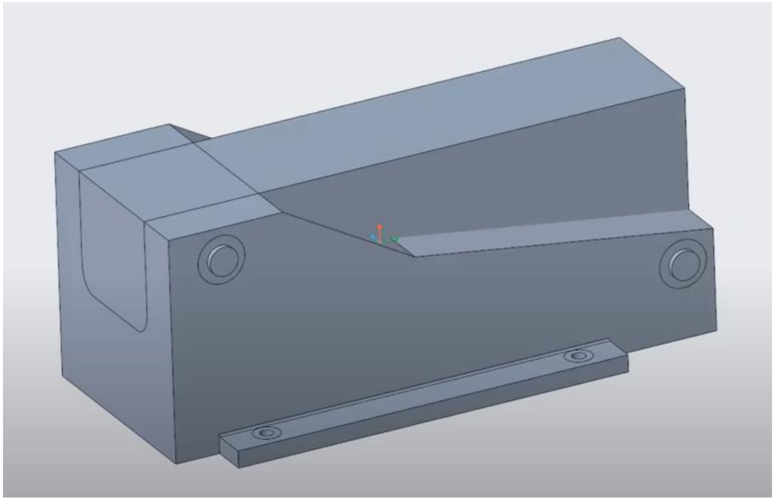


Figure 47; Tutorial Initial design (Boulton 2020).

Once the initial geometry is defined then preserve regions need to be defined. In the tutorial the bracket being optimised is shown by the clear area shown in Figure 48. This is an important step in the process, as it’s only this area which will be changed during the simulation step.

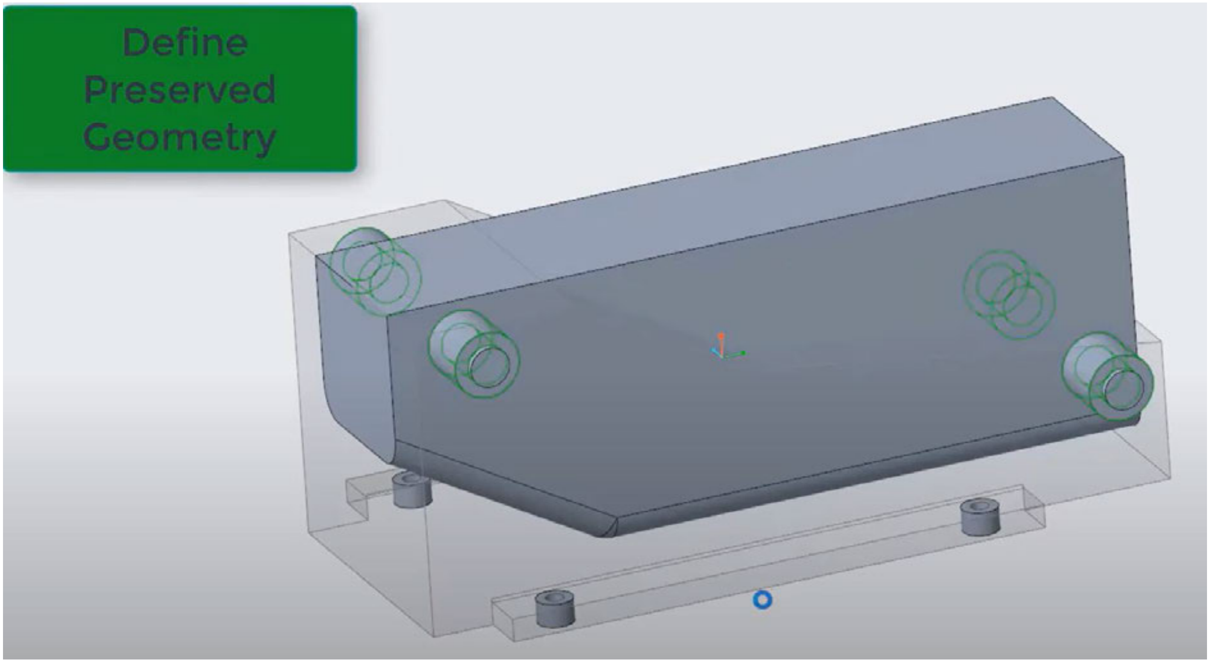


Figure 48; Define Preserve geometry (Boulton 2020)

The next step in the proposed methodology is to define the areas that are part of the final design. In Figure 49, the blue bodies are the preserve bodies that are where the pins/ bolts are placed. These bodies are similar the green bodies that are presented in Figure 12, these are the critical bodies to the integration into the final assembly of the component. In the situation of the chassis design the point where the sensors will mount, or the suspension mounting points.

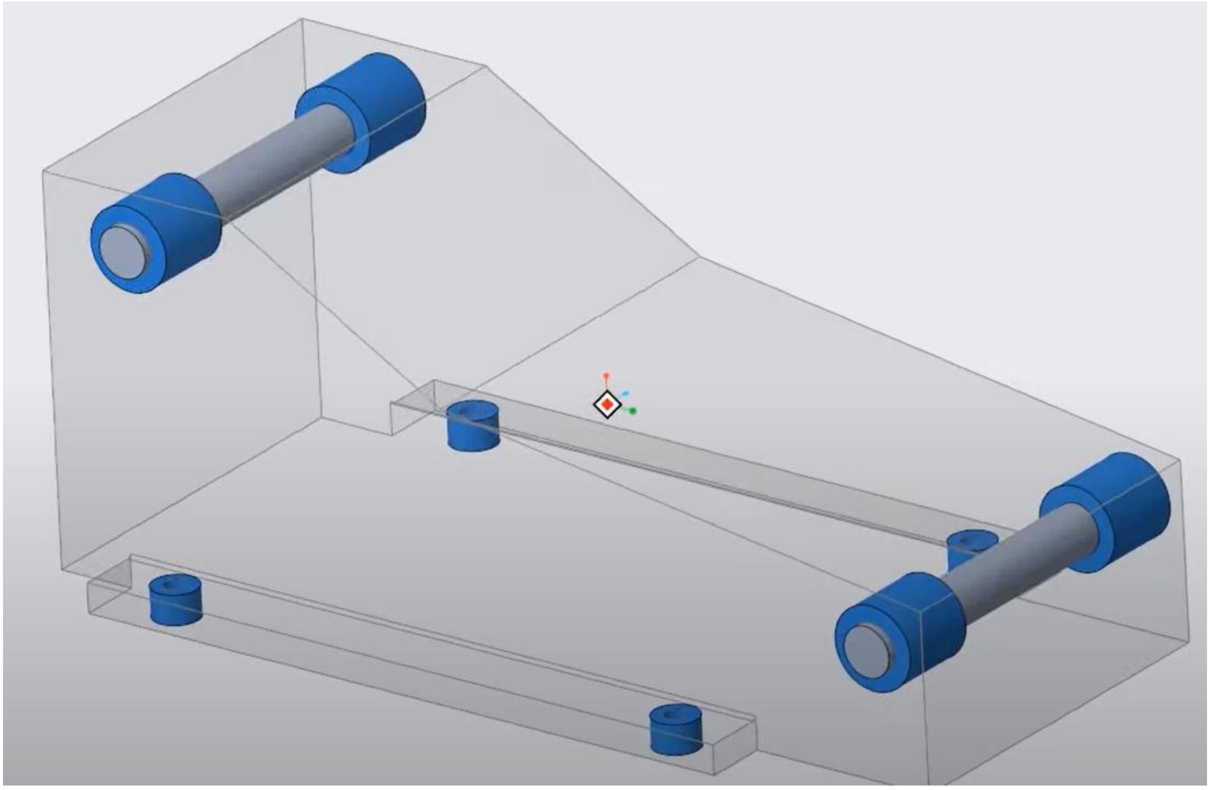


Figure 49; Preserve Geometries (Boulton 2020)

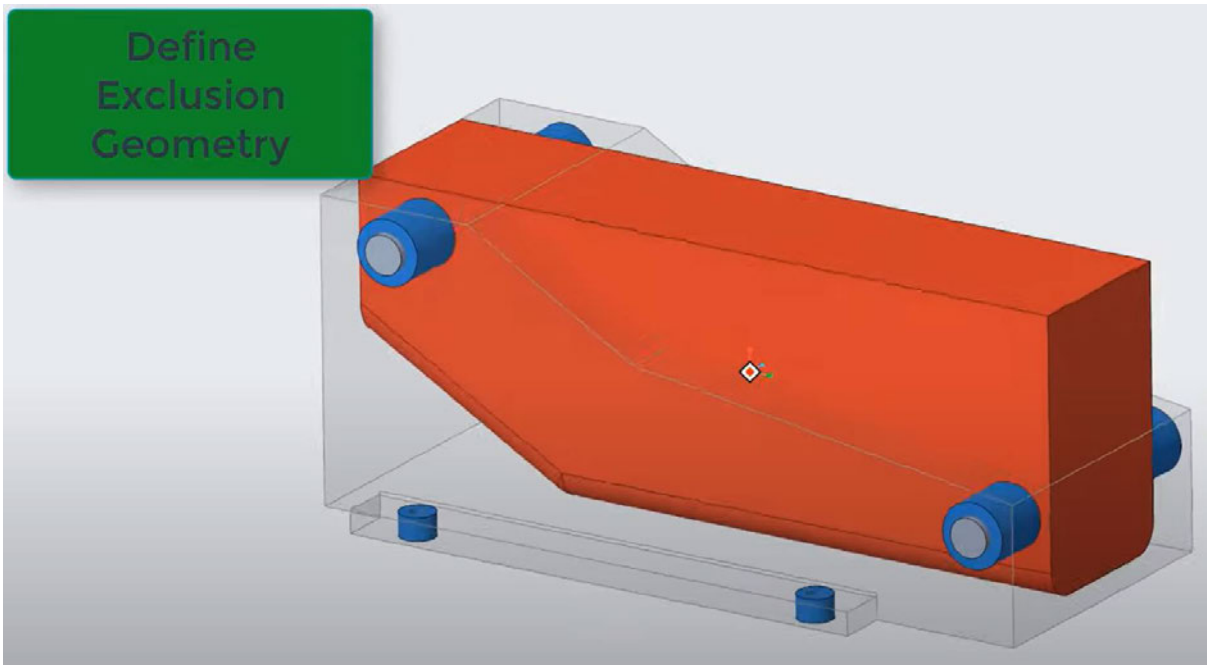


Figure 50; Exclusion Geometry(Boulton 2020)

Defining exclusion areas is similar to that of the GD process. Areas that the final geometry cannot protrude through. The orange body shown in Figure 50 details the body that is the exclusion zone in the tutorial. For the chassis design the areas in red shown in Figure 10 are the exclusion zones for this methodology.

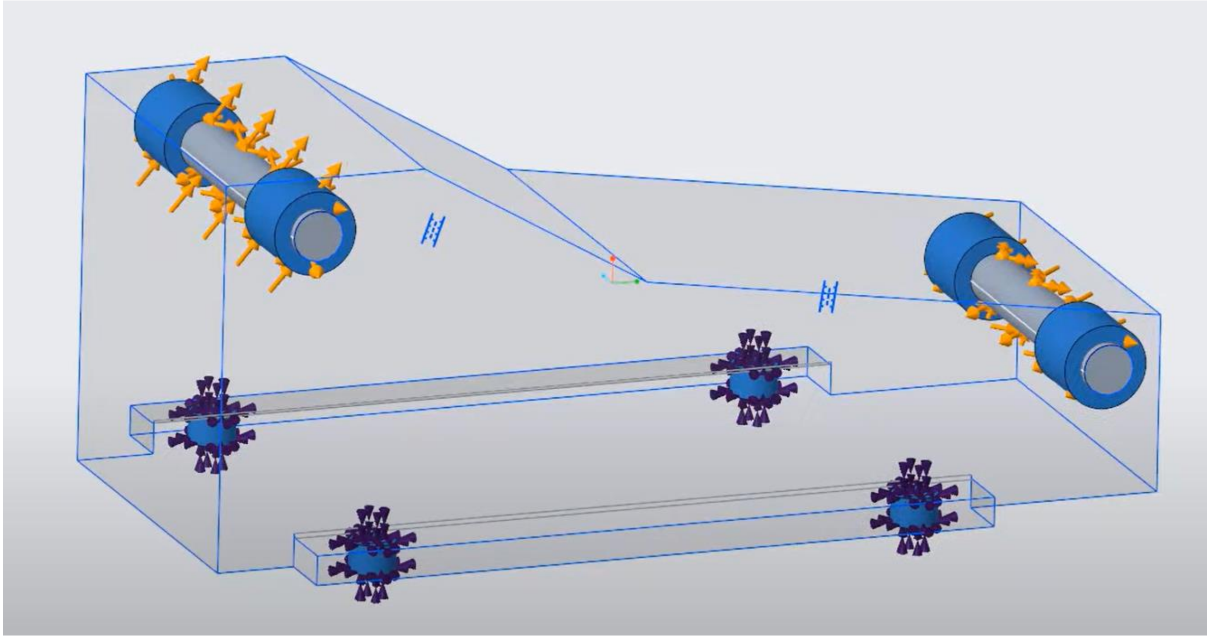


Figure 51; Define Constrains and External forces (Boulton 2020)

Defining constraints and forces, this can typically be done from a study or in the case of the bracket from pre-analysis of the component in service. The application of the forces to the mounting geometry is very standard across the software were running TO or FEA. In the instances of TO the contact surface is defined, as a pinned connection. In Figure 51 the forces are applied to the blue pin pockets. Whereas the fixtures are applied to the holes on the base of the bracket.

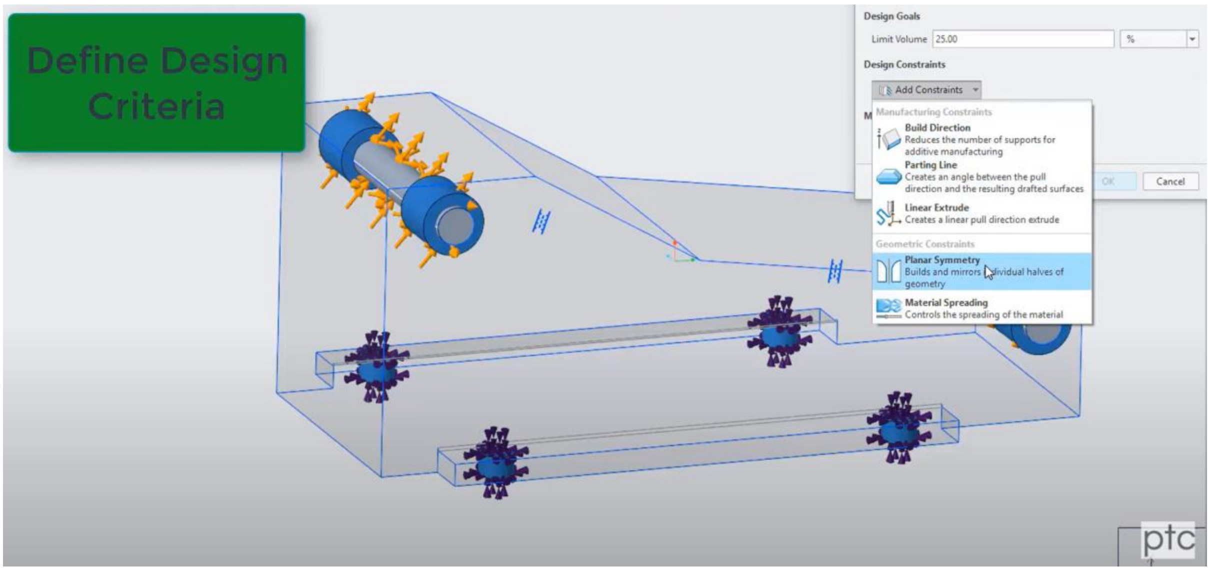


Figure 52; Defining Design Criteria (Boulton 2020)

Defining the design criteria is where control over the final is introduced. The function to introduce a ‘Plane of symmetry’ ensure that the model symmetrical. This is typically important for a structure like a chassis. In Figure 52 it is demonstrated how to apply the plane of symmetry design constraint. Other criteria include materials and manufacturing methods for the final component. With Creo the design can be made for simple two DOF laser cut parts, a common manufacturing method of metallic components. The component can also be optimised for additive manufacturing and can be simulated into the built-in manufacturing module for the best print results.

Simulation is easy with Creo as it doesn’t require cloud upload time. The design simulation gives live feedback into the model space. Figure 53 shows how the model is being optimised in real time, the blue body is the design.

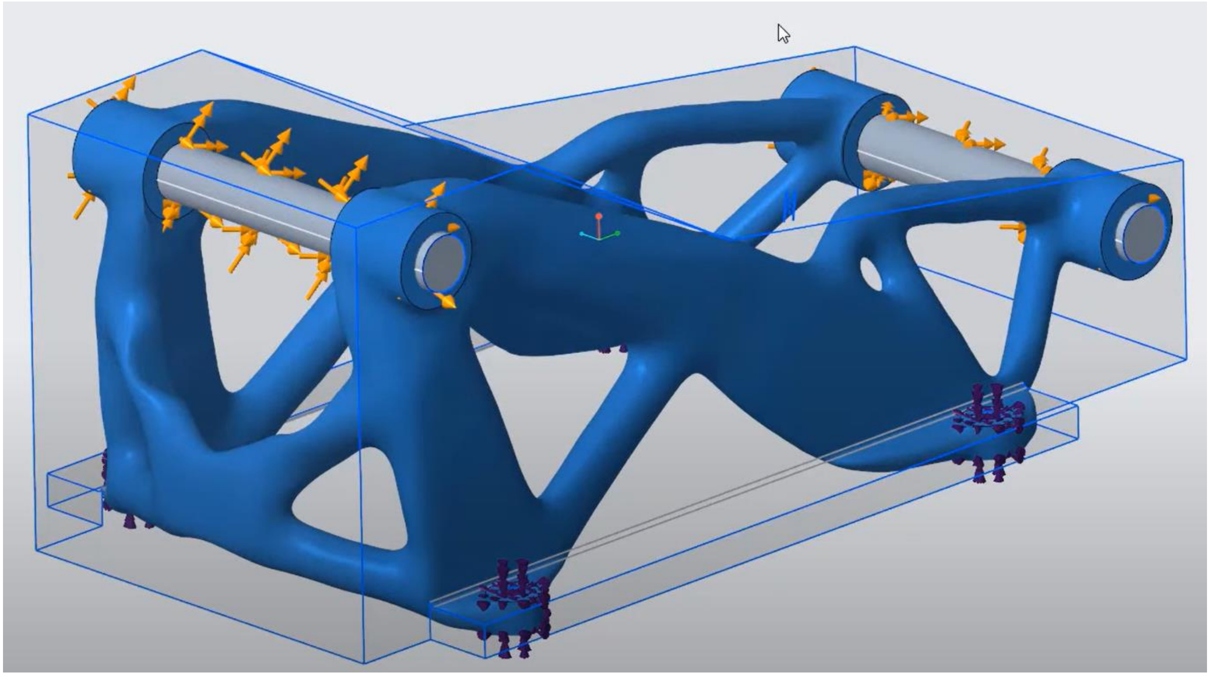


Figure 53; Live Modelling (Boulton 2020)

4.3.5 Outcome Evaluation

The results can be easily viewed in any desired plot. In Figure 54 shows the Von Mises Stress plot of the bracket in the tutorial by Ian Boulton. The stresses are significantly low across the design except for a few small concentrations around the forward mounting holes. But as can be seen in the video this can be relieved with simple modifications. Returning to the design criteria and setting the minimum radius to be larger can relieve stress concentrations. When the displacement is the key element being analysed a displacement simulation can be run to view the maximum amount of displacement occurring within the model.

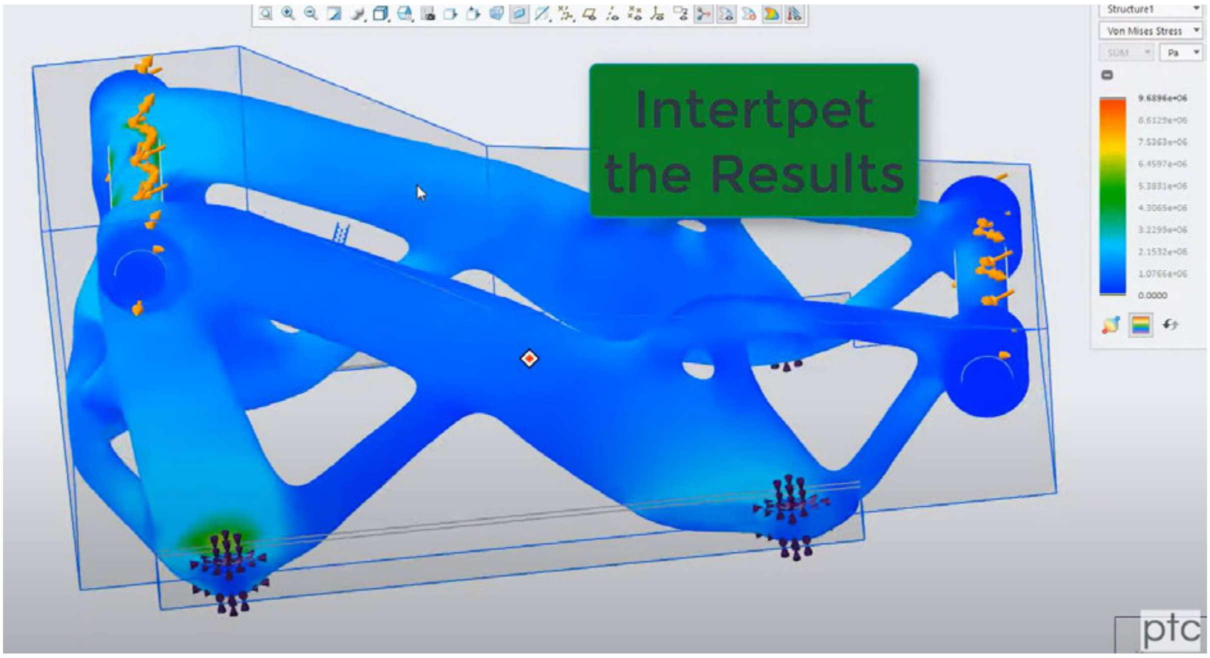


Figure 54; Von Mises Stress Plot (Boulton 2020)

4.3.6 Outcome Model and Validation

Once a suitable solution is found within the TO module it can be exported into a solid model. Unlike other software options Creo creates editable model with solid features (extrusion, fillet, sweeps, holes) this allows for any features to be easily changed without the need to rerun the simulation. This model can also be validated with any of the features in Creo, such as Simulate. Figure 55 shows the results from the Creo Simulate simulation presented in the tutorial by Boulton. These results correlate the results found inside the TO simulation. In addition, performing simulations of thermal, dynamic and vibration loads can be run using this external function of Creo.

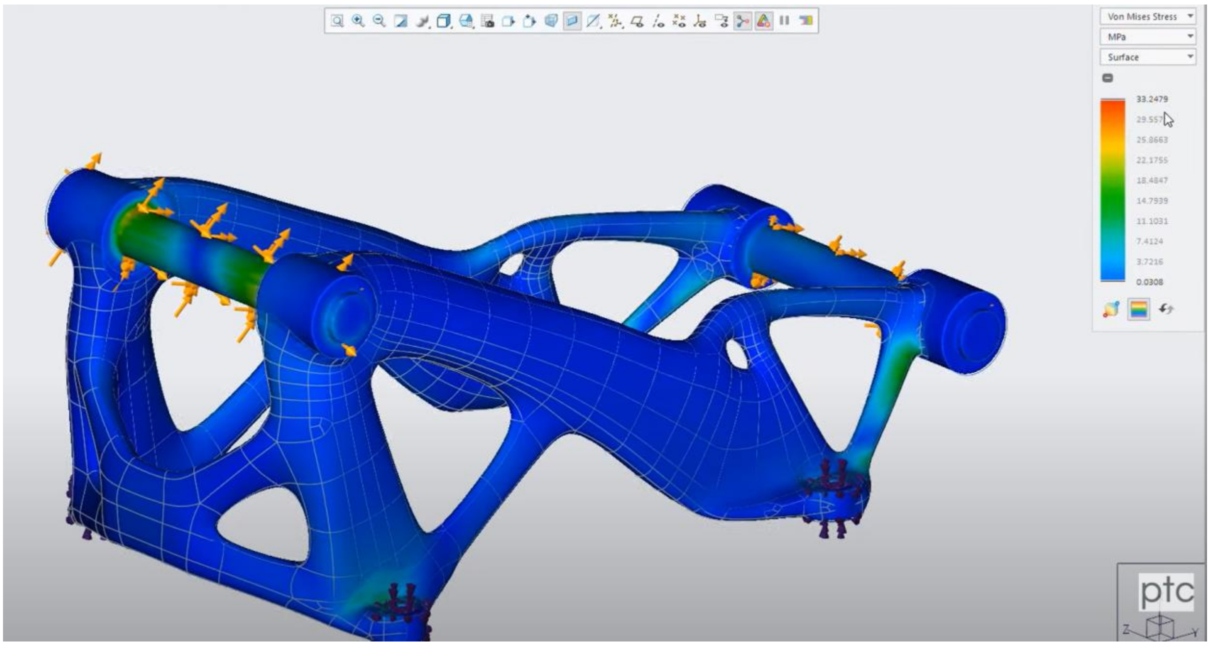


Figure 55; Creo Simulate results(Boulton 2020)

4.3.7 Conclusion

In conclusion the methodology present in theory would be applicable to the chassis design problem. Optimising a problem with so many unknowns will be complex, but the process is still applicable. As with GD there are many modifications and considerations to be made, but in general it would work. The main difference with TO is a known starting point, that is then optimised makes a difference to the outcome of the design. With more control over the design criteria, time is not used in determining of which model is optimal. Although future work needs to be done in this methodology the limitation of access to design tools is restricting.

4.5 summary

In summary both methods will produce an organic chassis design. The work done with the GD software was completed to the limit of what is possible with the available data. Whereas once licensing for the TO software is made available its application can be explored. Much more work needs to be done to finalise the design, but the processes proposed have proven to be successful. This process is heavily based on the known data and would be far easier if supply of all components and geometries were supplied. Some more work can be done to finalise this process, but its successful use well depends on the project its being applied to.

Chapter 5 – Materials and Manufacturing

5.1 Additive Manufacturing

5.1.1 Introduction

The chassis designs in this project are to be manufactured using additive manufacturing (3D Printing). Printer size and type will need to be assessed to determine how the design can be printed. The printing will be conducted by university staff who are trained and competent in the use of the equipment. The other print will be done by an external contractor who prints professionally.

5.1.2 Specification

Commercially available printing is typical done using two main methods. These are Stereolithography (SLA) and Fused Deposition Modelling (FDM) although Digital Laser Projector (DLP) is becoming more popular (Finnes 2015) The FDM printer available to print the design is located on the second floor of the engineering building. Its print bed measure 1x1x0.5 m allowing this design to be printed in a single print, but after meeting with staff they are not confident with such a large print. This will require the design to be split into several parts and assembled. This is not a problem once the design is finalised it can be modified to allow ease of assembly including locating dowl pins and interlocking surfaces. The other print will be done on a smaller scale, although this is sometimes complex in this situation it will produce superior results.

5.1.3 Risk Management Assessment

Risk assessment for the project is congruent with the risks stated in ENG4110 and is applicable to the work required for the project. The 3D printing portion of the project will be completed by USQ laboratory staff in accordance with Risk Management Plan (RMP) ID 3D printing RMP_2020_4128. This plan outlines the risks associated with using the laboratory for 3D printing. Due to having to be on campus during the pandemic risk of Covid 19 it is critical to follow the RMP ID General learning during covid19 RMP_2021_5248. The plan guides safe path to general leaning on campus during the pandemic. Both will be strictly followed during the completion of this research project.

5.1.3 Fusion Deposition Modelling (FDM)

Fusion Deposition Modelling is the most common type of printer on the market. It constructs objects layer by layer from the very bottom up by heating and extruding thermoplastic filament (Snikhovska 2021). The models produced can be of production quality and are seen in almost any print farm. Setting up these printers requires less training and takes significantly less time than other forms of printers (Finnes 2015).

5.1.3.1 Advantages

There are a number of advantages to this process, having readily available printers and operators. The printer operation has developed over recent years making user interface and software very easy to use. Filament types on the market come in a huge range of colours and depositions, from carbon reinforced to PLA. Many of the more common printers can use these types of materials. This type of printing is relatively cheap to operate and is a natural choice for most applications.

5.1.3.2 Disadvantages

A major downside to this is the supporting structure that needs to be post processed to remove the model from the supports. This time-consuming work can and often damages the final model. If the printer is not set exactly right it can lead to separation of layers, defect is caused when the layers are not fused sufficiently. The member will fracture under tension and ultimately fail.

5.1.3.3 Results

The resulting print using FDM was quite poor. Some of the structure failed to print correctly, the further scaling could be the root cause of this problem. The small structure moved during printing and failed to line up correctly. The cleaning process took roughly 3.5 hours and resulted in some reconstructive work as well as some broken members of the chassis. The use of Creo's down scan software to optimise the orientation of the chassis on the print bed is recommended for future printing using this method of additive manufacture.

5.1.4 Stereolithography / Digital Light Projection (SLA/DLP)

Stereolithography is one of the original types of Additive manufacturing (Snikhovska 2021). It has advance significantly in recent years and produces high quality even medical grade prints. The process using UV lasers to solidify liquid resin in the desire areas building the model. Generally, produced using petroleum-based thermosets (Maines et al. 2021) which cannot be recycled. Although it doesn't require large supporting structures so less material overall is used to produce the model.

5.1.4.1 Advantages

A major advantage of this type of printer is print quality. Because the z axis moves in such small increments the finish is quite smooth. This can also be contributed to the ‘baking’ of the final print solidifying the external surface of the printed object. Another advantage is less print time, printing an entire layer simultaneously greatly lessens the realistic print time.

5.1.4.2 Disadvantages

A major disadvantage is the Petroleum based thermosets adding to the plastic waste crisis (Maines et al. 2021). The longer set uptimes required for the print (Finnes 2015), even with the shorter print times this can cause potential for defective prints. The light bath and washing of the final models also take operator time and therefore money to print.

5.1.4.3 Results

The print results from either type of additive manufacturing differed greatly. The FDM print had a rough surface finish and required a significant amount of post processing. Although larger in size it still presented with imperfections and defects. The DLP print hard a greater print quality and limited number of defects. The defects that were present were due to the high amount of scaling required to produce the model. With a small amount of modification, the print quality will be greatly improved. Although a lot of work will be required to make the FDM print suitable for presentation.

5.2 Materials

The materials used for the printing of this model are vastly related to the cost of the final print. Due to funding limitations outsource of DLP printing was restricted to material the contractor supplied. The resin produced a high-quality print that performs quite well considering the fine nature of the structure at that print size. The FDM was also restricted to PLA because it is what the technician recommended in the workshop. Although the design was not optimised for these materials, they still were able to print, with varying levels of success.

5.3 Summary

The Materials and manufacturing of the chassis was successful on a smaller scale. The prints of the final design were presented during the conference of this research project. The fit and finish was of an acceptable level that will perform as expected. As future work it would be an advantage to attempt a print using a metallic alloy. Utilise this new print technology will add to the knowledge around this new process and its application.

Chapter 6 - Other Considerations

6.1 Introduction

During design of any engineered item, many considerations need to be made. This section presents the considerations that were made during the design phase of the project. It has been limited to five main considerations, the vehicle roof structure doubles as an access point and mounting for sensors. The vibration dynamics of the chassis will need to be part of future work of the design. Chassis monitoring will help to provide data for future designers using this process and help identify the optimal position for component mounting. The final section is end of life engineering a constant in modern engineering.

6.2 Vehicle Roof Structure

A major consideration of the design was to be able to access the inertia of the vehicle. To do this a removable roof needed to be constructed and integrated into the design. Using the same design process as the chassis, a model of the roof was designed. This design incorporates mounting platforms for sensors or lighting. They are the highest part of the design so will be visible for all surrounds of the vehicle. The side view of the design of the roof is presented in Figure 56 the members have good supporting structure and a combined flow of members. Across the middle of the structure.

Figure 56; Roof Side View.

The front view of the roof is shown in Figure 57. The trussed arm structures are shown have good strength characteristics and a conforming shape to the under body.

Figure 57; Roof Front View

The top-down view shows in Figure 58 shows the stability of the structure overall. The bracing of the top deck gives the roof a spider web appearance.

Figure 58; Roof Top View

Figure 59; Roof Isometric View

The isometric view of the roof presented in Figure 59 shows the overview of the roof design for the final structure. This design is visually pleasing and structurally sound. Its manufacturing will be relatively easy and cost effective and was included in the final assembly models.

6.3 The vibration dynamics

Vibration dynamics was considered as having the potential to destroy the chassis. Plastics are typically susceptible to fatigue failure in service and doing a vibration analysis is to be included in the future work required to validate the design. The final components will need to be added to properly assess what frequencies the chassis can withstand. Because of this the vibration analysis is outside the scope of this project.

6.4 Chassis Monitoring

The inclusion of monitoring technology was considered for this chassis. strain gauges would be moulded directly into critical areas. These gauges have the capability to give life feedback during operation of the vehicle. The data collected from these gauges could be used to design the next generation of the chassis. Having exact data can improve any design process

6.5 Component Mounting

The mounting of electronic components is critical to this vehicle. Some sensors have been identified and were added to the structure these can be easily mounted using fasteners. The remainder of the components will need to be identified and added using various method of mounting. This can be done in the generative design stages or after although removing materials from the final structure will eventually weaken it. Knowing what components at the beginning of the design stage greatly increases the effectiveness of the outcome.

Mechanical components will also need to be mounted. This includes suspension shocks and rod ends; simple clevis' can be moulded into the chasses. To simplify the process flat square sections were the defining features of these points but in the final build clevises will need to be added. Mounting the shock absorber may prove to be more complex depending on the type of mounting the specified part requires. Some commercially available shocks use a single bolt and rubber bush to mount this is vastly different than what has been modelled, so changes will need to be made.

6.6 End Life Engineering

End of life engineering is of critical importance. Where the final construction will eventually end up needs to be considered at every stage of the design process. For the chassis being printed from ABS, a recyclable material. Unless the chassis is used for display purposes that the materials be recycled into other components.

Chapter 7 – Results and Discussion

7.1 Results

The final assembly of the chassis presents as a successful project. The addition of other mechanical components finishes the look of the vehicle and puts the chassis into perspective. The mounting points for the suspension blend together flawlessly with the traditionally modelled suspension concept. The bumpers were assembled without any issues and can be either bolted or pinned in the full-scale build of the project. In Figure 60 the isometric view of the final assembly shows how well the roof compliments the chassis. It integrates into the design and will add to the finished design.

Figure 60; Final Assembly Isometric View

The front view Figure 61, of the assembly shows clearance of the vehicle. Having a small amount of clearance allows for suspension to travel during operation. Adding more travel will need to happen in the hubs of the final assembly and is outside the scope of this project.

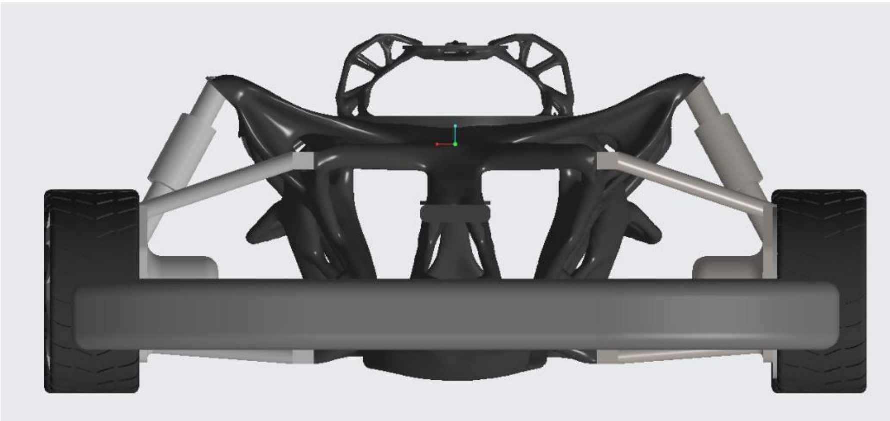


Figure 61; Final Assembly Front view

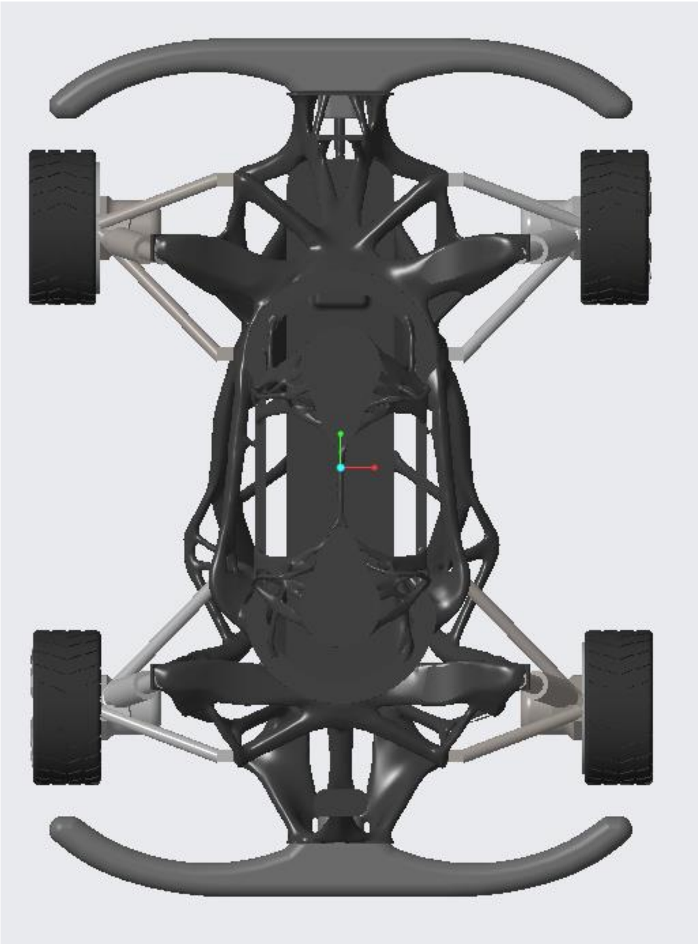


Figure 62; Final Assembly Top View

The top view of the assembly shows the footprint of the vehicle. In Figure 62 the bumpers can be seen to protect the front of the vehicle. They extend out to the wheels to protect against any damage. It also shows the overall geometry of the wheels showing that the assumed proportions were good assumptions to make.

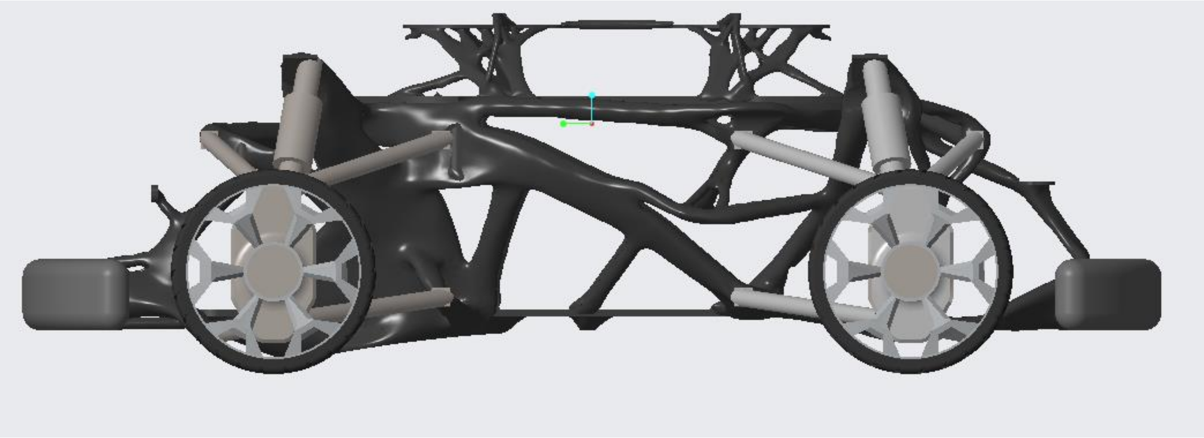


Figure 63; Final Assembly Side View

The side view in Figure 63 shows the height of the vehicle overall, it presents the visually appealing flow of the chassis. The design has nice aspects such as the front camera mounting, where mounting member flows nicely into the front brace of the roof. The upper hangers for the suspension protrude outward and about the chassis making it appear grown from the structure.

7.2 Discussion

The organic look of the chassis is visually appealing yet functional. The analysis of the chassis proves its strength attributes, designing in this way has bridged a knowledge gap into what is possible with this software. Utilizing the possibilities of modern manufacturing with modern design packages made this project possible. Although not perfect with refinement the process can be applied to this type of design situation. With technology and manufacturing continue to advance as engineering designers it's important to continue to develop methods of design complex structures maximising the potential of possibilities.

7.3 Future Work

7.3.1 Finalise Suspension Geometries

The suspension geometry used in the model are only representative of what can be expected in a chassis. defining suspension needs to be done before the vehicle can be finalised. This is outside of the scope of this projects as it requires specialised knowledge of vehicle handling and dynamics.

7.3.2 Confirm Design Components

Components for the final vehicle need to be confirmed with the rest of the design team. These components would include battery, processer, and sensors. The selection and specification is outside the scope of this project and is being worked on by other members of the design team.

7.3.3 Finish Evaluation of Vehicle

Once the much of the rest of the care is finalised the final evaluation can be processed. This will include running a simulation with real data from those components. Having this information will give the chassis validity, it can then be evaluated as a viable solution to the problem.

7.3.4 Gain access to Creo Software

Gaining access to Creo topology optimisation module will allow for a differing simulation outcome. Using this software will give a fixed outcome that can be easily modified and adapted for manufacturing and use. Having a professional software capable of computergenerated design is paramount to the success of this type of project. The access to this software was not granted by the university and will be part of the future work for this project.

7.3.5 Data collection

It was recommended during this project to include data collection sensors on the chassis. The addition of fibre optic strain sensors may help in data collection to build data on the performance of the chassis. This of course will not improve the current chassis but combining this information for the next iteration of chassis can improve its performance.

All the future work to be conducted for this project are limited to the current understanding of the requirements for generative design. New software is released annually and could improve the processes outlined in this project. Alternately different software may render this process irrelevant and easier for designers to apply to industry.

Chapter 8 – Conclusions

In conclusion the project was successful in producing an organic chassis design for a scaled FSAE chassis. Utilizing the information available at the time of the project and knowledge researched the project chassis has produced excellent results. The theory of applying generative design or topology optimisation to complex structures is still being explored by experts. Building understanding into the application and theory behind these design tools will be critical to the future of design in engineering. The solution-based study did in part complete the expected outcomes of a printable model. The computational model was not completed due to the limitations of components and their specifications. Without confirmed data much of the forces and applied to the model are assumptions. These were made with prior knowledge of vehicle performance expected. This project has made good progress into the knowledge of the capabilities of this technology.

Appendices

Appendix A

ENG4111/4112 Research Project

Project Specification

For: Gordon Drummond

Title: Design and Manufacture of Scaled FSAE Chassis

Major: Mechanical Engineering

Supervisors: Jayantha Epaarachchi

Enrollment: ENG4111 – EXT S1, 2021

ENG4112 – EXT S2, 2021

Project Aim: The aim is to design and manufacture a model FSAE chassis for use in developing autonomous driving algorithms. This will include developing a method for using Generative design and design optimization to design complex structures.

Program: Version 1, March 8, 2022

Example below

1. Conduct initial background research into traditional Spaceframe chassis including manufacturing techniques and analysis (FEA).
2. Confirm components and geometry utilized in final model.
3. Develop mathematical model for static load cases as seen in research.
4. Decide on appropriate manufacturing method and material.
5. Develop an optimized model for each load case.
6. Combine these into the final model
7. Perform FEA on the final model to Validate the final design.
8. Manufacture the final design directly from CAD files.
9. Process, review and evaluate mathematical model and design process

If time permits

10. Concept a master model if time permits this will later be optimized.

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