

Rocket Bracket Assignment - Michael Cheeseman

by Michael Cheeseman

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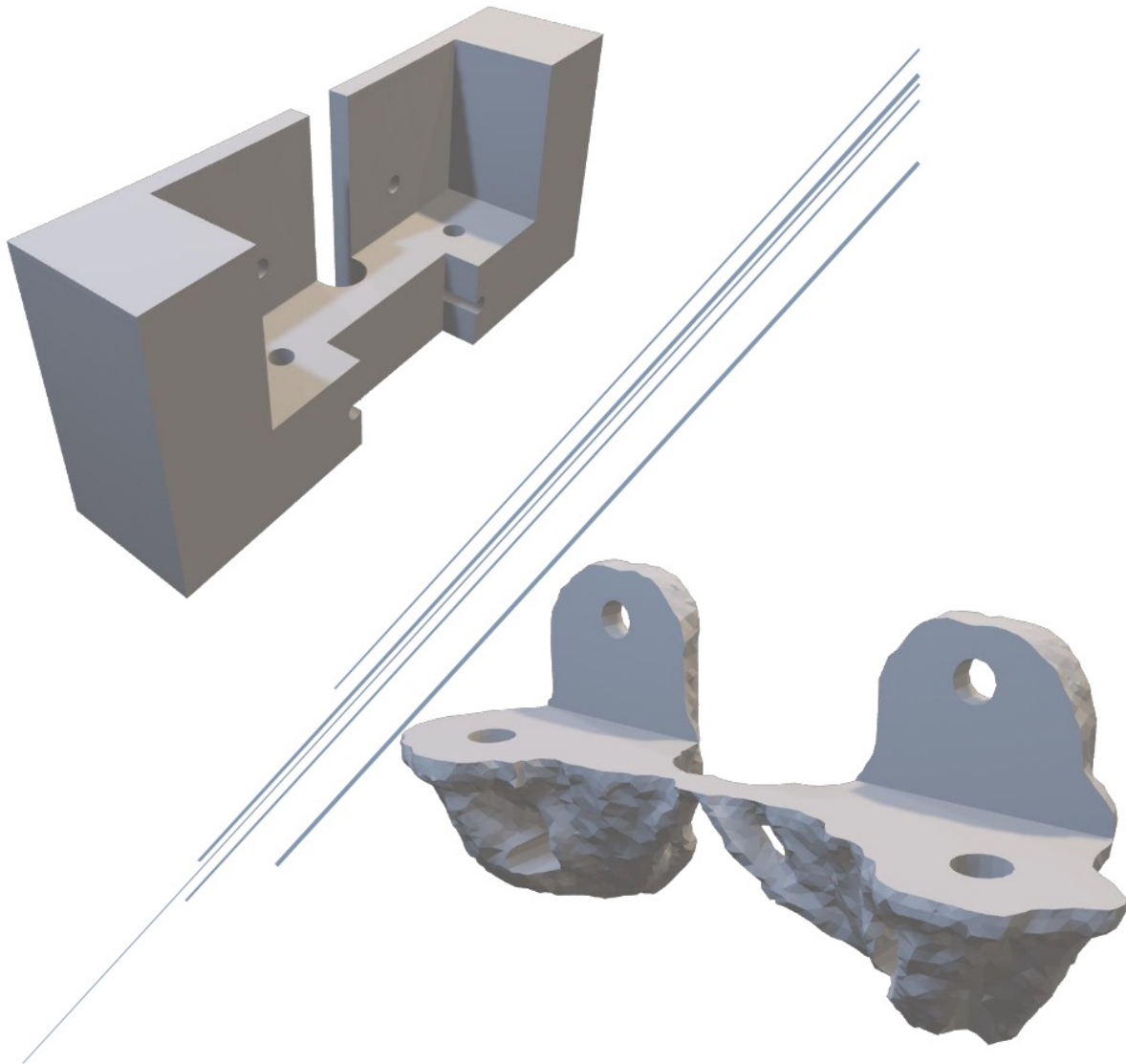
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ADVANCED COMPUTATIONAL METHODS

ULA Rocket Hardware Design



Michael Cheeseman (1707473)

1 Executive Summary

This report is a topology optimisation assessment on a ULA Bracket, this bracket is a fixing location between the Atlas V rocket and a working platform while the rocket is on the ground. The bracket model has been given for use within the report as well as the material for the bracket which is Ultem 9085. The properties for the material have also been provided which can be found in section 4.1.4 of this report.



This Report will conduct two studies on the original part the first is a static analysis on the before going through the topology optimisation. The static analysis showed that the part had only 6MPa of stress when the maximum material stress was 31MPa. This proved that the part could be optimised.

From the optimised part a clear result was achieved that showed that the maximum stress, strain and displacement had increased from the static analysis of the original part. Using the optimised part, the Author has made a few suggestions for a redesign of the original part. A few benefits of the redesign the part have also been highlighted within this report.

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3 Introduction

3.1 Support Bracket

The part that has been provide for analysis is called the “Internal Boattail Support Bracket” according to (GrabCad, 2020) this would be the part that will eventually sit on the Atlas V space rocket as shown in figure 1. This part is needed to be able to support the work platform to the rocket whilst it is on the ground. The breakdown of the Atlas V rocket is shown in figure 1. The Part will be located on the Boattail of the rocket as well as numerous places around the rocket and will not be unbolted from the rocket before launch. (GrabCad, 2020) (ULA, 2020)

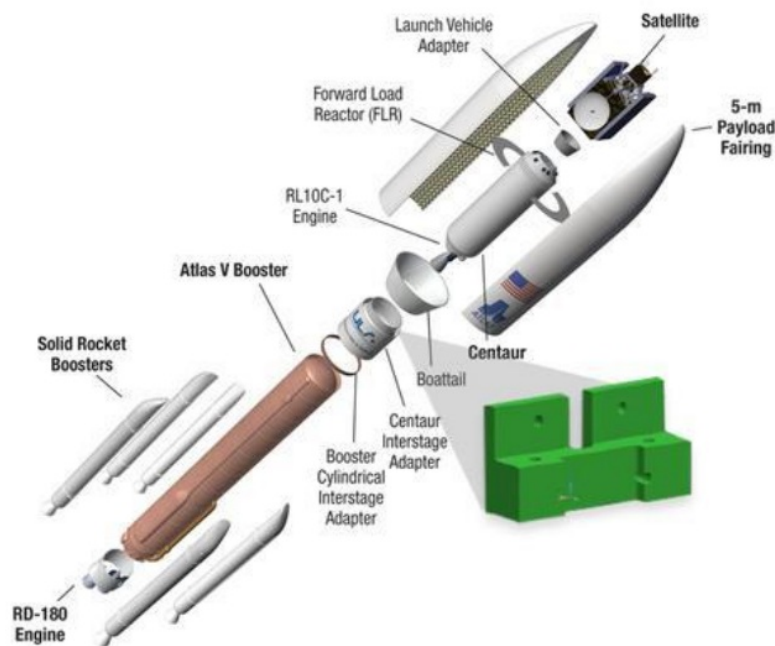


Figure 1: Atlas V Breakdown (GrabCad, 2020).

3.2 Material

The Material that this report was conducted with was Ultem 9085 this material is a “High-performance FDM PEI thermoplastic” according to (Stratsys, 2020). This type of plastic is typically used in Fused Deposition Modelling (FDM) or Selective Laser Sintering (SLS) 3D printing machines. Typical Applications for this material are prototyping parts, tooling and for low volume production parts according to (Stratsys, 2020). The material properties can be found in section 4.1.4 of this report in Table 1.

1. Material

3.3 How it is manufactured

For Ultem 9085 there are numerous ways that this type of plastic can be used to manufacture a part, one particular method is additive manufacturing. The type of additive manufacturing that is able to be used is Fused Deposition Modelling (FDM) according to (Stratsys, 2020). FDM Printers uses a thermoplastic filament that is heated to its melting point and the extruded layer by layer to create a part. This type of manufacturing method enables a way of creating complex geometry and removing some constraints that a tradition manufacturing method imposes on the part design (Chang, 2015).

3.4 Topology

A topology optimisation is a useful tool in the design of parts and structures, as it enables a designer to be able to reduce the weight of the part while keeping a required maximum strength of the part. This is important for industries that weight is a key issue such as automotive and aerospace industries (Chang, 2015). Topology Optimisation is a tool that makes the most Additive Manufacturing methods.



There is numerous topology optimisation software that are able to do the following according to (Ansys, 2020) (Chang, 2015)

- Consider multiple loadcases.
- Allow for minimum material thickness constraints.
- Observe manufacturing rules
- Have scope for both cyclic and planar symmetry
- Easily validate results

(Ansys, 2020)

4 Methodology

4.1 Stress, Strain and Displacement.

To be able to perform a topology optimisation study on the part, first a Finite Element Analysis (FEA) study was needed to be conducted on the part within Design Studio this will be able to determine what sections of the part can be removed by the software and what needs to be kept. The mesh used for the part is 1.5mm as this size mesh gives three sets of elements across the thinnest part of the envelope as shown in Figure 2.

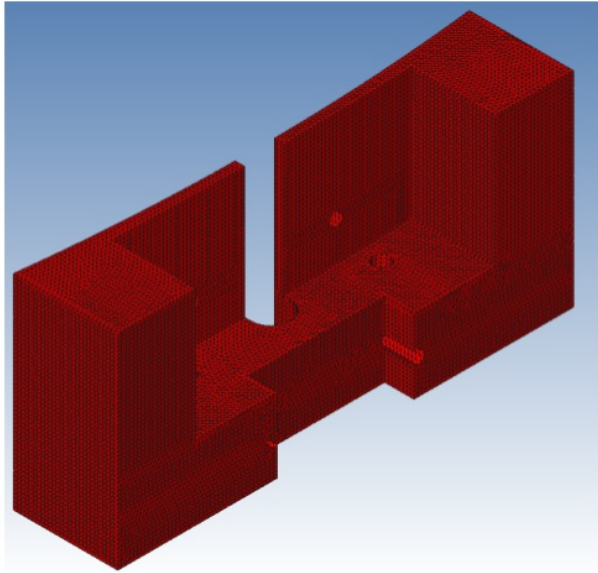


Figure 2: Meshed part in design studio (Cheeseman, 2020).

4.1.1 Boundary Conditions

The boundary conditions that would be acting on the part in service is the “4x $\varnothing$.22-hole pattern D” (GrabCad, 2020), therefore the part would use some sort of fixings through holes as shown in Figure 3 on the rocket. With the requirements of the part a set of single point contacts were used to set the nodes around these four holes in six degrees of freedom. As shown in Figure 4 and Figure 5. Following on from the research carried out at previous optimisations for the bracket, the decision was made to use the same number nodes to fix the part on the top hole as per the bottom this would ensure the stress, strain and displacement of these positions would react similarly to the optimised design as shown in figure 5. The “2x $\varnothing$.27. Hole pattern E” (GrabCad, 2020) holes have been neglected from the Boundary conditions as they are to hold the working platform to the bracket these would have a minimal effect on the outcomes of this report.

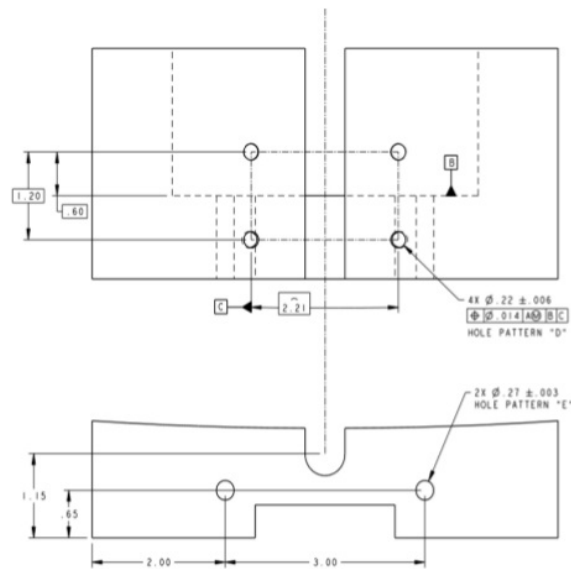


Figure 3: Engineering drawing of the part (GrabCad, 2020).

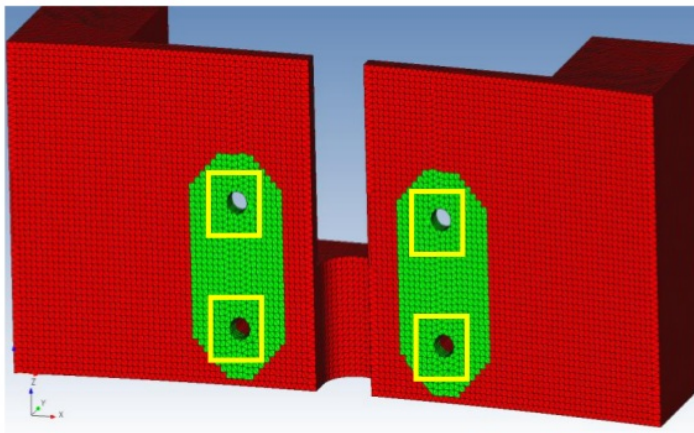


Figure 4: Rear of the part envelope (Cheeseman, 2020).

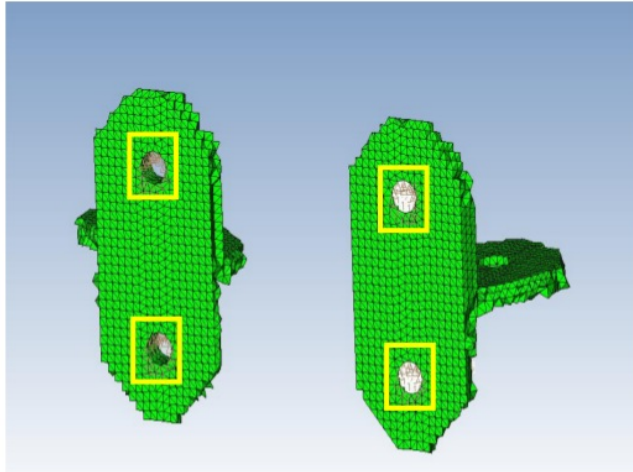


Figure 5: Part envelope with a region hidden showing the boundary conditions (*Cheeseman, 2020*).

4.1.2 Applied Force

The Applied force for the part is “600lbf” which has been given for the use of the study by (GrabCad, 2020), this has been converted to its SI units which was “2668.93 N” (Convert Units, 2020). From further research carried out, no other loads were found to be acting on the part whilst the part would be used in the manner it is intended for (Adams, 2020) (Gandhele, 2020) (GrabCad, 2020) (ULA, 2020). There would however be a load on the part when the rocket is in flight, however this part is only in use when the rocket is on the ground, therefore the force of the rocket in flight was neglected for this study. The applied load was set up as a UDL over the top face. From researching similar designs taken from (Adams, 2020), (Gandhele, 2020) and (GrabCad, 2020) as shown in figure 6 and figure 7. The area of the force can be reduced so that it is mainly concentrated around the two bolt holes leaving some points connecting the two larger areas to be able to create a platform between the attachment holes as shown in figure 8.

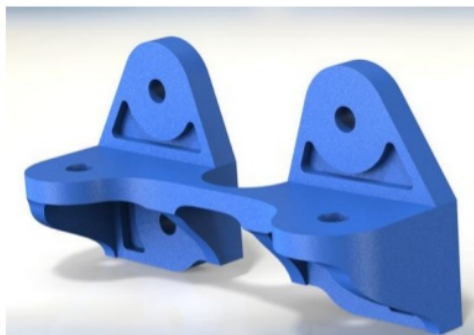


Figure 6: ULA Bracket (Gandhele, 2020)



Figure 7: ULA Bracket (Adams, 2020).

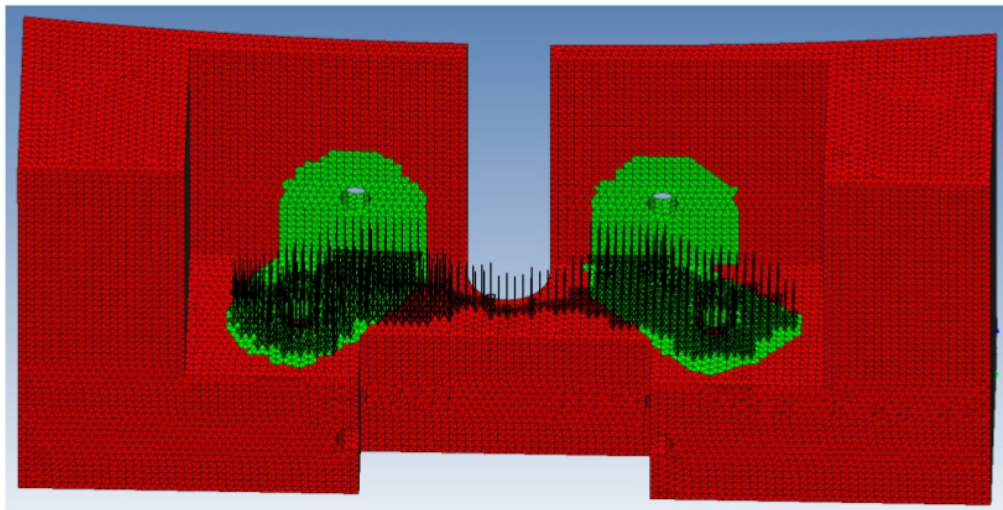


Figure 8: Part envelope with force applied (Cheeseman, 2020).

4.1.3 Loadcase

As previously stated from research carried out there seems to only be one set of boundary conditions that need to be considered and only one loading force. Therefore, it leads to this part in only having one loadcase that can be carried out. The loadcase that has been chosen for the part is the single boundary condition which are the fixing holes and the force acting on the top of the bracket. The loadcase for this system is the fixing holes and the UDL Force as shown in Figure 9. These values have been given to use from (GrabCad, 2020) There is however one other loadcase for this part is when the rocket is taking off and traveling through the air. This loadcase was considered but then neglected from the study as when the rocket takes off the part will no longer be used for how it is intended for (GrabCad, 2020), (Gandhele, 2020) and (Adams, 2020).

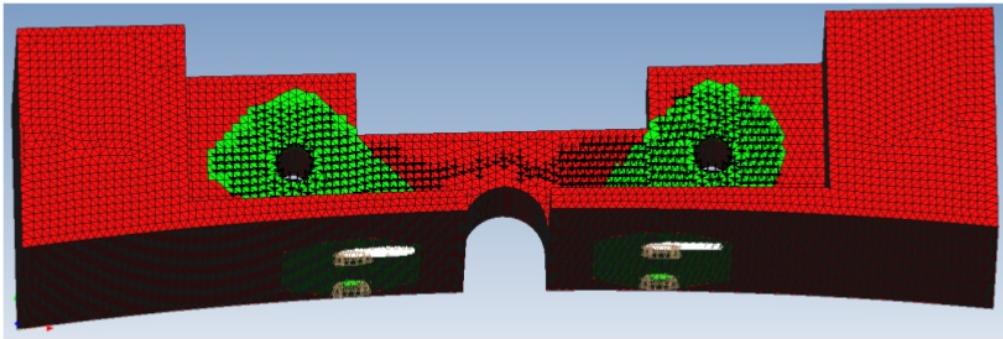


Figure 9: Part envelope with loadcase applied (Cheeseman, 2020).

4.1.4 Material Properties

As previously stated, the material that was used for this report was Ultem 9085. The properties for this material can be found in Table 1, these properties were given to be used for the optimisation but these values were in imperial units (GrabCad, 2020). These values were converted into their SI units to be able to input them into Design Studio for Genesis. One value was found within the material Data sheet which was the shear Modulus this was to ensure that design studio had enough information to solve optimisation, these properties are found in Table 2.

<u>Properties</u>	<u>Given Values</u>	<u>Source</u>
Youngs Modules (E)	325 KSI	(GrabCad, 2020)
Poissons Ratio (ν)	0.41	(GrabCad, 2020)
Specific Gravity	1.34	(GrabCad, 2020)
Material Strength (ST)	4500 PSI	(GrabCad, 2020)

Table 1: Properties for Ultem 9085.

<u>Properties</u>	<u>Metric Values</u>	<u>Source</u>
Youngs Modules (E)	2240 MPa	(Chapel Steel, 2020)
Shear Modulus (G)	2050 MPa	(Stratsys, 2020)
Poisson Ratio (ν)	0.41	(GrabCad, 2020)
Specific Gravity	1.34	(GrabCad, 2020)
Density (ρ)	1340 Kg/m ³	Equation 1
Material Strength (ST)	31 MN/m ²	(Just In Tools, 2020)

Table 2: Material properties for the part in SI unit.

These properties from table 2 were inputted into design studio as shown in Figure 10.

Figure 10: Material properties in design studio (Cheeseman, 2020).

4.2 Topology

4.2.1 Topology Region

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To be able to set the topology regions to remove a selection of elements where grouped together to ensure that the software would keep an area roughly twice the diameter of the holes as stated in the design requirements by (GrabCad, 2020) as shown in Figure 11, Figure 12 and Figure 13. This would be to ensure that there would be enough material around the holes to safely support the loading of the bracket by working platform. By looking at figure 13 the study has been manipulated into a design by the author, this will ultimately have an effect the result of the topology.

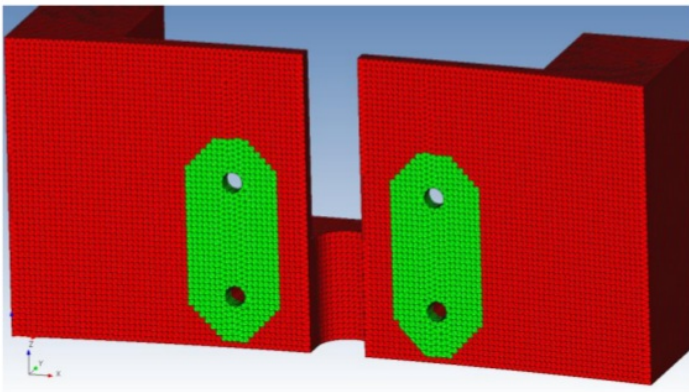


Figure 11: Topology region set up on the rear view (Cheeseman, 2020).

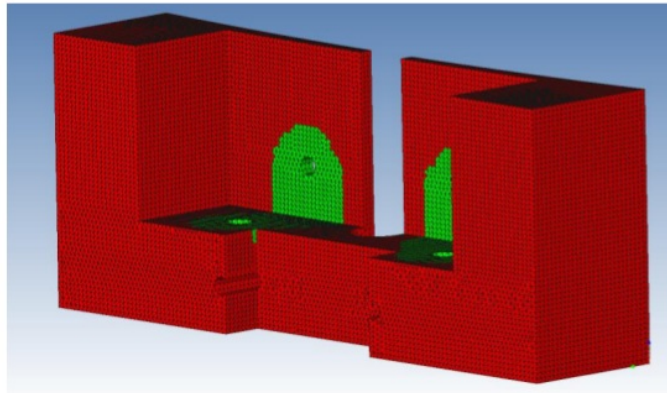


Figure 12: Topology region set up on the front view (Cheeseman, 2020).

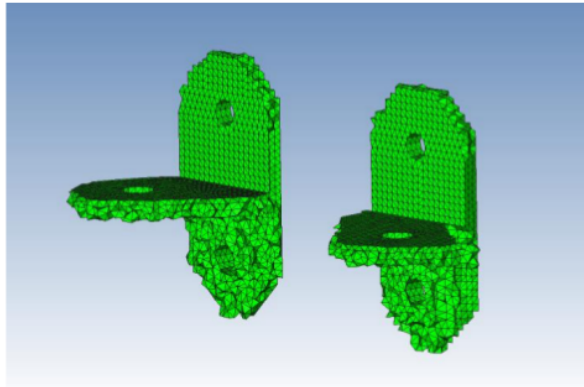


Figure 13: Topology region with regions to keep (Cheeseman, 2020).

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With the elements grouped the red group was selected to be optimised at a 0.1 initial mass fraction which meant that the software was looking to minimise the mass to 10%. With the same region the author added two fabrication constants on the part these were to "Mirror about YZ plane" (Vanderplaats R&D, 2020), this was chosen to ensure that both sides of would be symmetrical to be able to influence the final design. The second constraint was to "Fill Y axis (Inside to Out) to ensure that there were no voids inside the part and to keep them as holes instead, a minimum thickness was set to 10 mm which correlates to this constraint. The minimum size was set at 3mm which is twice the mesh size. The spread fraction is set to 0.5 due to the possibility of multiple load paths through the parts structure. The topology region set up is shown in Figure 14.

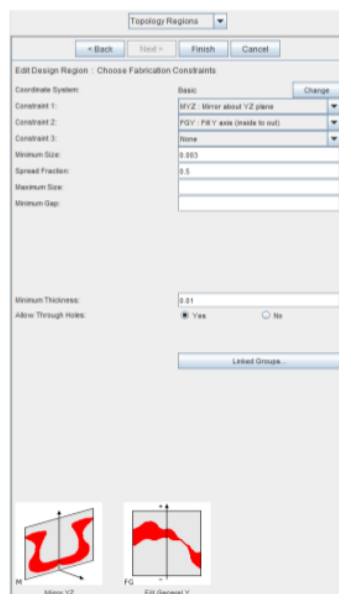


Figure 14: Topology region settings (Cheeseman, 2020)

4.2.2 Topology Objective

The objective that was set in the optimisation was chosen as the strain energy throughout the entire model. This was chosen so that the software would look at this objective and reduce the material where there was not needed by analysing the strain energy and seeing where it can remove material. As shown in figure 15. This was the only objective set, so the weighing was left as 1.0 which is 100% of weighting.

Topology Objectives

< Back Next > Finish Cancel

Edit Topology Objective : Enter Name and Type

Name: Obj3

Response Type

- ☒ Strain Energy: Entire Model
- ☐ Frequency Mode Number: 1
- ☐ Mass Fraction: All Designed Groups
- ☐ Displacement
- ☐ Relative Displacement
- ☐ Reaction Force (SPCF)
- ☐ Temperature
- ☐ Heat Transfer Compliance
- ☐ Von Mises Index
- ☐ System Inertia: Box at CG
- ☐ Buckling Load Factor: 1
- ☐ Dynamic Displacement: From Model (MODP)
- ☐ Dynamic Velocity: From Model (MVELO)
- ☐ Dynamic Acceleration: From Model (MACCE)
- ☐ Contact: Pressure (CPRESS)
- ☐ Equivalent Radiated Power: (SRP)
- ☐ Synthetic Response

Objective Definition Switch

- ☐ Max
- ☒ Min

Weight: 1.0

19

Figure 15: Topology object settings
(Cheeseman, 2020).

4.2.3 Topology Constraint

The topology constraint that was set was to reduce the overall mass down to 0.1lbs as per the requirement (GrabCad, 2020). This mass is which is equivalent to 0.045 Kg (Rapid Table, 2020). The part envelope calculates a theoretical weight of 0.412 Kg taken from Table 3 which has been calculated in Equation 3.

Property	Value	Source
Volume	$3.08 \times 10^{-3} \text{m}^3$	Figure 16
Density	1340 Kg/m^3	Equation 1
Mass	0.412 Kg	Equation 2

Table 3: Topology constraint values table.

Volume = 307734.76 cubic millimeters
Surface area = 52132.09 square millimeters
Center of mass: (millimeters)
X = 88.90
Y = 19.94
Z = 33.11

Figure 16: Mass Properties from (Solidworks, 2020)

This to be worked out to a percentage was worked out by using solidworks mass properties to find the volume of the profile which then used in equation 5 gave the result of 10.9 % of the envelope needed to be kept. The set value for this report was 10% as shown in figure 17.

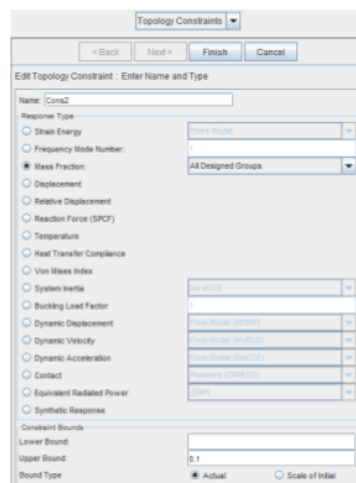


Figure 17: Topology constraint settings (Cheeseman, 2020).

5 Analysis

5.1 Single Analysis

20 Before running a topology optimisation, a single analysis was run which run an FEA study to find the stress, Strain and the displacement of the part envelope to ensure that it the software was able to remove any wasted material of the envelope. The results can be seen in table 4.

Type	Value	Picture
Strain	1.5	
Stress	240MPa	

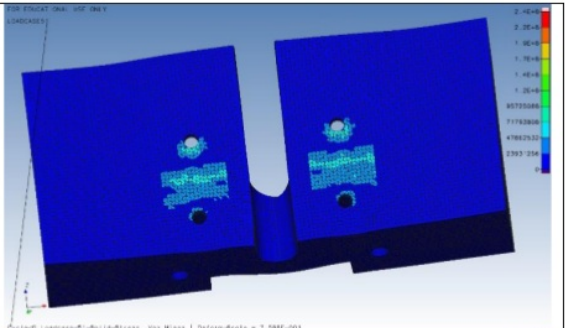
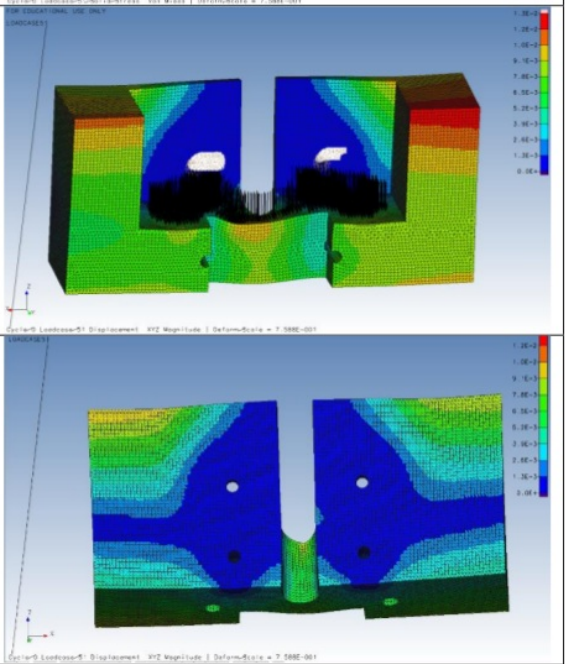
		
Displacement	13 mm	

Table 4: Results of single analysis study (Cheeseman, 2020).

Table 4 shows the maximum value for the stress, strain and the displacement of the part according to (Vanderplaats R&D, 2020). The results show a maximum stress value of 240MPa which exceeds the maximum allowable for this specific material which is 31MPa. This would mean that either the part would fail in its current design or that these results are questionable due to such high values. To ensure the reliability of these results a static analysis was conducted using Solidworks using the same part and loading conditions the results are shown with in table 5. These results show a 6MPa maximum stress rather than a 240MPa stress. The displacement for the part shows a 0.13mm rather than a 13mm displacement. And a strain of 3.3×10^{-3} rather than 1.5. The results from solidworks show that the part is able to be optimised as the maximum stress is under the allowable 31MPa maximum stress for the material. From the data sourced in Solidworks the part is able to be optimised.

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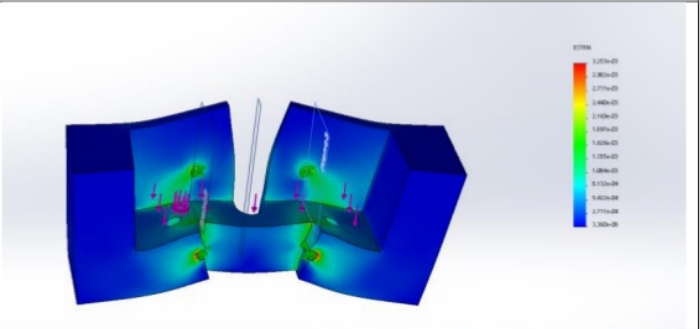
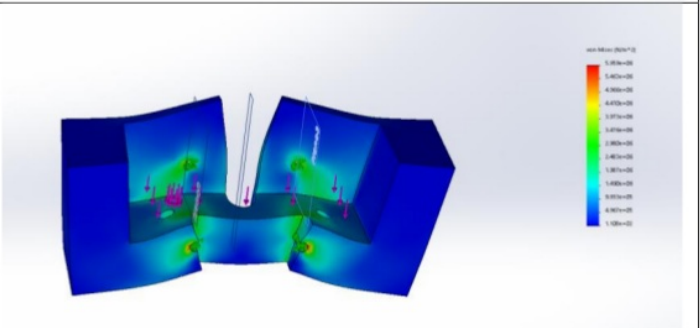
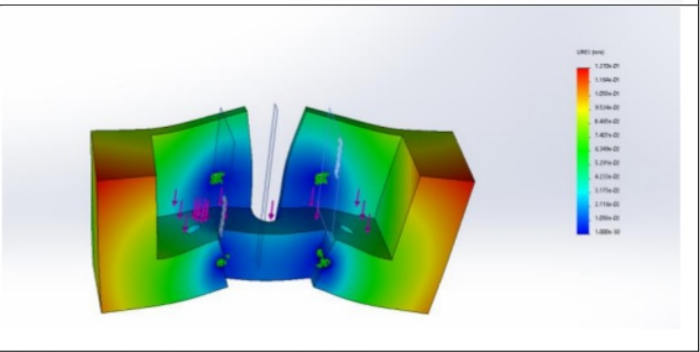
Type	Value	Picture
Strain	3.3×10^{-3}	
Stress	5MPa	
Displacement	0.13 mm	

Table 5: Solidworks static analysis results (Cheeseman, 2020).

5.2 Topology Optimisation

The results of the optimisation are shown in figure 19. From this result it can be worked out that the topology optimisation on the envelope has been reduced by 10% of the material to be able to go down to 0.041kg which is under the target weight that was specified to be 0.045kg or 0.1lbs as given by (GrabCad, 2020) as shown in Table 6.

Properties	Values	Source
Volume of Optimised Part (V)	30633.92 mm ³	Figure 18
Density of Material (ρ)	1340 Kg/m ³	(GrabCad, 2020)
Weight of Optimised Part	0.041 Kg	Equation 3
Target Weight	0.045 Kg	(Rapid Table, 2020)
Mass Percentage Difference	10.0%	Equation 5

Table 6: Optimisation table.

Volume = 30633.92 cubic millimeters
Surface area = 12618.05 square millimeters
Center of mass: (millimeters)
X = 0.51
Y = 0.10
Z = -1.71

Figure 18: Solidworks mass properties for optimised part (Solidworks, 2020).

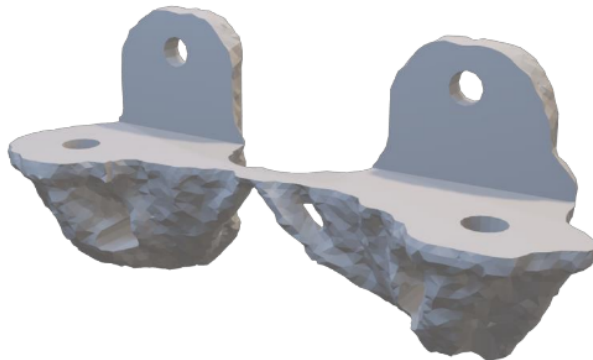
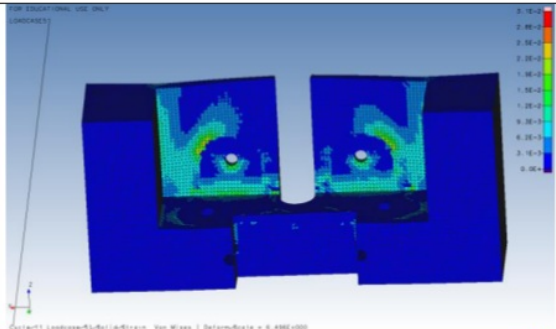
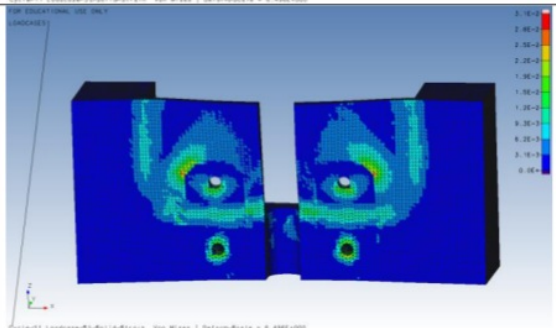
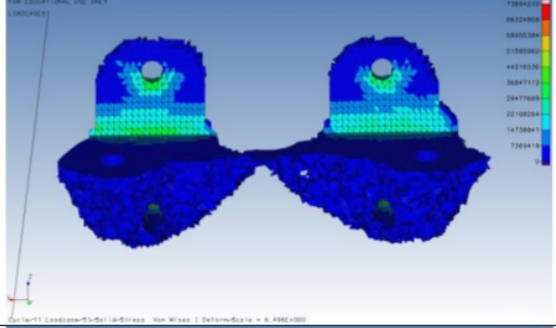
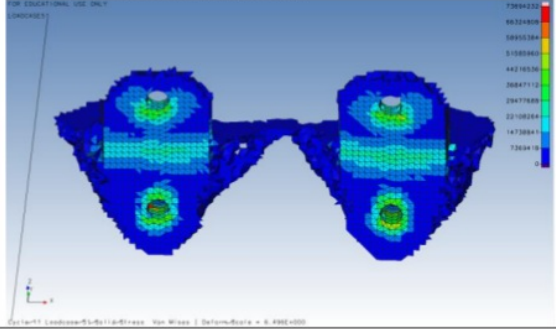


Figure 19: 3D Model of the optimised part (Cheeseman, 2020).

The stress strain and displacement of the final part is shown in table 7.

Type	Maximum Value	Image
Strain	0.031	
		
Stress	73.7MPa	
		

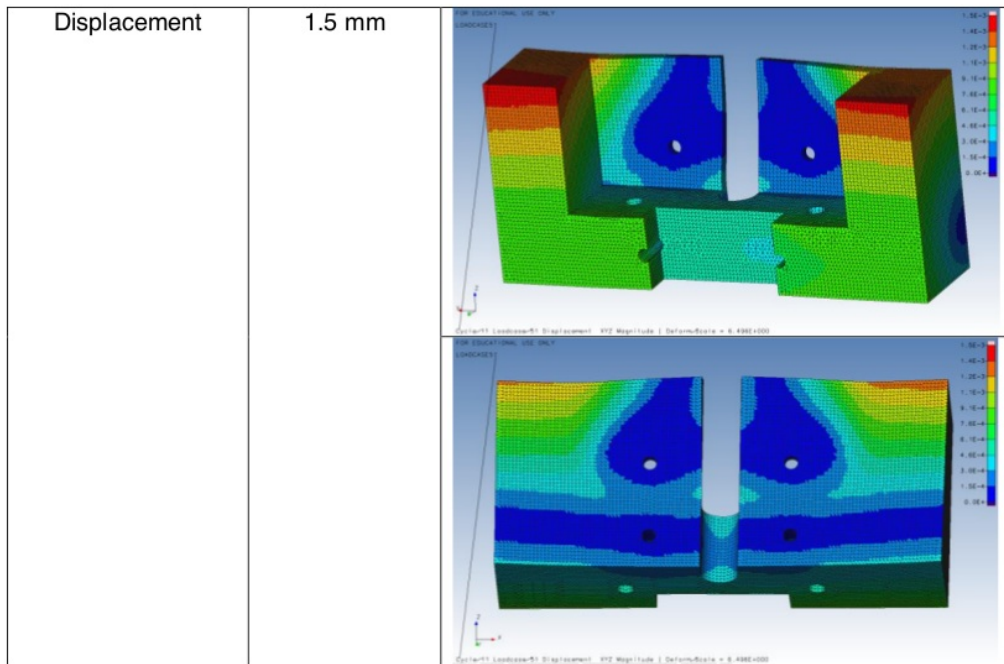


Table 7: FEA results of the optimised part (Cheeseman, 2020).

For the optimised result the part is show a maximum stress of 73.7MPa, Strain Ratio of 0.031, and a displacement of 1.5mm as shown in Table 6. There are a few highly stressed elements around the set boundary contidions as shown in figure 20. These nodes have been disregarded as they are attached to the boundary conditions where the rest of the model is showing an approximate maximum stress of 30MPa which would prove that the optimisation has been successful as it is under the maximum allowable stress for the material.

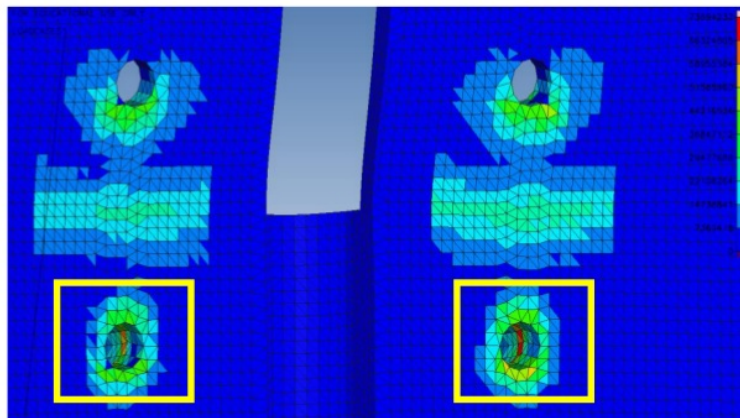


Figure 20: High stress elements within the holes (Cheeseman, 2020).

The result is shown in Figure 21, Figure 22, Figure 23 and Figure 24. This result can be used as a suggestion for a redesign the initial part. As shown the part is able to remove the side walls and a lot of material above the top holes without causing the part to fail. The part redesign would need to keep twice the diameter of all the holes on the assembly. The new design would need to consider using rounded edges and fillets to remove as many possible sharp edges as possible across the entire part thus minimising any potential stress points within the part. From the study the part would be able to benefit from removing a selection of the material from the underside of part this will enable further reduce the parts weight this can be achieved by using shelling out the center section to be able to retain a most of the second moment of area for the part and incorporating the use of ribs to add strength to the design. The results show jagged edges around the part as shown in figure 25 these edges are due to the meshing of the original part as well as to software limitations these should be smoothed out and not taken in consideration.

24

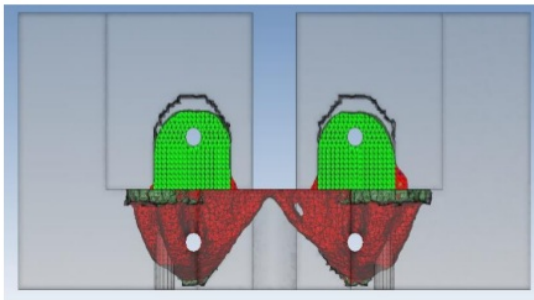


Figure 21: Topology optimisation result front view (Cheeseman, 2020).

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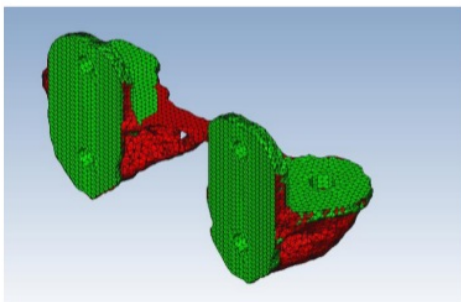


Figure 23: Topology optimisation result iso view (Cheeseman, 2020).

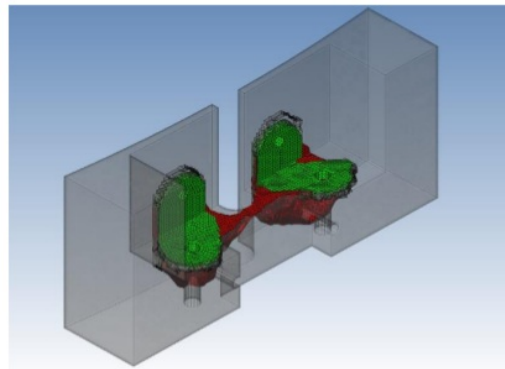


Figure 22: Topology optimisation result iso view (Cheeseman, 2020).

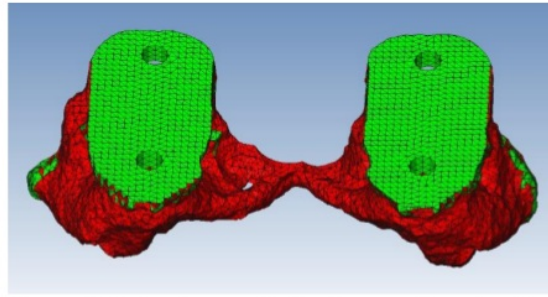


Figure 25: Topology optimisation result underside view (Cheeseman, 2020).

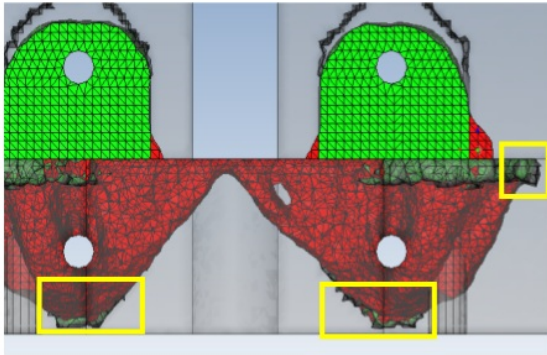


Figure 24: Topology limitations (Cheeseman, 2020).

The benefits of using an optimised part on the final assembly rather than the initial part will reduce the component weight, this will have a positive impact on the manufacturing cost for the part. This will also reduce the time taken to manufacture the part. Due to the reduced weight the rocket will be come lighter and therefore potential be able to take a higher payload, or it would be able to increase the rockets full consumption if the payload weight stays the same.

6 Appraisal of results

The results that have been formulated with in this report has been set with a number of known values given by (GrabCad, 2020) with one value which was the Shear Modulus that was found using the Datasheet (Stratasys, 2020). The optimisation of the part has been conducted in accordance to the known values but the loadcase have been applied in a way that will ultimately affect the topology.  26

The part was influenced by the author to concentrate the load over the two fixings and be able to keep the material roughly twice the diameter around the holes, the results gain from the optimisation run should not be used as a final design. The results should be used to do a re-design of the existing part, this redesign would benefit from another topology optimisation to see where further reduction of the material can be utilised to get a useable part.

If the result wasn't influenced by the concentrating the loadcase around the holes and setting up the regions to keep, the optimisation would be similar to what is shown in figure 26.

Although this result would be able to influence the design of the part the it appears that it has kept some un-necessary material which could be removed.

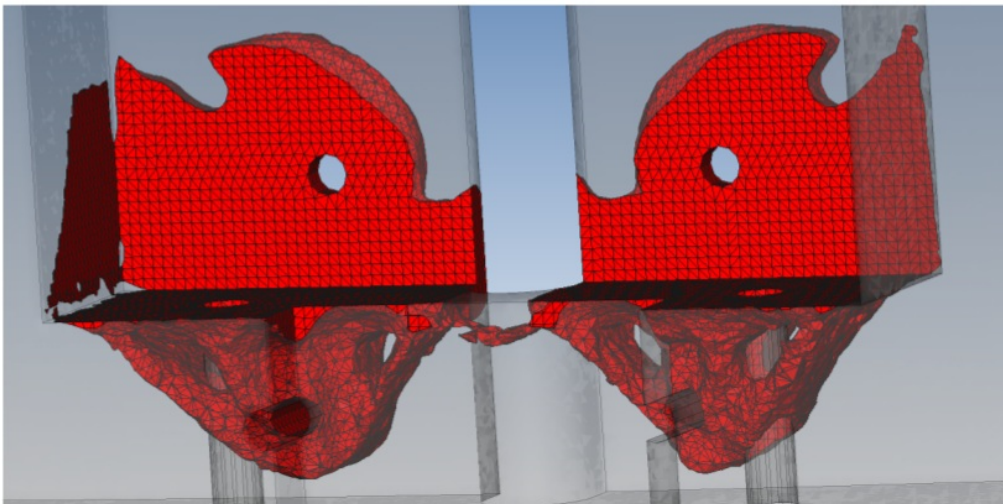


Figure 26: Uninfluenced topology result (*Cheeseman, 2020*).

7 Conclusion

From this report the given part is able to be optimised to 10% of the original part envelope. Although the static analysis is showing a high stress value of 73MPa which is over the maximum allowable stress of the material the high stress point is located on the boundary conditions where at least one node is fixed in 6 degrees of freedom. Due to this these elements have been disregarded due to their position within the structure, the rest of the model is showing an approximate value of 30MPa which is under the maximum allowable. The benefits of using an optimised part on the rocket will not only save on manufacturing costs for the part, but also on the time to manufacture the part. The topology of the part has been influenced by the author to ensure that the software kept specific areas of the component. The optimised part will be able to reduce the rockets overall weight, which intern will make the rocket more fuel efficient. With the bracket using less weight the rocket could be able to take on a larger payload.

 27

8 Recommendation

From the results gathered from the topology optimisation the recommendation would be to redesign the part based of the results, this report would recommend that a re-design is required to the original component based of the results obtained from the topology optimisation. The redesigned part would benefit in having another topology study preformed on it to ensure that it meets the requirements set for this part. The component would need to be designed using features such as fillets to be able to remove any potential stress concentrations, the use of ribs to add strength and the use of shell elements to remove any unnecessary areas.

9 References

- Adams, N., 2020. *ULA Bracket*. [Online]
Available at: <https://grabcad.com/library/ula-bracket-space-racer-1>
[Accessed 18 01 2020].
- Ansys, 2020. *Topology Optimization*. [Online]
Available at: <https://www.ansys.com/products/structures/topology-optimization>
[Accessed 18 01 2020].
- Chang, K.-H., 2015. *Design Theory and Methods Using CAD/CAE*, Amsterdam: Elsevier.
- Chapel Steel, 2020. *KSI-MPa*. [Online]
Available at: <https://www.chapelsteel.com/ksi-mpa.html>
[Accessed 18 01 2020].
- Cheeseman, M., 2020. *Topology Assignment*. [Art] (UWTSD).
- Convert Units, 2020. *lbf to N*. [Online]
Available at: <https://www.convertunits.com/from/lbf/to/N>
[Accessed 01 18 2020].
- Gandhele, V., 2020. *ULA Bracket*. [Online]
Available at: <https://grabcad.com/library/ula-bracket-26>
[Accessed 18 01 2020].
- GrabCad, 2020. *ULA Rocket Hardware Challenge*. [Online]
Available at: <https://grabcad.com/challenges/3-2-1-liftoff-ula-rocket-hardware-challenge>
[Accessed 12 01 2020].
- Just In Tools, 2020. *Unit Conversion*. [Online]
Available at: <https://www.justintools.com/unit-conversion/pressure.php?k1=psi&k2=meganewton-per-square-meter>
[Accessed 18 01 2020].
- Rapid Table, 2020. *Pounds to Kg Conversion*. [Online]
Available at: <https://www.rapidtables.com/convert/weight/pound-to-kg.html>
[Accessed 18 01 2020].
- Solidworks, 2020. *Mass Properties*, Vélizy-Villacoublay: Dassault Systèmes.
- Stratasys, 2020. *Ultem 9085 Data sheet*, Rehovot: Stratasys.
- Stratasys, 2020. *Ultem 9085*. [Online]
Available at: <https://www.stratasys.com/materials/search/ultem9085>
[Accessed 12 01 2020].
- ULA, 2020. *Atlas V*. [Online]
Available at: <https://www.ulalaunch.com/rockets/atlas-v>
[Accessed 20 01 2020].
- Vanderplaats R&D, 2020. *Design Studio for Genesis*, Colorado Springs: Vanderplaats R&D.

10 Appendix 1

Equation 1: Density Equation.

$$\text{Density} = \text{Specific Gravity} \times \text{Density of Water}$$

$$\rho = S \times 1000$$

$$\rho = 1.34 \times 1000$$

$$\rho = 1340 \text{ kg/m}^3$$

Equation 2: Mass equation for the envelope.

$$\text{Mass} = \text{Density} \times \text{Volume}$$

$$M = \rho \times V$$

$$M = 1340 \times 0.308e^{-3}$$

$$M = 0.412 \text{ kg}$$

Equation 3: Mass equation for the part.



$$\text{Mass} = \text{Density} \times \text{Volume}$$

$$M = \rho \times V$$

$$M = 1340 \times 30.63e^{-6}$$

$$M = 0.041 \text{ kg}$$

Equation 4: Mass percentage difference.

$$\text{Percentage Difference} = \frac{\text{Target Mass}}{\text{Envelope Mass}} \times 100$$

$$\text{Percentage Difference} = \frac{0.045}{0.412} \times 100$$

$$\text{Percentage Difference} = 10.9\%$$

Equation 5: Mass equation for the part.

$$\text{Percentage Difference} = \frac{\text{Part Mass}}{\text{Envelope Mass}} \times 100$$

$$\text{Percentage Difference} = \frac{0.041}{0.412} \times 100$$

$$\text{Percentage Difference} = 10.0\%$$

Rocket Bracket Assignment - Michael Cheeseman

GRADEMARK REPORT

FINAL GRADE

GENERAL COMMENTS

Instructor

62/100

PAGE 1



Comment 1

date?

PAGE 2



Comment 2

comma



Comment 3

Why does this start with a capital letter?



Comment 4

on the what? Proof read your work.

PAGE 3

PAGE 4



Comment 5

There is no need to reference yourself like this if you are presenting information for the first time.



Comment 6

Be consistent with your formatting.



Comment 7

provided



1. Material

The manufacturing process will mean that the resulting material will not be isotropic. What are the implications of this?



Comment 8

good



Comment 9

By applying the force directly to an area that you have defined you are pre-empting the design. Ideally you would apply the load to a 'platform' and then set up contacts between the platform and the bracket. Alternately you could have taken the udl and split this between the two holes. You are then allowing the topology to determine where material should be placed, rather than you defining this by choosing the area that the load is applied over.



Comment 10

is this 'bridge' actually needed? By applying the force in this location you have forced material to be placed here.



Comment 11

considered



Comment 12

used



Comment 13

were



Comment 14

were



Comment 15

Design Studio

PAGE 13



Comment 16

The lack of punctuation in this sentence makes it hard to read.



Comment 17

To

PAGE 14



Comment 18

Why did you choose 0.1? Did you try changing this?

PAGE 15



Comment 19

There is no need to add a step by step guide of which buttons you pressed. What does this image actually add this is not explained in the above paragraph?

PAGE 16

PAGE 17



Comment 20

Why do stress and displacement start with lower case letters, yet Strain starts with an upper case s?

PAGE 18



Comment 21

Do not start sentences with and.



Comment 22

Why do you think that Design Studio and Solidworks show such different answers?

PAGE 19

PAGE 20

PAGE 21

PAGE 22



Comment 23

This is a reasonable observation. It may be that your unrealistic boundary conditions have lead to larger stresses.

PAGE 23



Comment 24

Correct - the topology result should be used to INFORM your design - it does not give you a final design.



Comment 25

Why is this part not symmetrical - you have stated that you have added this constraint.

PAGE 24

PAGE 25



Comment 26

yes

PAGE 26



Comment 27

in turn

PAGE 27

PAGE 28



Comment 28

spelling

MICHAEL
CHEESEMAN

62.40

RESEARCH-INFORMED LITERATURE



12

KNOWLEDGE AND UNDERSTANDING



12.4

ANALYSIS



19.5

PRACT. APP. & DEPLOYMENT



13

SKILLS FOR PROF. PRACT.



5.5