University of Sydney

MECH3460: Mechanical Design 2

Finite Element Design Analysis

Part A - Bracket

Authors:

Vishant Prasad *470416309*

Contents

Design Brief

The primary objective of this investigation is to perform a revised final design upon a CAD modelled bracket structural member. Furthermore, the revised design of the part is to ultimately have a reduction upon maximum stress endured by the bracket when undertaking specified load and torque conditions. These conditions are highlighted below, alongside requirements of the design that this report will follow.

Specifications:

- Factor of Safety > 1.5 & < 3.0.
- Load $2kN$
- Torque $200Nm$
    - See *figure 1* for Illustration of Load & Torque (Purple & Red Arrows respectively).
- Aluminium Alloy Material.

Requirements:

- Mass is not Increased $\leq 166.98g$.
    - Final mass ideally reduced by a percentage factor of original.
- Bolt Holes within *figure 1* must be constrained.
    - Relative positions of the Main Bore & Bolt Holes.
    - 12mm Unbrako Socket Head Cap Screw used for reference.
- Selection of a suitable Manufacturing Method.

Assumptions:

- CAD Software used for Design – Solidworks 2019.
- Mass Production of Bracket Component.
- Cost is a Priority.

Key Terms – *Solidworks, CAD, Bore, Bracket, Bolt, Factor of Safety*.

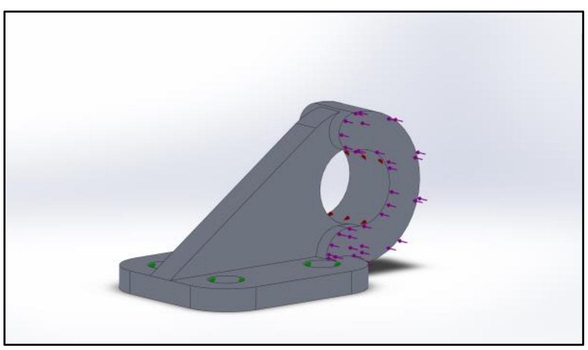


FIGURE 1 - SPECIFICATIONS OF LOAD & TORQUE

Executive Summary

The final design is illustrated in the *figures 2* and *3* below. It was denoted through results mentioned more specifically in the methodology of this report and project, that the maximum stress, displacement, material cost and mass was reduced however, the FOS was not able to be adjusted into the specified range. The material selected is **Aluminium Alloy AA380.0 – F**

die with manufacturing method of **casting**. The current FOS has been minimised to 0.86 and an estimated material cost of 1.21 AUD.

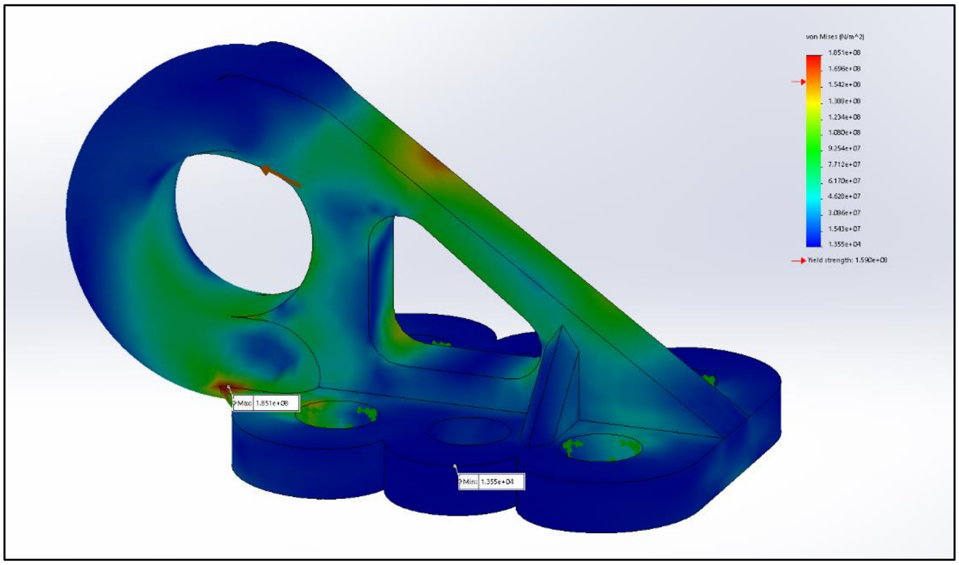


FIGURE 2 – STRESS PLOT

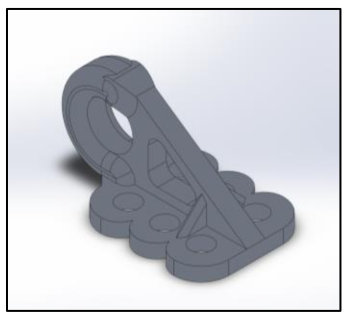


FIGURE 3 - VIEW 2

Method

Manufacturing Considerations

The material employed for the bracket component is required Aluminium Alloy, more specifically the exact material employed onto the redesign of the component is **Aluminium AA380.0-F die Alloy**.

Specification	Value	Units
Elastic Modulus	*71000*	N/mm^2
Poisson's Ratio	*0.33*	N/A
Shear Modulus	*26500*	N/mm^2
Mass Density	*2760*	kg/m^3
Tensile Strength	*317*	N/mm^2
Yield Strength	*159*	N/mm^2
Thermal Expansion Coefficient	*2.12e-05*	$/K$
Thermal Conductivity	*109*	W/mK
Specific Heat	*963*	J/kgK
Material Damping Ratio	-	N/A

FIGURE 4 - AA380.0F DIE PROPERTIES

From the properties specified concerning this material, it has been decided that this material will suit the manufacturing method of **casting**. Furthermore, the table below denotes a comparison between majority of viable methods with this material. [6]

Specification	*CNC Machining*	*Casting*	*Fabrication Welding*	*Thin Sheet Metal Forming*
Tool Cost	LOW	MODERATE	LOW	MODERATE
Unit Cost	LOW	MODERATE	HIGH	HIGH
Added Machining	MODERATE	MODERATE	HIGH	HIGH
Lead Time	LOW	MODERATE	LOW	MODERATE
Size Range	MODERATE	MODERATE	HIGH	HIGH
Metal Selection	MODERATE	HIGH	MODERATE	MODERATE
Surface Finish	MODERATE	HIGH	LOW	MODERATE
Tolerance Control	MODERATE	HIGH	MODERATE	MODERATE
Design Freedom	HIGH	HIGH	MODERATE	LOW

FIGURE 5 - MANUFACTURING METHOD COMPARISON

Since the cost has not been defined in the requirements or specifications and measures will be taken to reduce mass and therefore, directly translate to manufacturing cost, it is acceptable to employ **casting** as the manufacturing method employed within production of this component. Furthermore, requirements and objectives of this redesign is to minimise stress values and reduce consequential negative effects of load and torque, therefore, employing **die casting** would allow for greatest results in terms of quality of component. [1]

Furthermore, with a large production of these parts casting would be the viable option as there would be greater consistency in quality. In contrast, if this bracket was employed for a smaller batch size of production then utilizing **CNC Machining** would be preferable. [2] Hence, for this redesigning of the bracket component the employed method of manufacturing is **casting**. [3]

With the range of options for casting such as sand, die and permanent mould casting, it would recommend that **die casting** is the most viable as it would fit high-volume production such as brackets of this nature. Furthermore, it can be reasonably assumed that the bracket would require minimal machining and finishing, while also be produced with precision for the Head Cap Screw as mentioned earlier.

Material Selection

The selection of material being aluminium is preferrable as in comparison to other conventional metal options, aluminium provides a lower manufacturing cost. Furthermore, aluminium is easier to cut and provides lower maintenances costs. Other options on processing is possible with aluminium such as wax, low corrosion, weight-to-strength ratio, high ductility, and thermal conductivity. The material can also have a range of finishes applied such as anodizing, powder and liquid paint common for such applications. [5]

The properties of **Aluminium AA380.0-F die Alloy** is denoted in *figure 2*. The main properties are also redefined below in *figure 4*.

Properties	Value	Units
Elastic Modulus	*71000*	N/mm^2
Mass Density	*2760*	kg/m^3
Tensile Strength	*317*	N/mm^2
Yield Strength	*159*	N/mm^2

FIGURE 6 - KEY PROPERTIES OF AA380.0-F DIE

The reason why this is a viable selection for die casting manufacturing is due to:

- Yield strength being relatively low.
    - Controllable FOS within range.
- Material being compatible with casting manufacturing methodology.
- Material is relatively cheap, reducing overall cost with redesign.
- Resistance to hot cracking.

Load Specifications

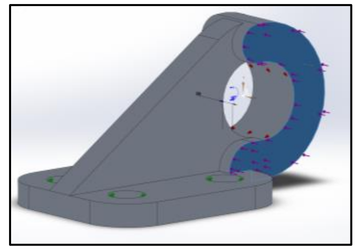
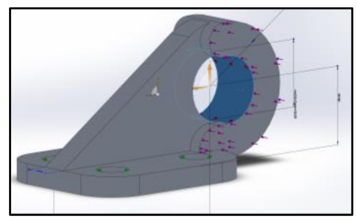
Load Type	Details	Location
Force	- *Entities:* Single Face - *Type:* Normal to Face - *Magnitude:* -2000N	 7 - FORCE
Torque	- *Entities:* Circular Face - *Type:* Torque along Axis (1) - *Magnitude:* 200Nm	 8 - TORQUE

FIGURE 9 - LOAD APPLIED TO PART

Original Design

The following defines the original stress and displacement with the load applied onto the part:

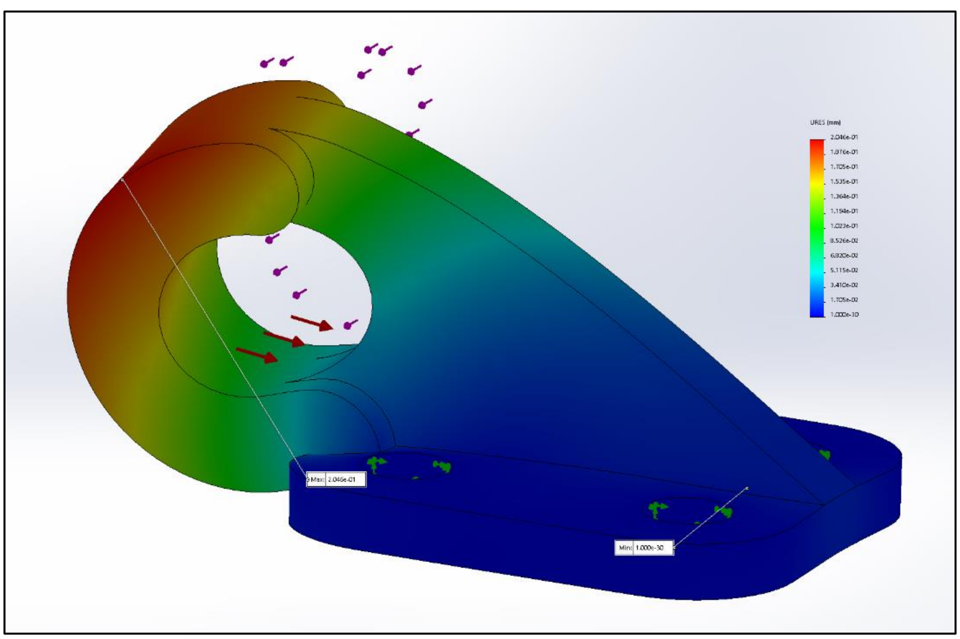


FIGURE 10 - DISPLACEMENT PLOT - ORIGINAL DESIGN

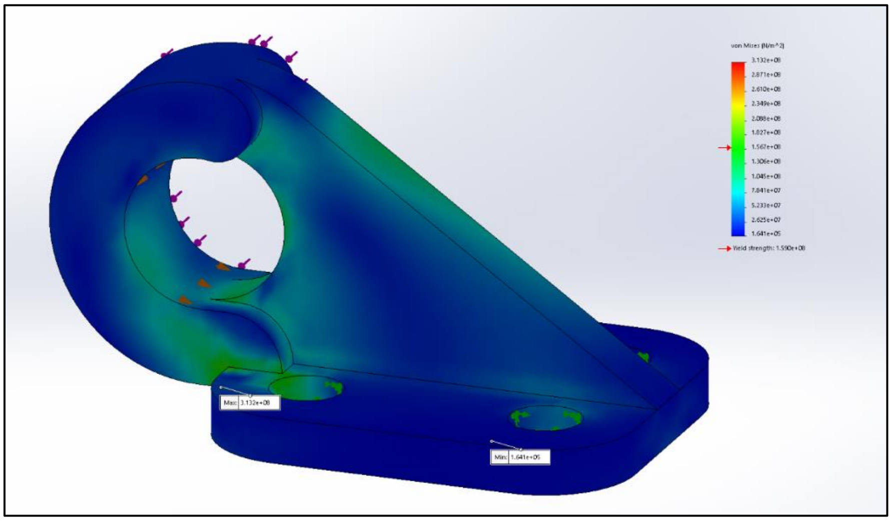


FIGURE 11 - STRESS PLOT - ORIGINAL DESIGN

DESIGN TABLE 1 - ORIGINAL DESIGN RESULTS

Maximum Stress (N/m^2)	**Maximum Displacement** (mm)	**Minimum FOS** $(nearest\ 2dp)$	**Mass** (g)	**Estimated Material Cost** (AUD)
$\mathbf{3.132 \times 10^8}$	2.046×10^{-1}	0.51	166.98	1.41

This is the baseline part as given in the problem statement. From *figure 8* and *figure* 9, the part appears to endure stress in the lower rear left section as depicted by the labels. Correspondingly, there is a high displacement in the upper rear region of the component. From the current results of stress and displacement, the redesign or iteration one should aim to decrease the maximum stress and maximum displacement when undergoing this identical load. Furthermore, the FOS must be increased to approximately 1.5 at least.

Design Iteration 1

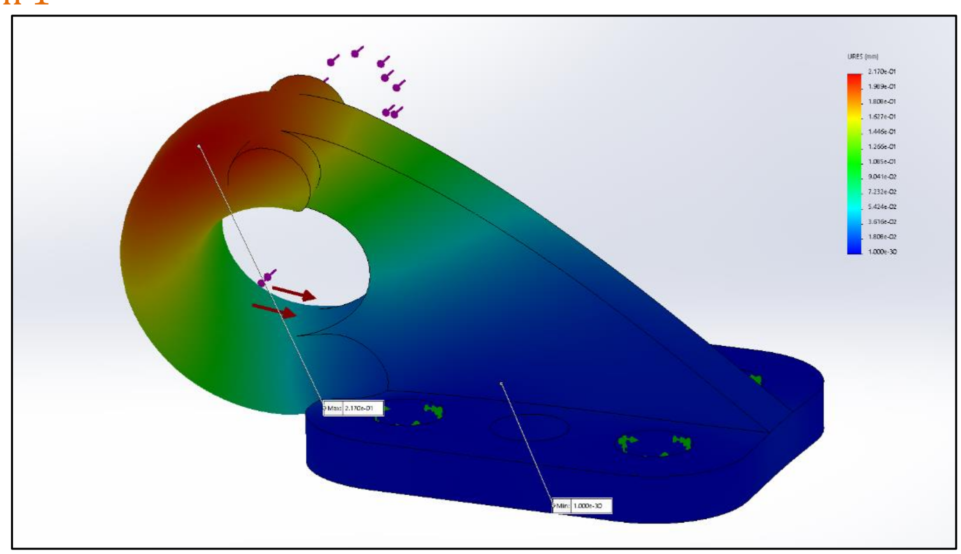


FIGURE 12 - DISPLACEMENT PLOT – DESIGN 1

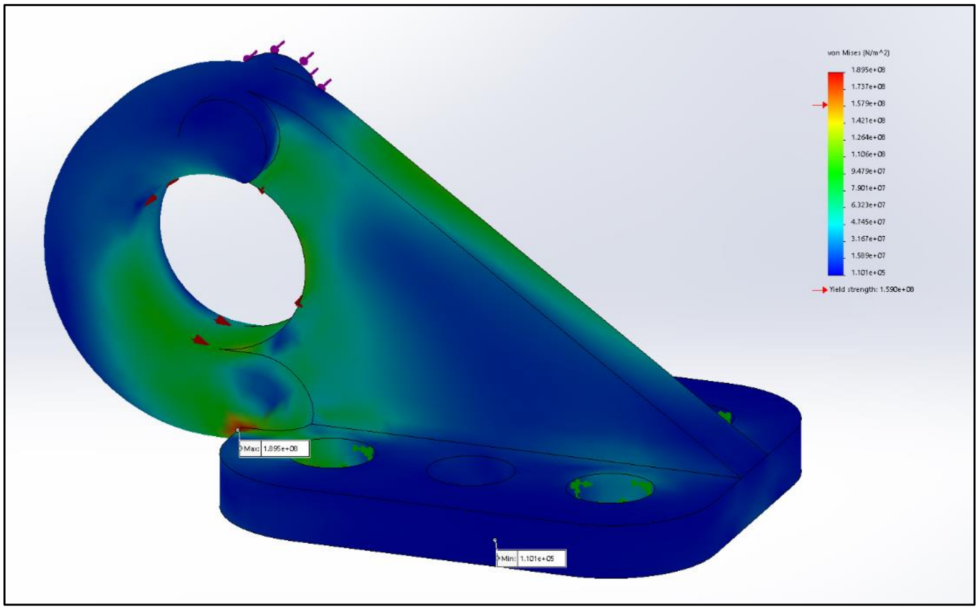


FIGURE 13 - STRESS PLOT - DESIGN 1

DESIGN TABLE 2 – DESIGN 1 RESULTS

Maximum Stress (N/m^2)	**Maximum Displacement** (mm)	**Minimum FOS** $(nearest\ 2dp)$	**Mass** (g)	**Estimated Material Cost** (AUD)
$\mathbf{1.895 \times 10^8}$	2.170×10^{-1}	0.84	156.97	1.33

From the data collated from design iteration one displayed in the above *figures 10* and *11*, the bracket redesign includes curvature and filleting of the face where force is applied and mirrored onto the opposite face. This design decision has been made as the force will have application on a less linear face and therefore, result in a lower maximum stress experienced by the location identified on the *figures* above.

The design has had a reduction in maximum stress by a 60% and the minimum FOS has been increased to 0.84, closer to the desired 1.5. Furthermore, the mass has been reduced, but improvements can be made to reduce greater weight.

Design Iteration 2

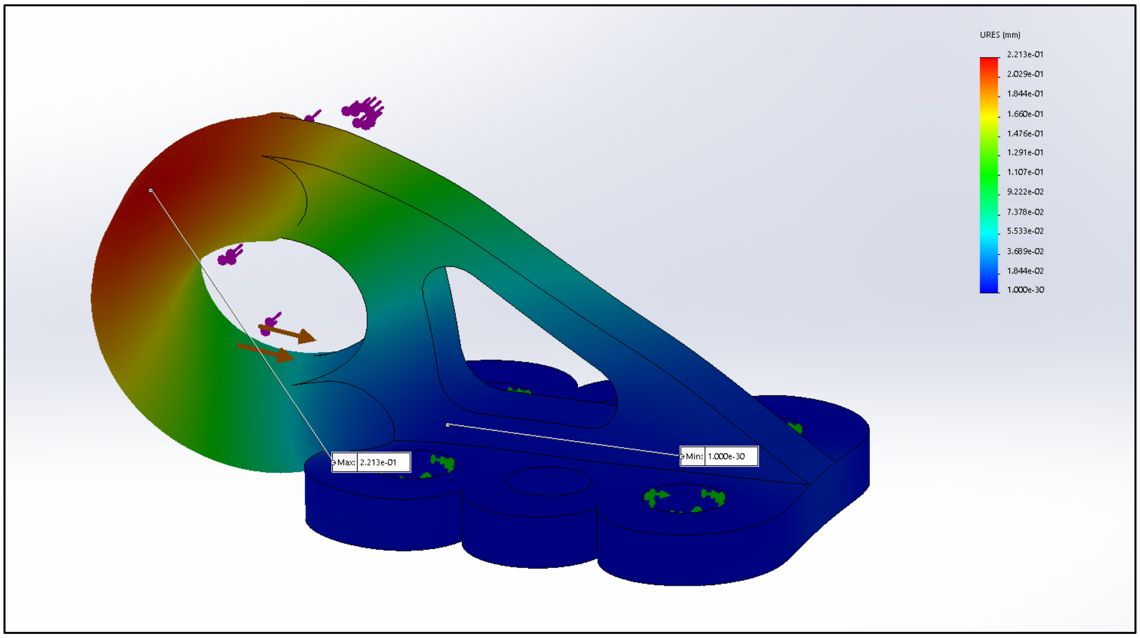


FIGURE 14 - DISPLACEMENT PLOT - DESIGN 2

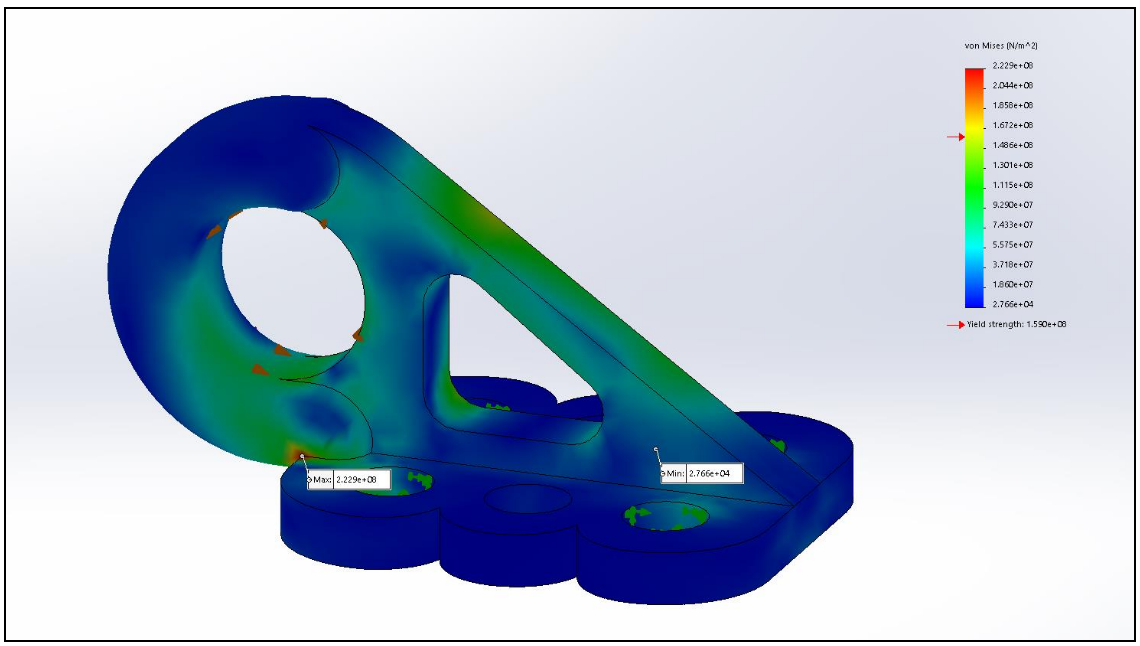


FIGURE 15 – STRESS PLOT - DESIGN 2

DESIGN TABLE 3 - DESIGN 2 RESULTS

Maximum Stress (N/m^2)	Maximum Displacement (mm)	Minimum FOS $(nearest\ 2dp)$	Mass (g)	Estimated Material Cost (AUD)
$\mathbf{2.229 \times 10^8}$	2.213×10^{-1}	0.71	141.36	1.19

With further redesign, we have material cost through Solidworks estimation reduced and weight reduced. In contrast, this design has increased maximum stress results in comparison with design iteration one and a reduction in FOS out of the desired range. Furthermore, the maximum displacement has been increased. A priority at this stage would be to lower maximum stress and displacement and increase FOS while maintaining a similar mass and material cost. This redesign specifically involved removing a section of the main vertical body of the bracket and cutting a relatively large section of the base with proper regard and consideration to the area of the bolt in this case being, the 12mm Unbrako Socket Head Cap Screw used for reference.

Design Iteration 3

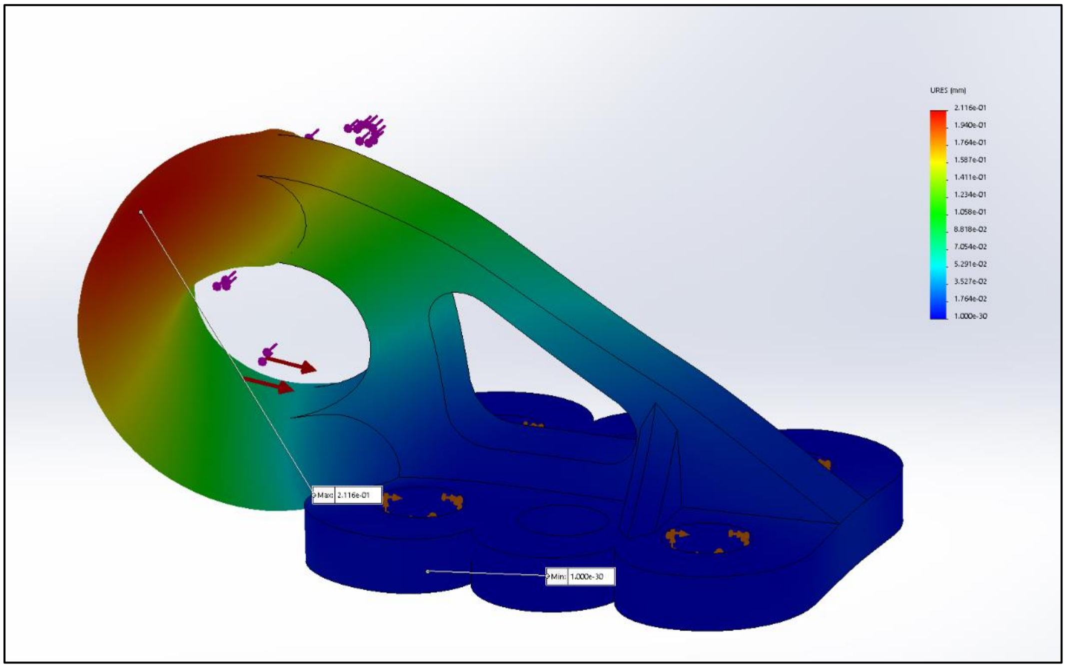


FIGURE 16 - DISPLACEMENT PLOT - DESIGN 3

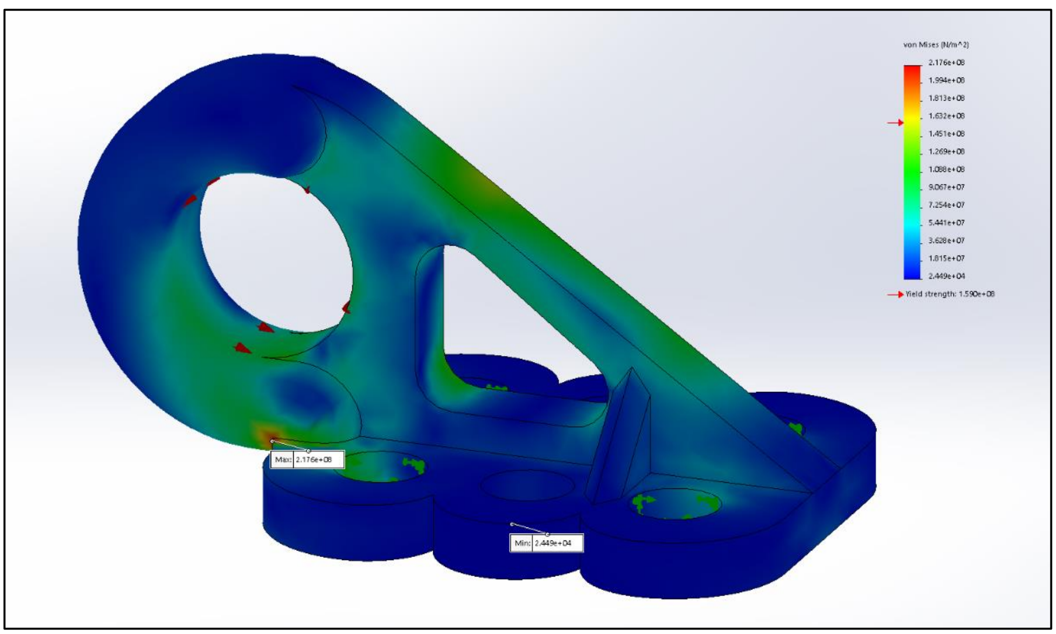


FIGURE 17 - STRESS PLOT - DESIGN 3

DESIGN TABLE 4 - DESIGN 3 RESULTS

Maximum Stress (N/m^2)	**Maximum Displacement** (mm)	**Minimum FOS** $(nearest\ 2dp)$	**Mass** (g)	**Estimated Material Cost** (AUD)
$\mathbf{2.176 \times 10^8}$	2.116×10^{-1}	0.73	143.75	1.21

This is the third iteration of the bracket redesign. This redesign involved addition of webbing in the body of the bracket as well as smoothing or filleting near the stress point to act almost as a web for the maximum stress point denoted on the *figure 14* and *15*. This is the final redesign attempt with now the final design to be selected. This design has denoted results of an increase from FOS in comparison with design iteration two however, not as effective as design iteration one. FOS is a priority of concern as this value has still not been able to be increased to the range.

Final Design

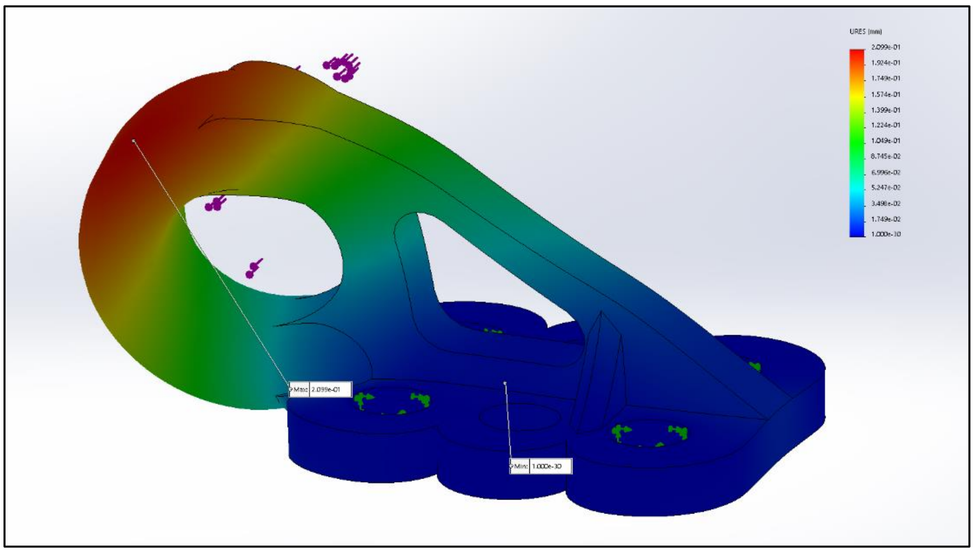


FIGURE 18 - DISPLACEMENT PLOT - FINAL DESIGN

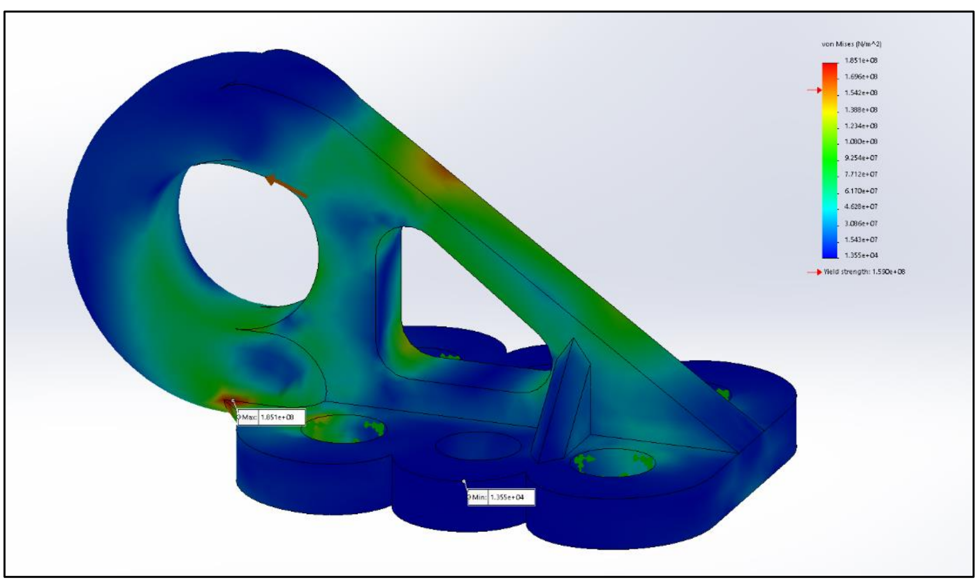


FIGURE 19 - STRESS PLOT - FINAL DESIGN

DESIGN TABLE 5 - FINAL DESIGN RESULTS

Maximum Stress (N/m^2)	**Maximum Displacement** (mm)	**Minimum FOS** $(nearest\ 2dp)$	**Mass** (g)	**Estimated Material Cost** (AUD)
$\mathbf{1.851 \times 10^8}$	2.099×10^{-1}	0.86	145.19	1.21

TABLE 6 - COMPARISON OF RESULTS – ORIGINAL VS ITERATIONS

Maximum Stress (N/m^2)	**Maximum Displacement** (mm)	**Minimum FOS** $(nearest\ 2dp)$	**Mass** (g)	**Estimated Material Cost** (AUD)
$\mathbf{3.132 \times 10^8}$	2.046×10^{-1}	0.51	166.98	1.41

Design	**Feature**	**Change in Stress** (%)	**Change in Displacement** (%)	**Change in FOS**	**Change in Mass** (%)
Bassline	Original Features	-	-	0.51	-
1	Fillet/Chamfer Hole	−39.50	106.06	+0.33	−6.00
2	Middle Body Cut Cut Edges Fillet Top Section	−28.83	108.16	+0.20	−15.34
3	Webbing Rear Section Fillet	−30.52	103.42	+0.22	−13.91
Final Design	Larger Rear Section Smoother Fillet Top Larger Top Section	−40.90	102.59	+0.35	−13.05

As denoted from the results the final redesign of the bracket has been achieved through integrating the most effective design decisions off the previous iterations. This final design involves adjusting the webbing or filleting near the maximum stress point by using a chamfer and additionally, adjusting the rib of the upper section of the bracket, in comparison with design iteration three primarily. Therefore, this has allowed a greater reduction in maximum stress and displacement, in comparison with other design iterations. Furthermore, the final design can increase the minimum FOS to 0.86, however is still not able to be adjusted to fit the required 1.5 minimum FOS requirement. A breakdown of the FOS can be seen visually in *figure 18*. Finally, there has been no addition to the original mass, in fact there has been a successful reduction in weight with the current weight being a reduction of 13.05%.

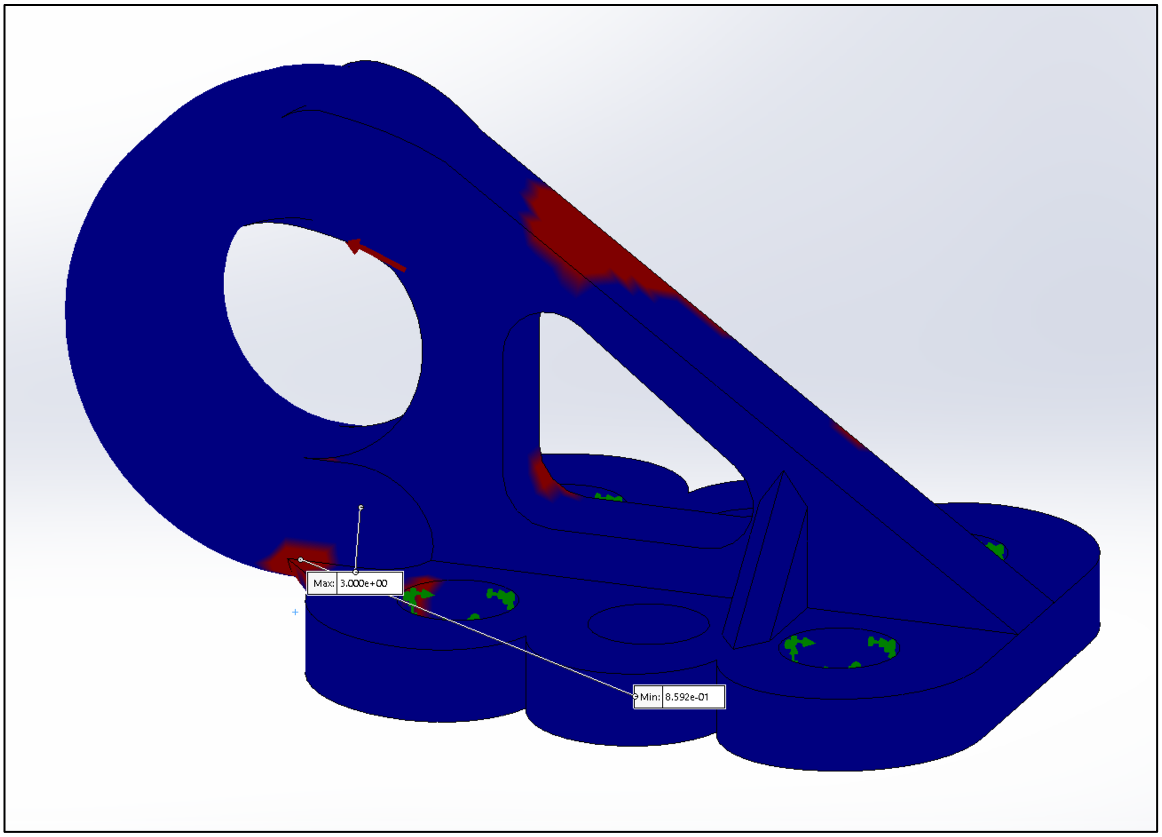


FIGURE 20 - FOS - FINAL DESIGN

Conclusion

The final design that has been selected meets most of the requirements defined as apart of the project however most notably, the minimum FOS has not been able to be adjusted to the range required via redesign of the bracket. Therefore, focusing on the reduction of the minimum FOS and coinciding with the set requirements, recommendations for future redesign of this bracket includes readjusting the base design, that would include moving the rear underside of the bracket to overlap the maximum stress area, as denoted on multiple *figures* above, while also adding further webbing potentially from more directions. Furthermore, shelling can be used on webs to reduce mass, materials used and cost of material. Finally, the specified material selection coincides with the manufacturing method of casting selected.

References

[1] Anon, Castings. *Aluminum Castings - The Aluminum Association*. Available at: https://www.aluminum.org/industries/processing/castings [Accessed August 20, 2021].

[2] Anon, Metal fabrication Method Quick Comparison Chart. *Metal Fabrication Comparison Chart - Metal Casting Chart*. Available at: https://www.aerometals.com/metal-casting-101/methods/#forging [Accessed August 27, 2021].

[3] Author, 2018. The Differences between Die Casting & CNC Machining: Die Casting. *Die Casting Blog*. Available at: https://diecasting.com/blog/die-casting-vs-machining [Accessed August 20, 2021].

[4] Brennan, J., 2019. Metal forming Vs. Casting. *HomeSteady*. Available at: https://homesteady.com/info-12146962-metal-forming-vs-casting.html [Accessed August 20, 2021].

[5] EMP Tech Co. Ltd ed., 2020. A380 Die Cast Aluminum Properties. *A380 Die Cast Aluminium Properties*. Available at: https://www.empcasting.com/a380-die-cast-aluminum-properties.html [Accessed August 20, 2021].

[6] Anon, MatWeb. *Aluminum A380.0-T5 - Casting alloy*. Available at: http://www.matweb.com/search/datasheet_print.aspx?matguid=7441a0886ba142cc82eb7af5d4eece6d [Accessed August 25, 2021].