ENME406

Engineering Product Design and Analysis

Homework 2 – Structural Analysis by ANSYS

Structural Analysis of a Seatbelt Buckle

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Objective

The aim of this assignment is to perform structural analysis on a chosen part using ANSYS. A seatbelt buckle was modelled in 3D using Solidworks, and imported into ANSYS workbench where Static Structural analysis was undertaken.

The basic geometry of the tongue plate was taken from an existing design, and was then refined through various approaches to reduce weight and/or increase performance. The results of this analysis were then discussed, and conclusions were drawn.

Known Data and Assumptions

The base geometry used was from an existing 2-inch buckle from Taiwanese manufacturer Yoyee[1. It was assumed that this buckle was made from A36 structural steel, as the Yoyee website simply lists the material as 'Steel'.

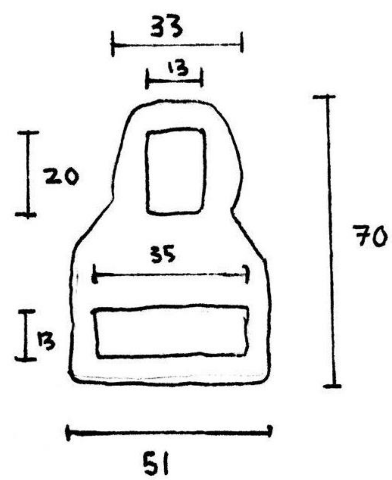


Figure 1: *Basic 2-inch buckle geometry*

A standard 48mm seatbelt webbing is able to support loads of up to 3kN[2], thus it was decided that the tongue plate needed to support the same load at the least.

List of Tasks

In order to improve the existing design, two separate investigations were undertaken. This first looked at the possibility of changing the material of the tongue plate to reduce weight, and increase performance. The second study investigated the effects of changing the geometry of the buckle to reduce stress concentrations and/or weight.

Contribution

James – Created base geometry and setup the initial study in ANSYS workbench.

Chris – Completed study on changing the geometry of the tongue plate

George – Completed study on changing the material of the tongue plate

Preliminary Solution

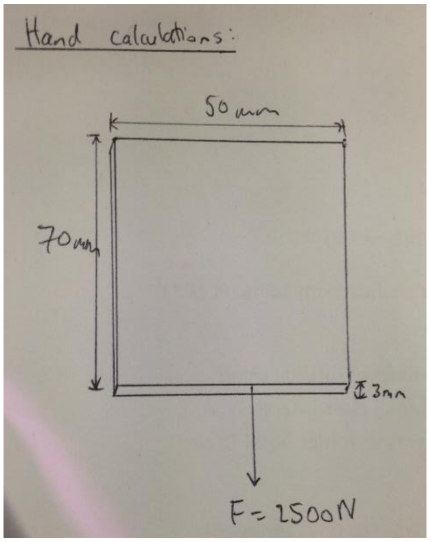


Figure 2: Geometry for hand calculations

Hand Calculations:
Objective: to get a rough idea of the deflection of the part

E = σ /ε = (F/A) / (e/L) = F*L / A*e

therefore := e = (F*L)/(A*E)

Structural steel: E = 450 MPa
e = (2500N * 70x10^-3m) / ((70x10^-3 * 3x10^-3)m * 450x10^6 Pa)
e = 1.852 mm deflection

Titanium Alloy: E = 930 MPa

e = (2500N * 50x10^-3m)/((70x10^-3 * 3x10^-3)m * 930x10^6 Pa)
e = 0.896 mm deflection

Results and Discussion

Changing Geometry

As well as changing the material of the buckle, investigation was made to see how changes to the geometry can affect the strength of the buckle. The initial geometry with the relevant measurements in mm is shown in Figure 2.

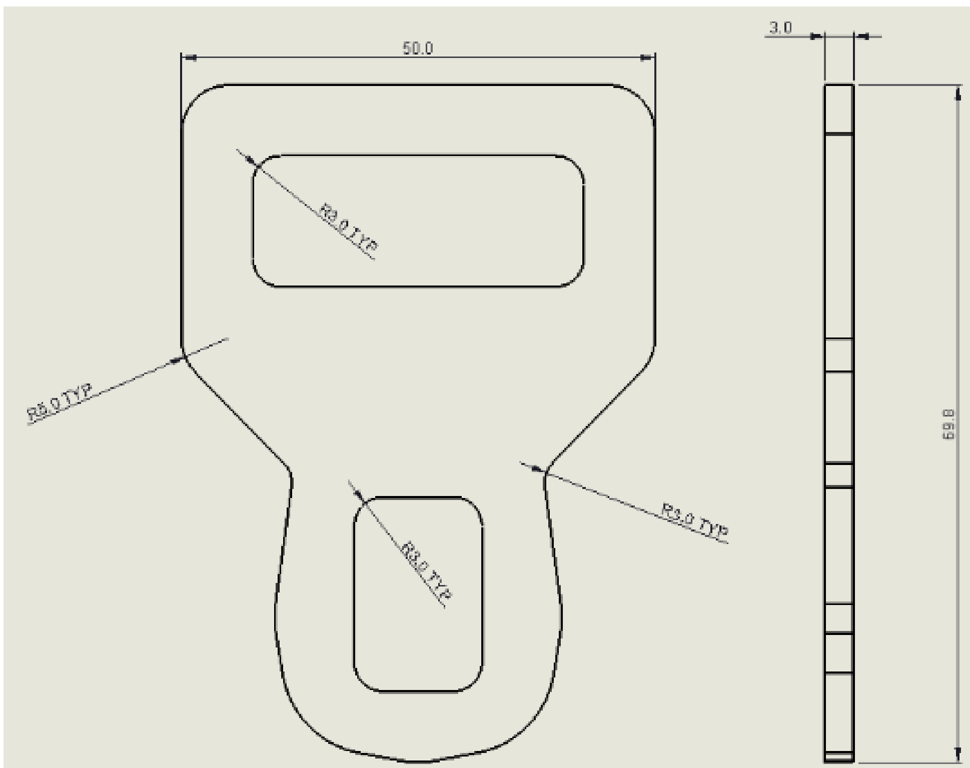


Figure 3: *Initial geometry of tongue plate*

Figure 3 shows the base test for equivalent stress. After some initial early studies it was shown to be more efficient to change the shape of the buckle as opposed to changing its thickness to increase the strength.

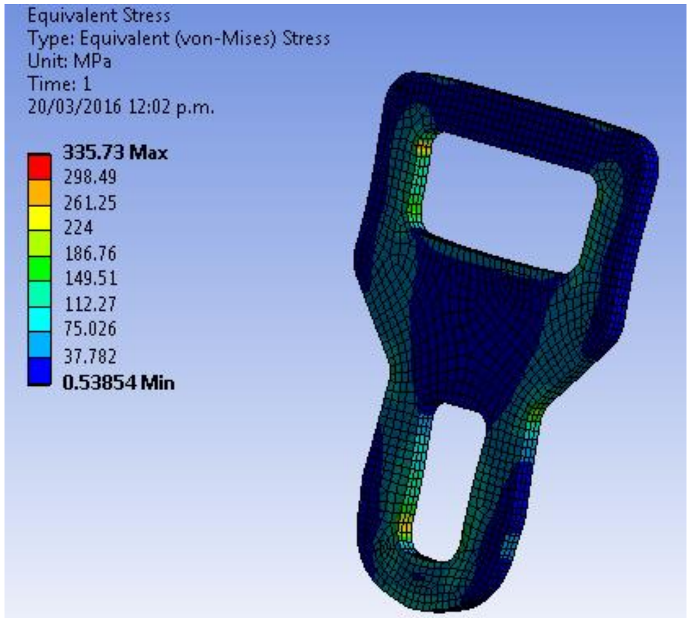


Figure 4: *Stress test with initial geometry*

It is visible in Figure 3 that the highest stress concentrations occur in the bottom two and top two inside fillets. Because of this, these will be the locations where change in geometry will be made.

Three different fillet sizes were chosen to be tested at both the top two and bottom two inside fillets: 3mm, 5mm and 7mm. The reason that 7mm was chosen as the maximum size was because at 7mm the fillets create a half circle at the bottom of the buckle. 5mm was chosen because it is situated at half way between 3mm and 7mm. Table 1 shows the results gathered from these combinations.

Table 1: *Maximum equivalent stresses with variations in geometry*

Maximum equivalent stress (MPa)				
		Top fillet sizes		
		3mm	**5mm**	**7mm**
Bottom fillet sizes	**3mm**	**335.73**	309.10	297.83
	5mm	329.92	309.28	280.40
	7mm	331.09	312.80	**264.17**

Figure 4 shows the stress concentrations in the buckle with 7mm fillets at the top and bottom. Compared to the original geometry of 3mm fillets at the top and bottom there is a difference between the maximum equivalent stresses in the buckle of 71.56MPa.

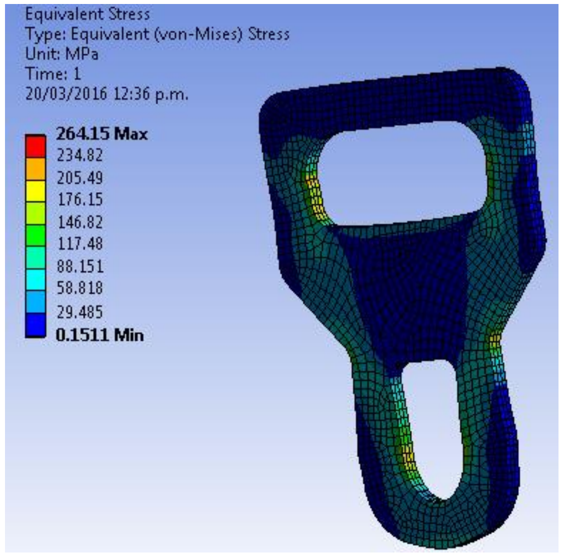


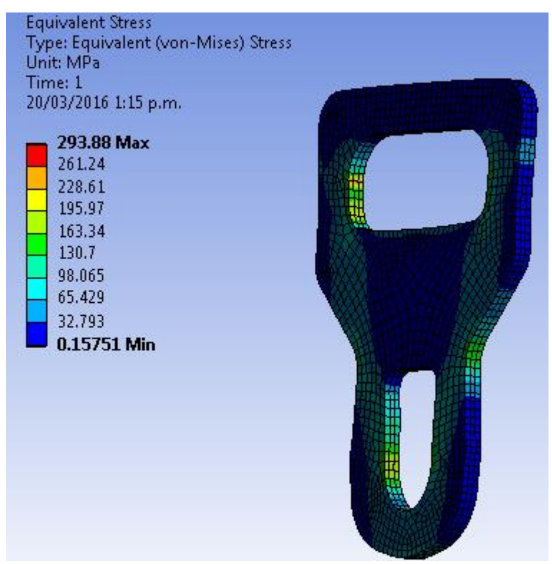
Figure 5: *Tongue plate with 7mm fillets*

The third area that contains high stress levels is the midpoint of the tongue plate where the buckle goes from being roughly 33mm in width to 50mm in width. Whilst keeping the optimal fillet sizes that have been concluded previously, the fillet sizes at this are were then increased from tested from 2mm to 7mm.

Table 2: *Maximum equivalent stress for different fillet sizes*

	Middle fillet size				
	2mm	3mm	5mm	7mm	9mm
Max equivalent Stress (MPa)	281.22	**264.17**	**293.88**	279.45	279.75

Table 2 show that 3mm is the best fillet size for this area of the buckle with 5mm giving the largest of the results for max equivalent stress. This study is shown in Figure 5 below.



Due to the testing carried out it was possible to improve the maximum equivalent stress exerted on the buckle by 71.56 MPa. Figure 6 shows the suggested new geometry of the buckle design.

Figure 5: *Tongue plate with 3mm fillets*

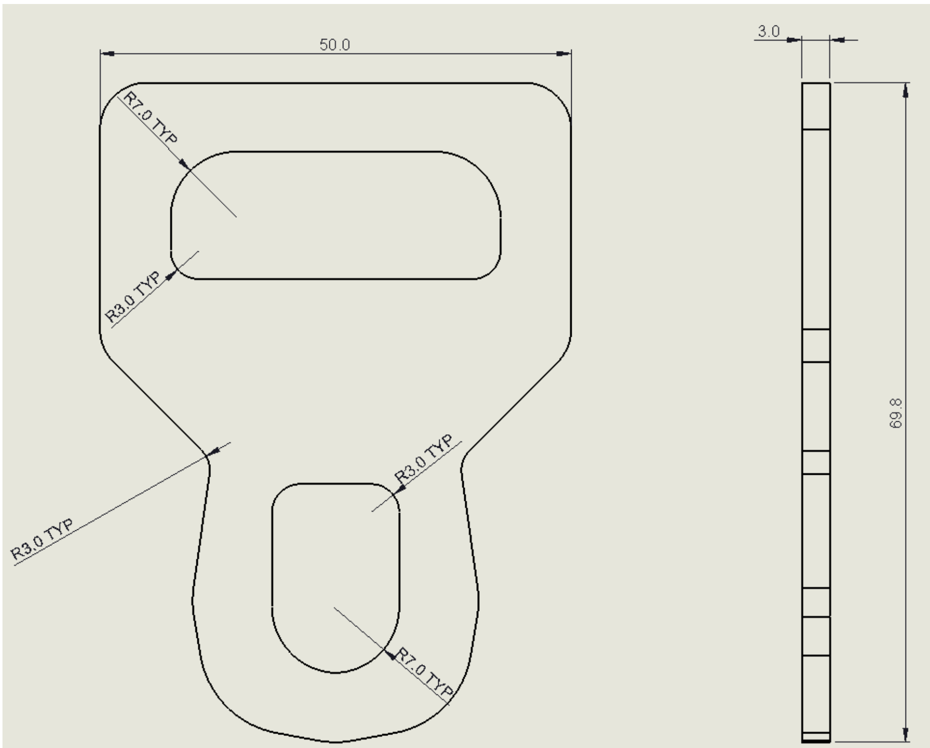


Figure 6: *Proposed buckle design*

Changing material

The part geometry was modelled using ANSYS and the material properties were altered to investigate which material would be the most suitable. The materials investigated were structural steel, stainless steel and aluminium alloy for the geometry with the 3 mm fillets. Table 3 below displays the results of the material investigations.

Table 3: Performance of the seat-belt buckle with varying materials

Material	**Elastic Modulus (tensile)**	**Total deformation**	**Max. Equivalent Strain**	**Max. Equivalent Stress**
Structural Steel	250 MPa	0.0321 mm	0.0022 mm/mm	360.9 MPa
Stainless Steel	210 MPa	0.0336 mm	0.0012 mm/mm	234.5 MPa
Aluminium Alloy	280 MPa	0.091 mm	0.0044 mm/mm	273.35 MPa
Titanium Alloy	930 MPa	0.067 mm	0.0046 mm/mm	360.17 MPa

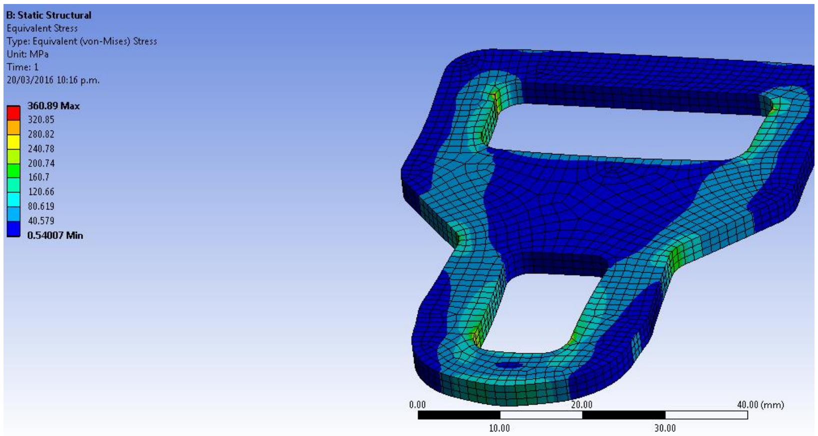


Figure 7: Structural Steel

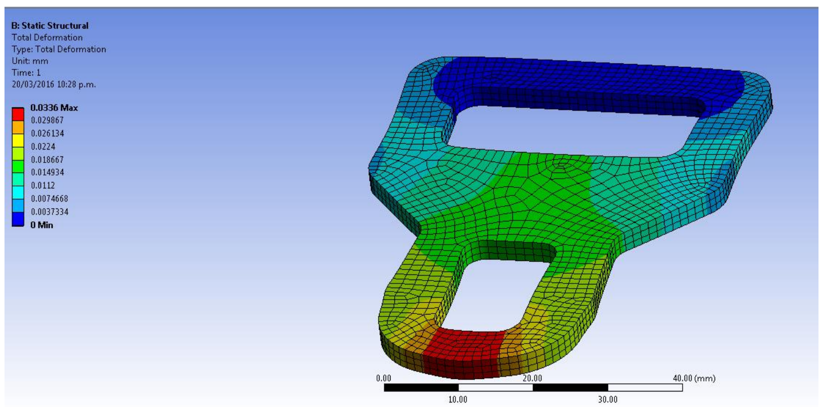


Figure 8: Stainless Steel

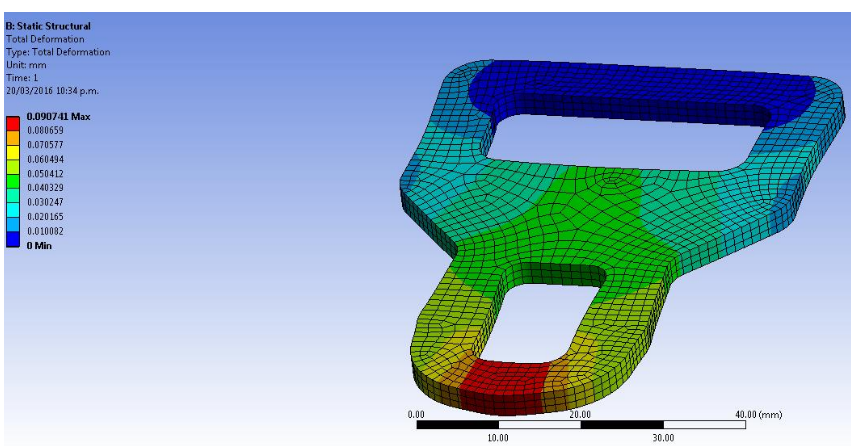


Figure 9: Aluminium Alloy

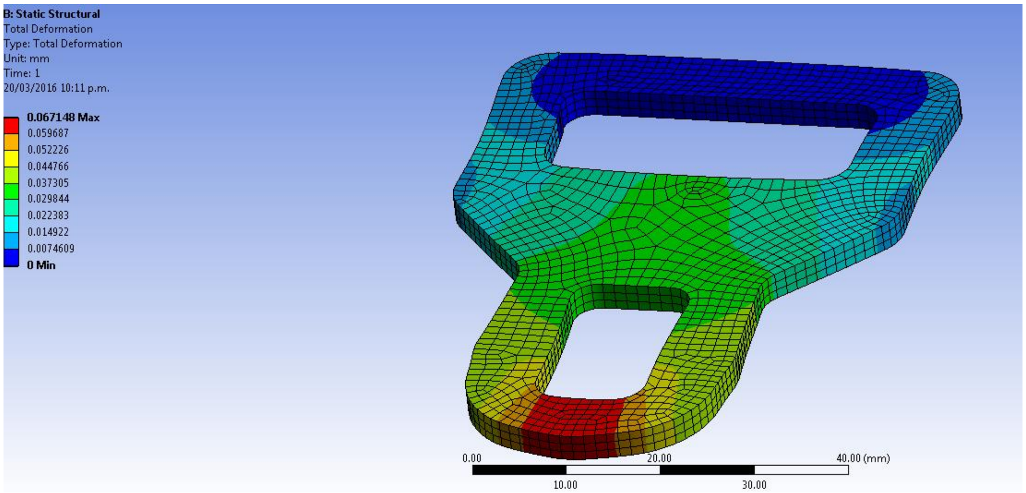


Figure 10: Titanium Alloy

The material that was determined to be the most suitable for the seat belt buckle part was Aluminium Alloy because the yield strength was above the maximum equivalent stress. It was not unnecessarily strong for the application which was a positive factor for manufacturability. If the part is not overly strong for its application then cost saving is enabled through the production processes.

Real Life Applications

The real life applications of the seat-belt buckle are plain to see in modern transport systems used by billions of people in everyday life. There is a direct correlation between the wearing of seat-belts in vehicles and the lowered likelihood of injury in the case of an accident. The seat-belt buckle is an integral component of this safety system which is employed in cars, trains and aviation solutions.

Appendices

[1] http://www.yoyee.com.tw/products_detail.asp?seq=313

[2] http://www.takata.com