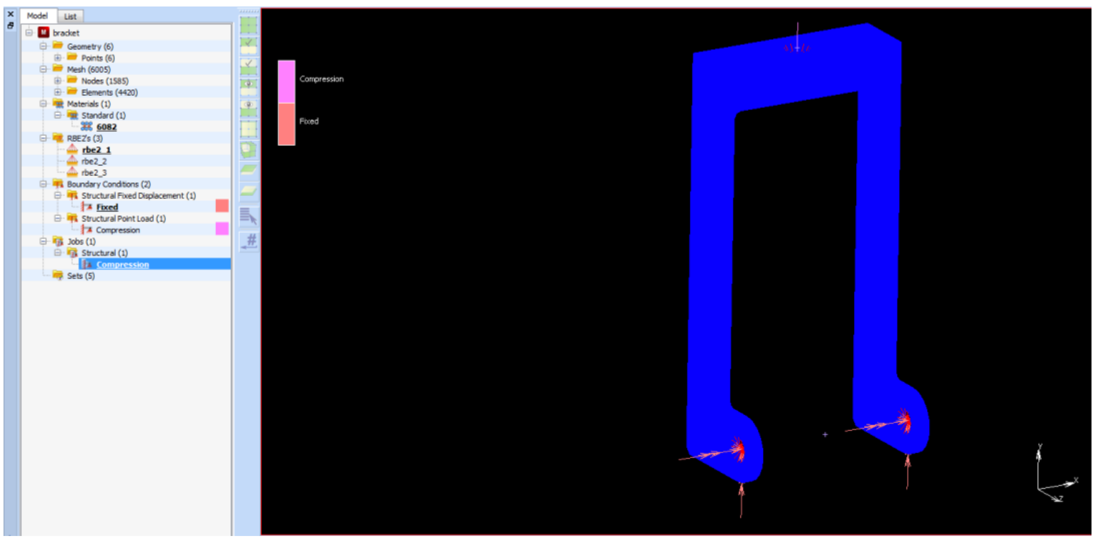
Biomedical Advanced And Computational Stress Analysis Coursework #2

Question 1:

Below can be seen the FE model of the bracket under a 500 N in compression.



In order to achieve this model I imported the stl file of the bracket onto the Marc Mentat software, clicking Fem in the option tab. Once the file loaded in the program I went onto Surfaces under the Geometry & Mesh tab and re-meshed the bracket with an element size of 3 to start with. After this I made the elements of the mesh tetrahedral instead of triangular in the Volumes sections, also under the Geometry & Mesh tab . After that, I added RBEs at the three holes to connect all the elements at the inner faces of the hole to a reference point where the boundary conditions would be applied to. Then I fixed the RBEs in all directions and rotation axes at the bottom and applied a compressing force of – 500 N in the Y- direction at the top. Finally, I added the material properties of 6082 T4 aluminium allow I found online[1].

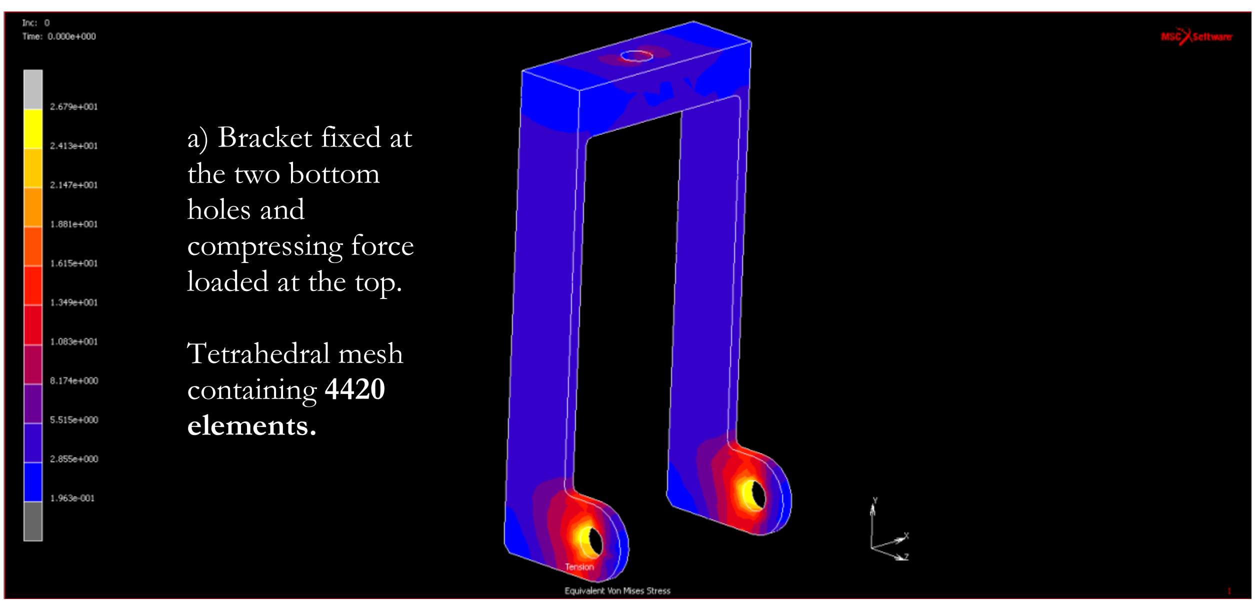
Question 2:

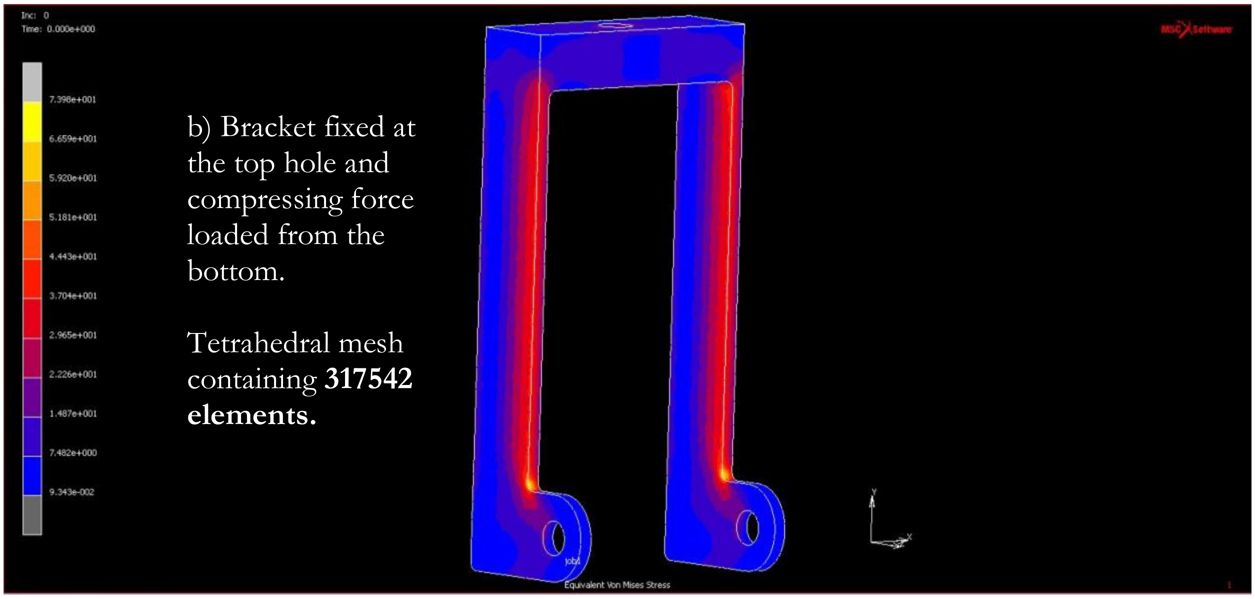
As stated before I first applied the force at the top and fixed the bracket at the bottom holes, as this seemed more intuitive as a loading scenario (Reaction forces at the bottom and weight facing downwards). I decided to try the loading scenario in the opposite way, I fixed the top RBE and applied half the compressing load at each of the bottom holes, the results were different:

		Mesh by Dr. Masouros (force on top support at bottom)	Mesh by Dr. Masouros (force at bottom support at top)
	Element size	Unknown	unknown
	Number of Nodes	1585	1585
	Number of Elements	4420	4420
Compression	Max Von Mises stress	26.79	31.95
	Max principal stress	16.72	21.07
	Min principal stress	-16.33	-37.41
	Max principal shear stress	14.38	16.29
Tension	Max Von Mises stress	16.07	19.17
	Max principal stress	9.797	22.44
	Min princpial stress	-10.03	-12.64
	Max principal shear stress	8.625	9.773

Table 1: Comparison of the two different loading scenarios under compression(500 N) and tension (300 N)

Figure 1: Comparison of the stress distribution of the two different loading scenarios under compression (500 N)



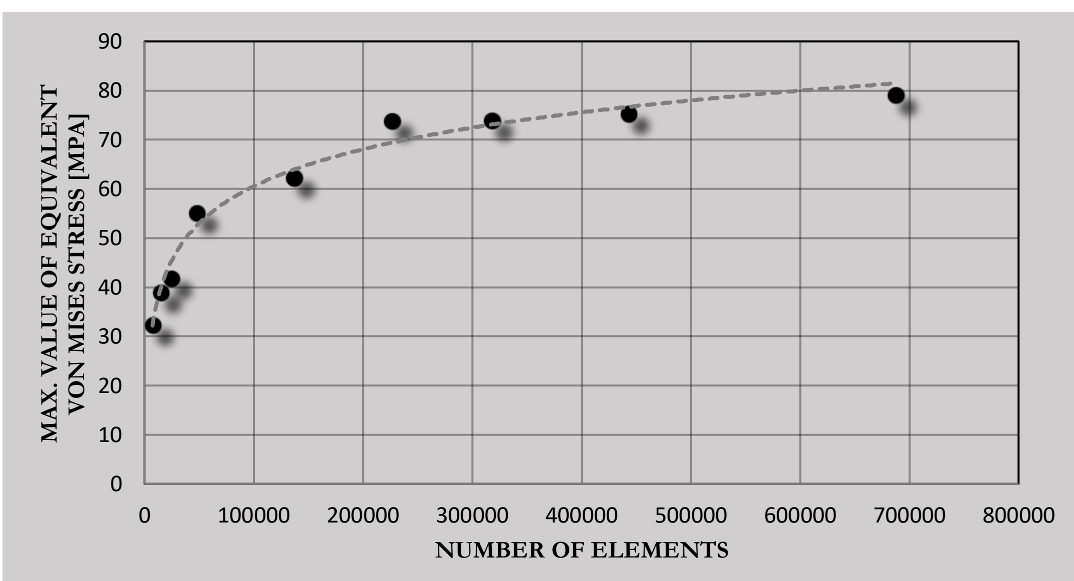


The stress distribution as well as the stress values are different under these two loading scenarios even though the force applied on the bracket is the same. I would predict to get the same values under different loading geometries if the bracket bottom holes were symmetrical with respect to top hole. The second scenario (figure 1b), despite not being as intuitive, gives out greater stresses (see Table 1) than the first scenario (figure 1a), therefore I have decided to consider it in order to perform the model in the worst case scenario.

Question 3:

After running a total of nine simulations gradually decreasing the element size (from 3 to 0.5) of the mesh I got the following convergence:

Figure 2: Convergence of the FE model



The bracket maximal equivalent Von Mises stress converges to approximately 80 MPa once the mesh contains more than 600,000 elements. All the values of the simulations can be found in Table 1 of the Appendix 1.1.

Question 4:

Under compression (500 N) and tension (300 N) the maximum stress is located at the intersection between the legs of the bracket and the structures containing the holes as it can be seen in Figure 2a (Compression) and in Figure 2b (Tension). In both situations some lower stress is also observed on the inner side of the legs of the bracket.

When the brackets is tested against compression(500 N) and shear (150 N) at the same time, the highest stress is located at the edges where the legs of the bracket connect to the central part that connects to the wheel chair main body. Also a great stress is located on both inner and outer sides of the legs of the brackets. This can be seen in Figure 2c.

We use maximum Von Mises stress as our measure of stress as it gives us a theoretical equivalent to the Yield stress. While the Tresca criterion "simply" uses the maximum normal and shear stress the von Mises criterion gives us a value of stress at any point in the structure considering stress in all directions. The safety factor is then calculated by the following equation:

$$SF = \frac{Yield\ stress}{Max.Von\ Mises\ Stress}$$

The yield stress of 6082 T4 aluminium alloy is 120 MPa. The required safety factor is 3, therefore we aim for 40 MPa as maximum allowed stress in all scenarios.

The safety factor for compression is:

$$SF_1 = \frac{120}{79} = 1.52$$

The safety factor for tension is:

$$SF_2 = \frac{120}{38} = 3.16$$

The safety factor for compression and shear is:

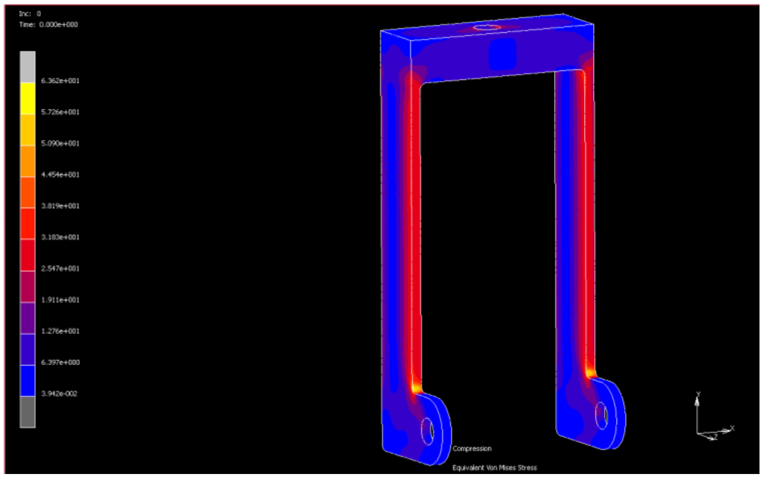
$$SF_3 = \frac{120}{79} = 1.52$$

Figures can be seen on the next page.

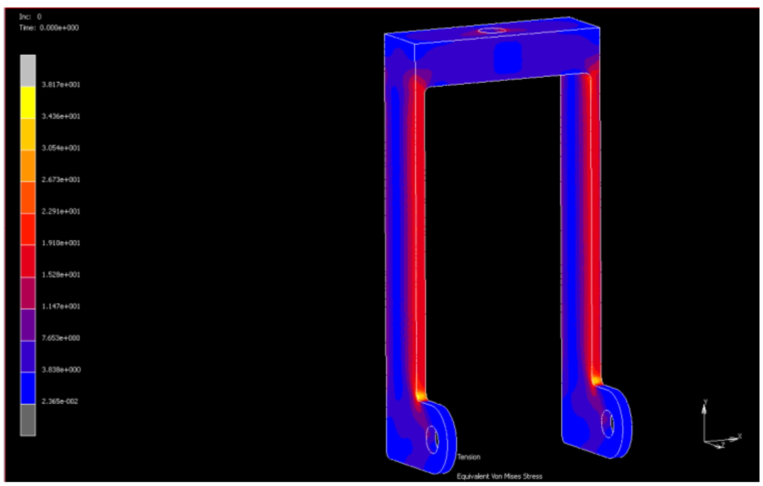
<u>Figure 2: Location of maximum stress for all three loading scenarios</u>

Element size = 0.5 ; Number of elements: 687096

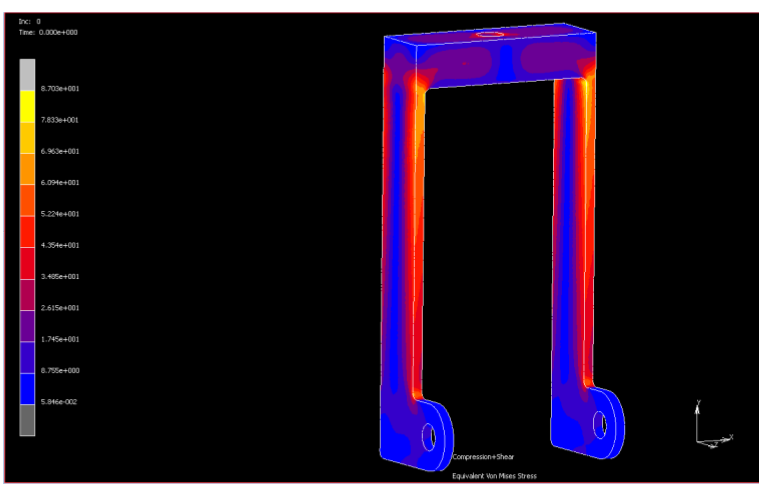
a) <u>Compression:</u>



b) <u>Tension:</u>



c) <u>Compression & Shear:</u>



Question 5:

After several trials I came up with the design found in the figure 1 from the Appendix 1.1. The volume of the bracket 2.88 times greater than the original one. The volume of the new brackets is 87 cm^3 and the density of 6082 T4 aluminium alloy is 2.7 g/cm^3 , hence the weight of one bracket is 235 grams. This may seem a great change, but adding together the weight of the four new brackets it only represents the addition of 616 grams to the whole chair, which is 1% of the average weight of a person. More over this new structure is much more safe. The results are the following:

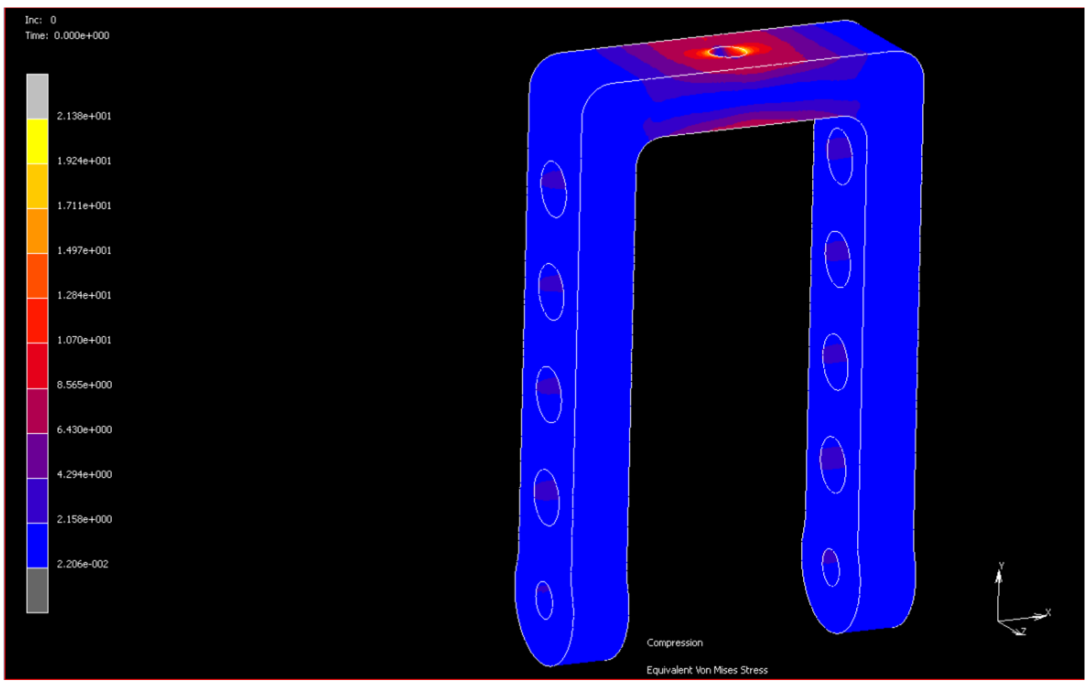
Figure 3: Testing of the new bracket under the required loading scenarios

Element size = 0.6 ; Number of elements: 787904

a) **Compression:**

Maximum Von Mises stress = 21.4 MPa

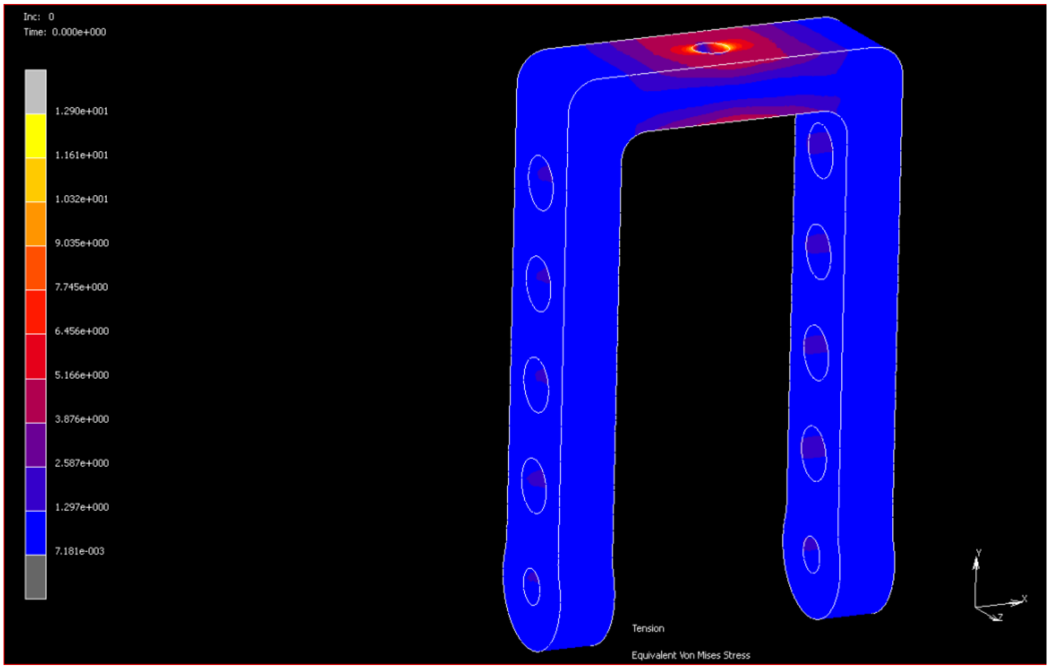
$SF = \frac{120}{21.4} = 5.6$



b) <u>Tension:</u>

Maximum Von Mises stress = 12.9 MPa

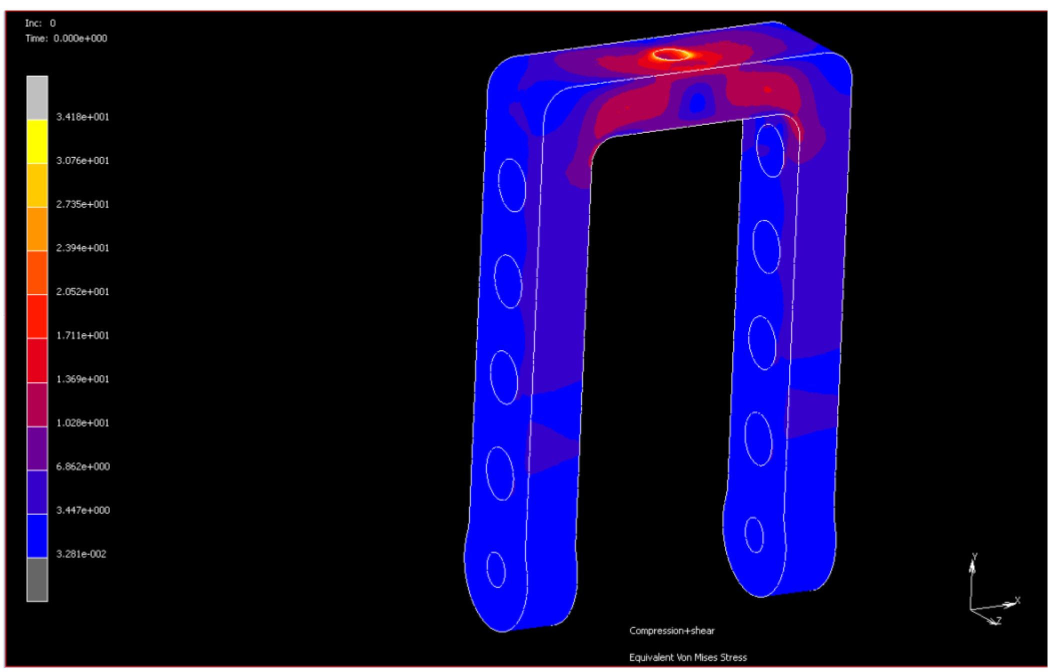
$$SF = \frac{120}{12.9} = 9.3$$



c) <u>Compression + Shear:</u>

Maximum Von Mises stress = 34.2 MPa

$$SF = \frac{120}{34.2} = 3.51$$



Question 6:

What Finite Element Analysis cannot calculate are the top thread shear, the clevis joint, and the stress at the wheel axle that can be considered a pin joint. The shear strength of 6082 T4 aluminium alloy is 140 MPa, considering a SF of 3, we will take 46 MPa as our maximum allowed Yield stress.

1) Top thread shear:

The average shear stress at the top thread is given by:

$$\tau = \frac{2F}{\pi d L_e}$$

Where d is the nominal, major diameter, here d = 8mm

L_e is the engagement length, here L_e = 13 mm

F is the force applied on the structure containing the thread, here either 500 N in compression or 300 N in tension.

In compression,

$$\tau = \frac{2 \cdot (-500)}{\pi \cdot 8 \cdot 13}$$

$$\tau = -3.06\ MPa$$

Given a safety factor of:

$$SF = \frac{140}{3.06} = 45.8$$

In tension,

$$\tau = \frac{2 \cdot (300)}{\pi \cdot 8 \cdot 1}$$

$$\tau = 1.84\ MPa$$

Given a safety factor of:

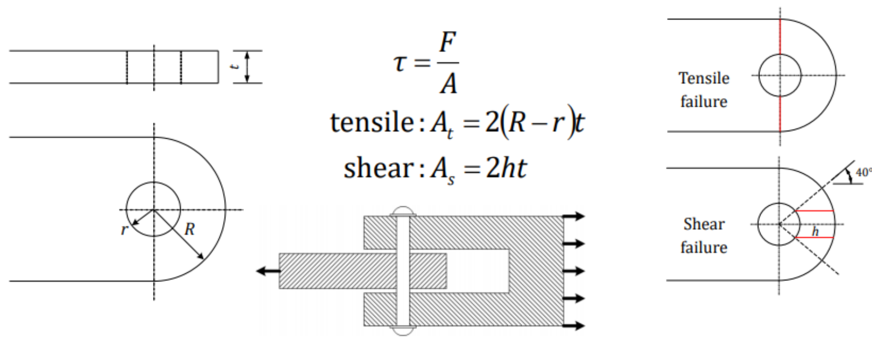
$$SF = \frac{140}{1.84} = 76.1$$

2) Clevis joint

The clevis joint shear stress is measured by simply dividing force over the area in which the shear takes place:

$$\tau = \frac{F}{A}$$

Where A can be either A_s for the shear or A_t for the tensile failure as defined below.



In my final model as it can be seen on Figure 4 and in Appendix 1.1:

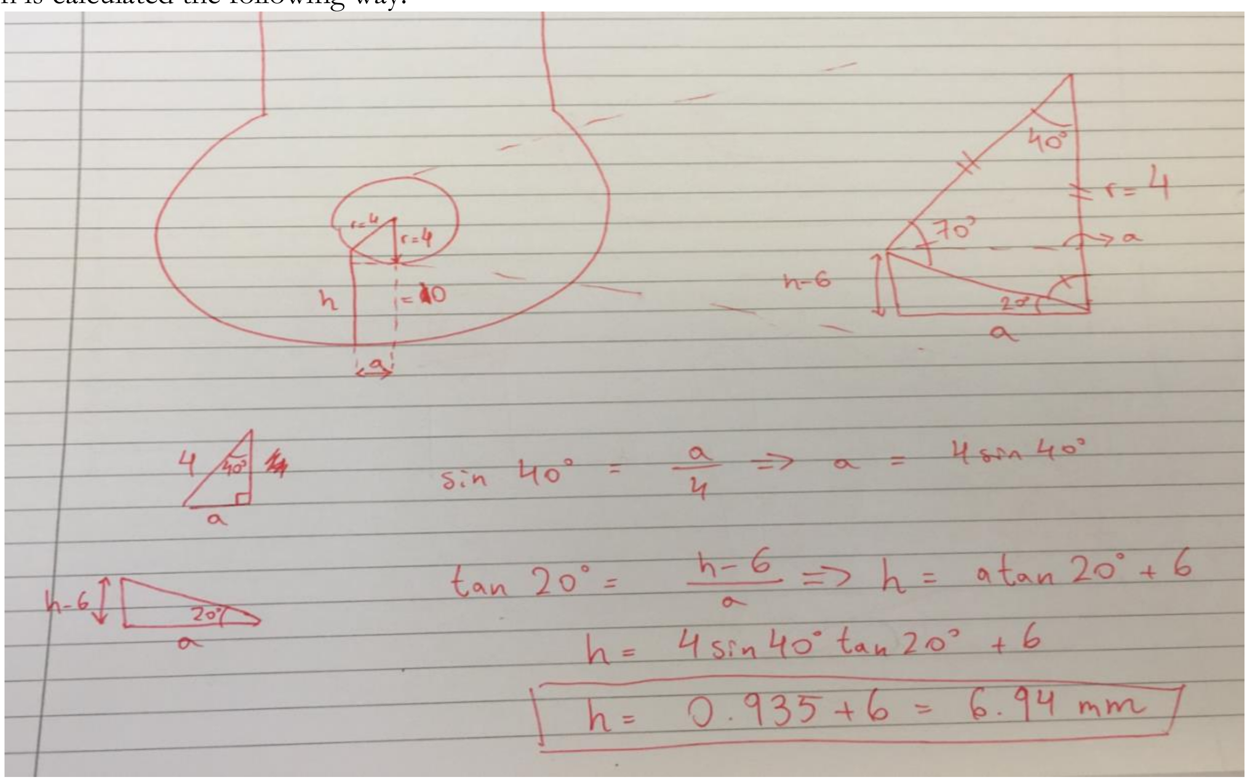
R = 14mm

r = 4mm

t = 13mm

$$A_t = 2(14-4)\cdot 13 = 260\ mm^2$$

h is calculated the following way:



Giving:

$$A_s = 2\cdot 6.94\cdot 13 = 180\ mm^2$$

In compression (500N):

- Tensile:

$$\tau = \frac{F}{A_t} = \frac{-500}{260} = -1.92\ MPa$$
$$SF = \frac{140}{1.92} = 72.9$$

- Shear:

$$\tau = \frac{F}{A_s} = \frac{-500}{180} = -2.78\ MPa$$
$$SF = \frac{140}{2.78} = 50.4$$

In tension (300N):
- Tensile:

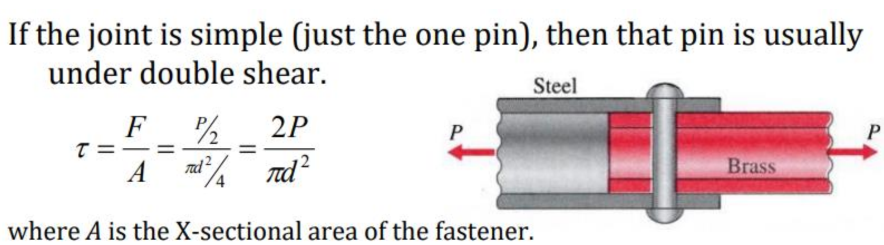
$$\tau = \frac{F}{A_t} = \frac{300}{260} = 1.15\ MPa$$
$$SF = \frac{140}{1.15} = 122$$

- Shear:

$$\tau = \frac{F}{A_s} = \frac{300}{180} = 1.67\ MPa$$
$$SF = \frac{140}{1.67} = 83.8$$

3) Wheel axle:

The shear at the joint can be calculated from
$$\tau = \frac{F}{A} = \frac{2P}{\pi d^2}$$
The yield strength of the wheel axle is 205 MPa[2].
As shown here,



For compression:
$$\tau = \frac{2\cdot(-500)}{\pi\cdot 8^2} = -4.9\ \text{MPa}$$
$$SF = \frac{205}{4.9} = 41.8$$

For tension:

$$\tau = \frac{2 \cdot 300}{\pi \cdot 8^2} = 3 \text{ MPa}$$

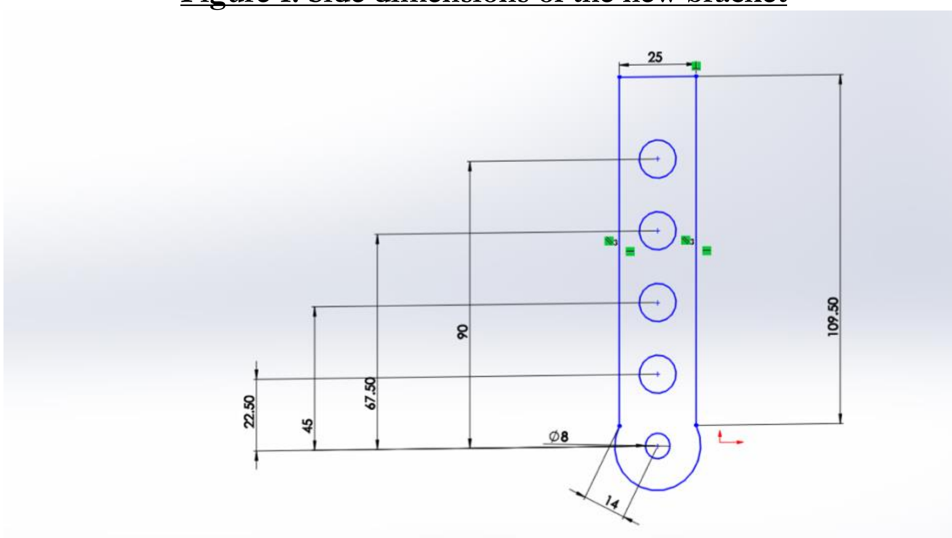
$$SF = \frac{205}{4.9} = 68.3$$

Appendix

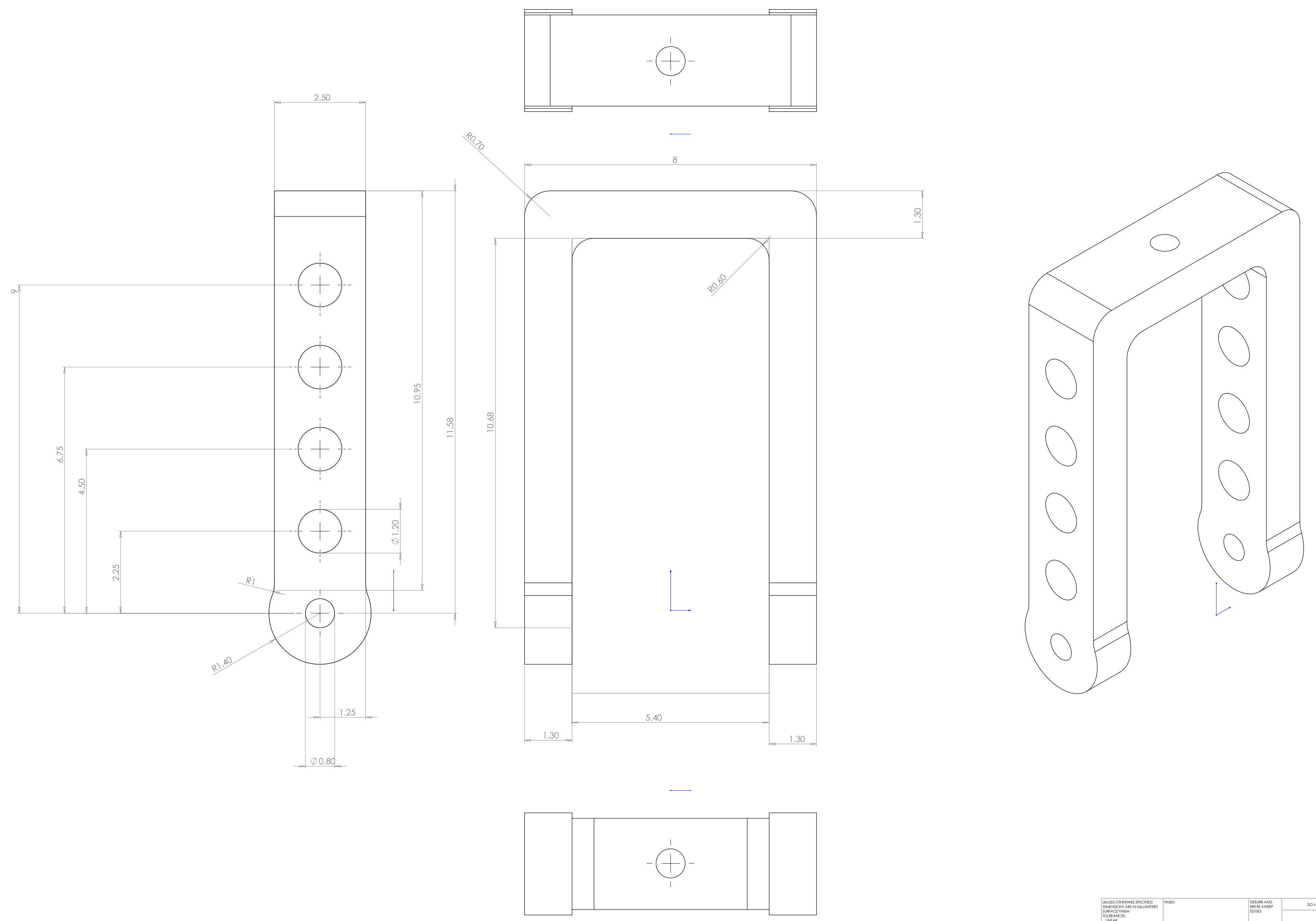
Table 1: Bracket model convergence

Element size	3	2.5	2	1.5	1	0.8	0.7	0.6	0.5	0.3
Number of Nodes	2289	3932	6349	11823	31347	51016	70780	97541	148494	428190
Number of Elements	7346	14150	24032	47313	136220	226219	317542	442553	687096	2004552
Max. Von Mises Stress	32.47	39.06	41.9	55.19	62.42	73.85	73.98	75.3	79.16	did not compile

Figure 1: Side dimensions of the new bracket



APPENDIX 1.1 [SEE NEXT PAGE]



UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN MILLIMETERS SURFACE FINISH: TOLERANCES: LINEAR: ANGULAR:	FINISH:	DEBURR AND BREAK SHARP EDGES	DO NOT SCALE DRAWING	REVISION
NAME / SIGNATURE / DATE			TITLE:	
DRAWN				
CHK'D				
APPV'D				
MFG				
Q.A	MATERIAL:		DWG NO. 5th_try	A1
	WEIGHT:		SCALE:2:1	SHEET 1 OF 1

References

1. **Makeitfrom.com. (2018). *6082-T4 Aluminum :: MakeItFrom.com.* [online] Available at: https://www.makeitfrom.com/material-properties/6082-T4-Aluminum [Accessed 31 March 2018]**
2. **Stainless steel - grade 316 (uns s31600) *Stainless Steel - Grade 316 (UNS S31600)* [online] Available at: https://www.azom.com/article.aspx?ArticleID=863 [Accessed 3 Apr. 2018]**

Bibliography

1. **What is the meaning of the Von Mises Stress and the Yield Criterion? – Simscale[online] https://www.simscale.com/blog/2017/04/von-mises-stress/ [Accesed 1 April 2018]**