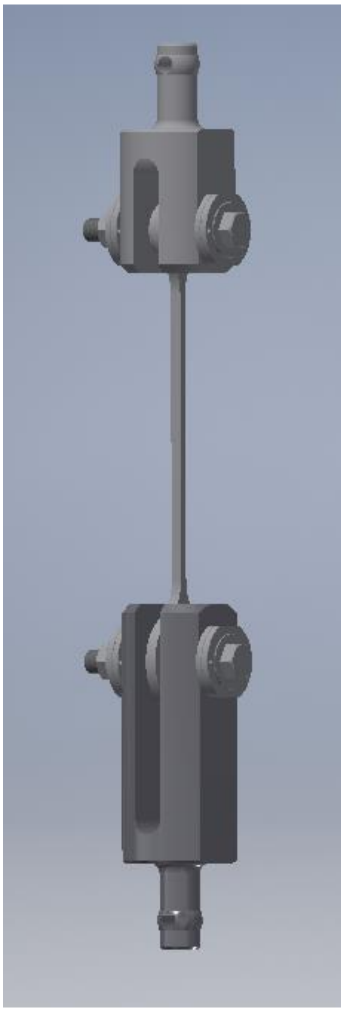
Date – 24/10/20

MEC3028 Hook Analysis Logbook

Ansys was validated with hand calculations by applying a known force to a test specimen of known dimensions.

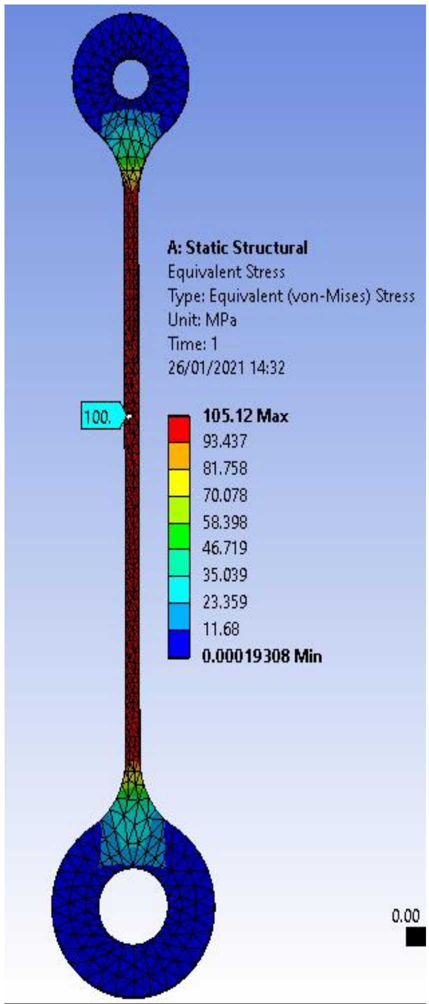
4800N was applied parallel to the thin section of the test specimen of width 6mm, length 200mm and thickness 8mm.

Test Rig Used



Constraints on Test Rig

Stress of Test Specimen



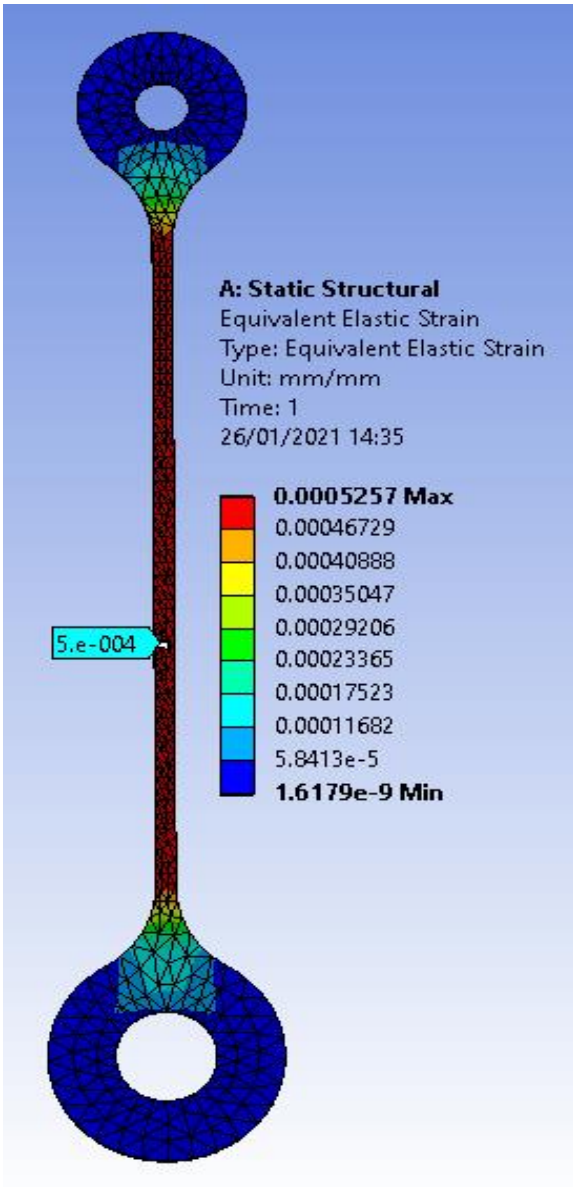
Test Specimen Contraints

Letter	Constraint	Value	Units
A	Force	(0,4800,0)	N
B	Fixed Support	(0,0,0)	mm

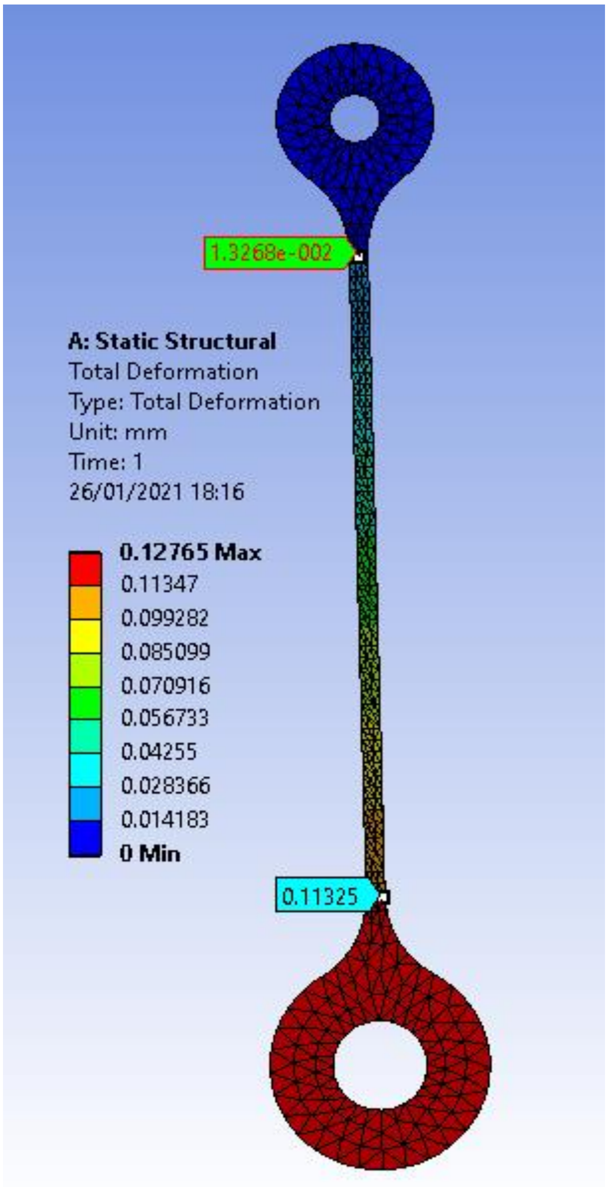
Name – David Stewart
Student Number - 180297339

Date – 24/10/20

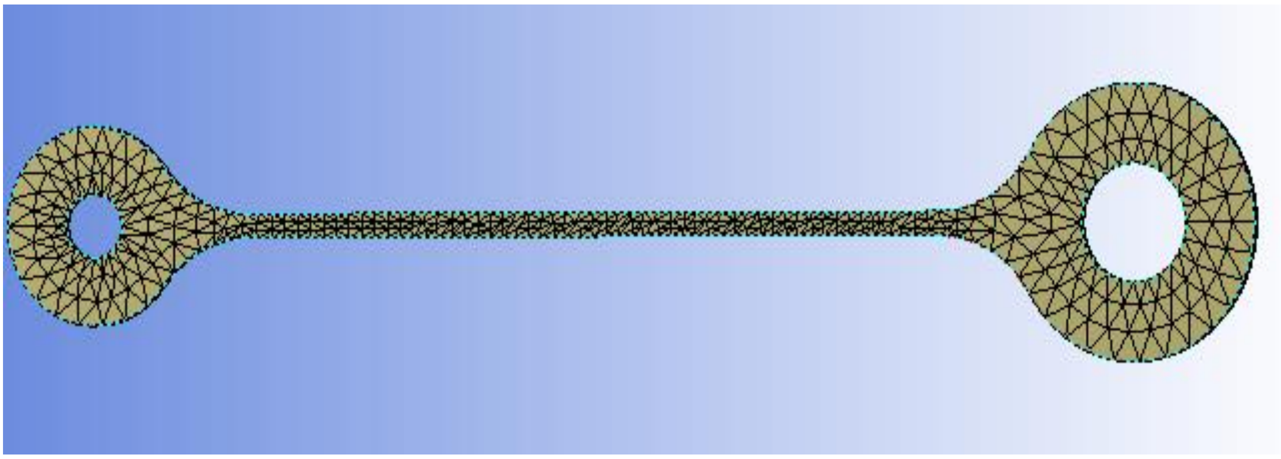
Strain of Test Specimen



Deformation of Test Specimen



Meshing of Test Specimen



Date – 28/10/20

FEA Validation

Width = 6mm
Thickness = 8mm
Force = 4800 N

Area = $6 \times 8 \times 10^{-6}$
$E = 2 \times 10^{11}$ Pa
$l = 0.2$m

Stress :

$$\sigma = \frac{F}{A} = \frac{4800}{6 \times 8 \times 10^{-6}} = 100 \text{ MPa}$$

✓✓ SAME AS ANSYS

Strain :

$$E = \frac{\sigma}{\varepsilon} \quad \therefore \quad \varepsilon = \frac{\sigma}{E}$$

$$\varepsilon = \frac{100 \times 10^{+6}}{2 \times 10^{11}} = 5 \times 10^{-4}$$

✓✓ SAME AS ANSYS

Deformation :

$$\varepsilon = \frac{\Delta l}{l} \quad \therefore \quad \Delta l = l\varepsilon$$

$$\Delta l = 0.2 \times 5 \times 10^{-4}$$

$$\Delta l = 1 \times 10^{-4} \text{ m}$$

Δl = deformation = 0.1m

✓✓ SAME AS ANSYS

Ansys $\Delta l = 0.11325 - (1.3268 \times 10^{-2})$

Ansys $\Delta l = 0.099982 \simeq 0.1\text{m} = \Delta l$

Date – 28/10/20

Specification

Design, analyse, optimise, have manufactured and test a crane hook to carry a static vertical load of 30kN (approximately 3 tonnes) without yielding. For lifting purposes, this would give a Safe Working Load (SWL) of 600kg with the usual safety factor of 5 x. The design should be of minimum mass.

The component MUST fit, easily and correctly, at the first attempt, on to the test rig. The top mount is the un-threaded shank of an M16 grade 12.9 socket cap bolt. The bottom mount is a pin of diameter 30g7. The centrelines of the bolt and the pin are parallel and 160mm apart. The component must function as a hook, i.e. not require axial removal of pin to attach.

The design work is to be done in Autodesk Inventor.
The stress analysis is to be done in Ansys Workbench (and checked by hand).

The components are to be laser cut from 8mm thick high strength hot rolled steel plate:
Strenx 700MC from Swedish Steel (SSAB.com for details). Yield strength is 680 to 760 N/mm^2, UTS (Ultimate Tensile Strength) 750 to 950 N/mm^2 and approx 10% elongation. Laser cutting gives an excellent cut but not a perfect edge: typical tolerances are +/- 0.25mm.

The components will be tested to their ultimate load by the technical staff in the Strengths Laboratory and the results saved as Excel spreadsheets of load against extension.

The yield load must not exceed 60kN, nor ultimate (failure) load exceed 90kN.

After the tests, the results must be reconciled with the specification.

All the work done must be properly recorded in contemporaneous log books.

Every member of the class is to complete the whole assignment.

Penalties will be given for careless work or work that does nor meet the requirements.

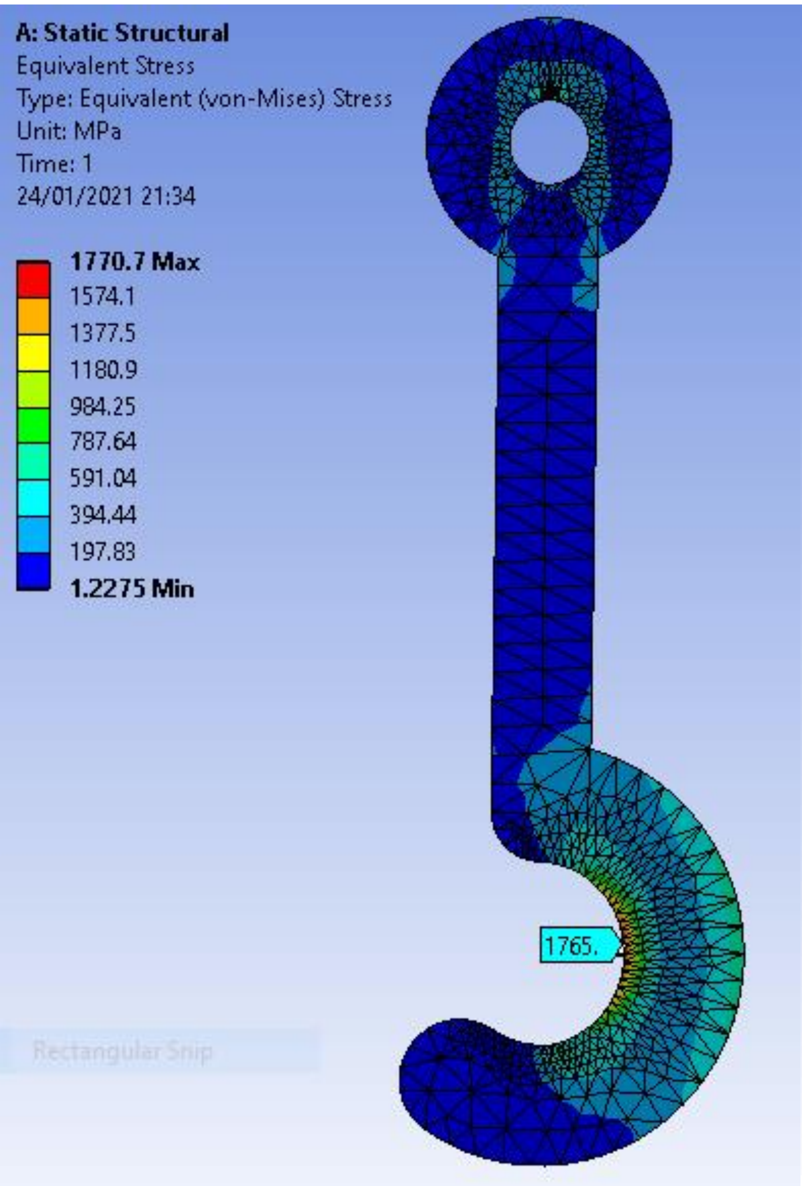
Name – David Stewart
Student Number - 180297339

Considering Different Designs

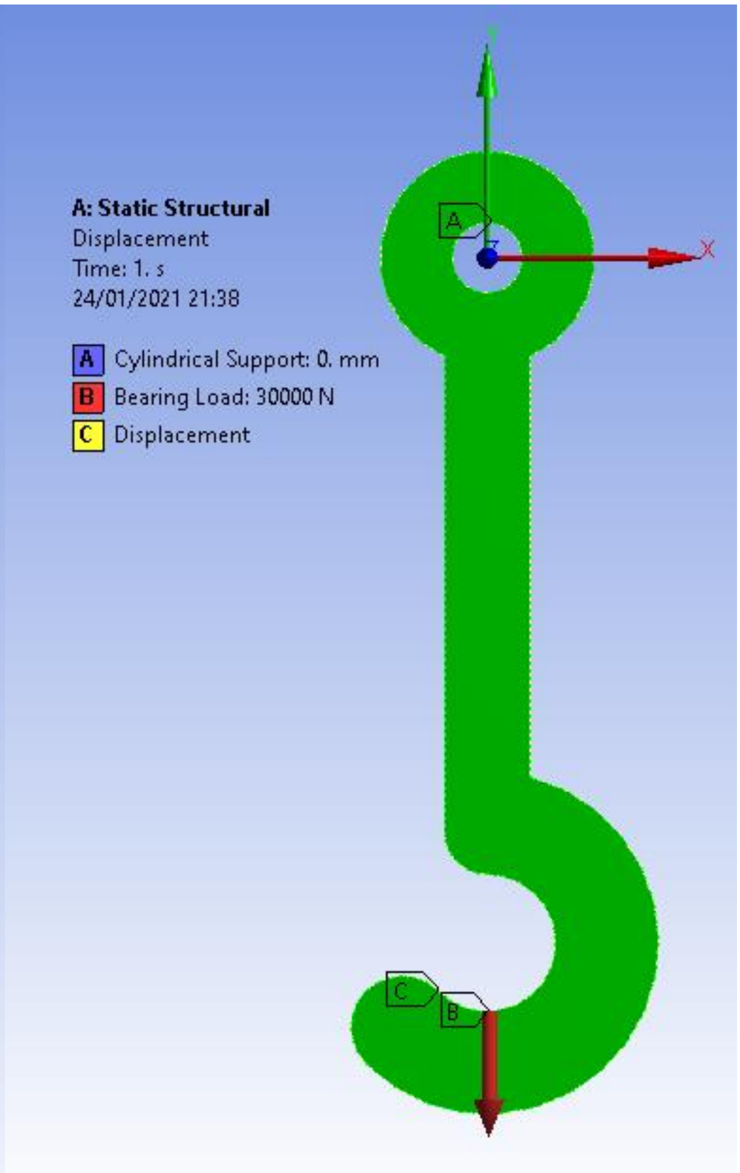
Date – 10/11/20

Hook v1

Stress results of Hook v1



Constraints of Hook v1



Hook 1 Stress Analysis	
Yield Stress Used (MPa)	700
Failure Stress Used (MPa)	800
Max Stress (MPa)	1765
Applied Load (kN)	30
Expected Yield Load (kN)	11.90
Mass (g)	424
Yield Load/Mass Ratio	**28.06**

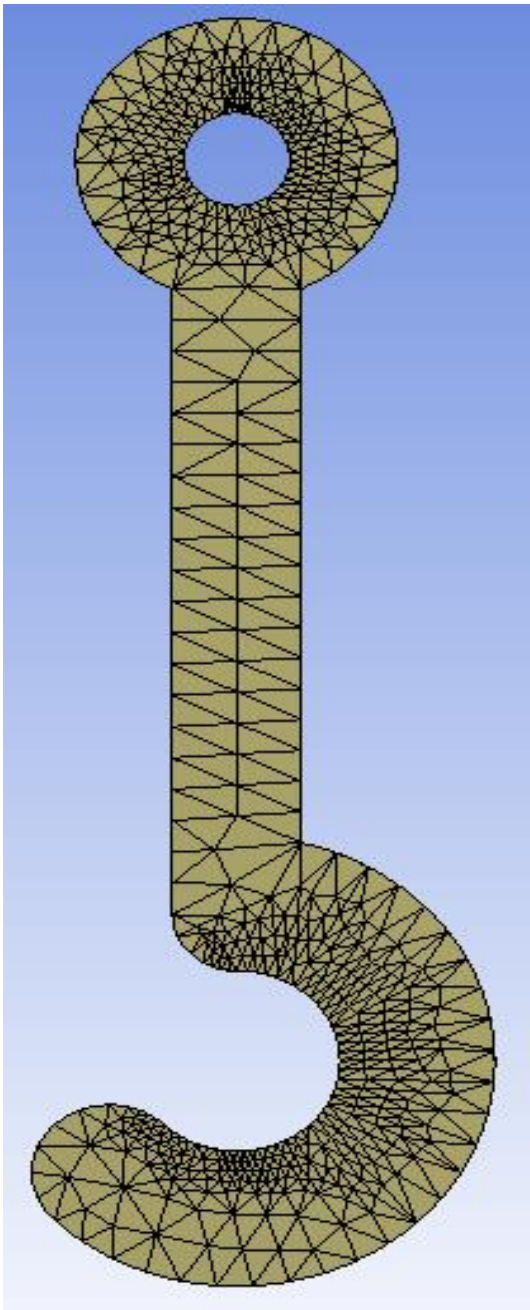
Hook 1 Contraints

Letter	Constraint	Value	Units
A	Cylindrical Support	(0,0,0)	mm
B	Bearing Load	(0.-30000,0)	N
C	Displacement	(0, Free, Free)	mm

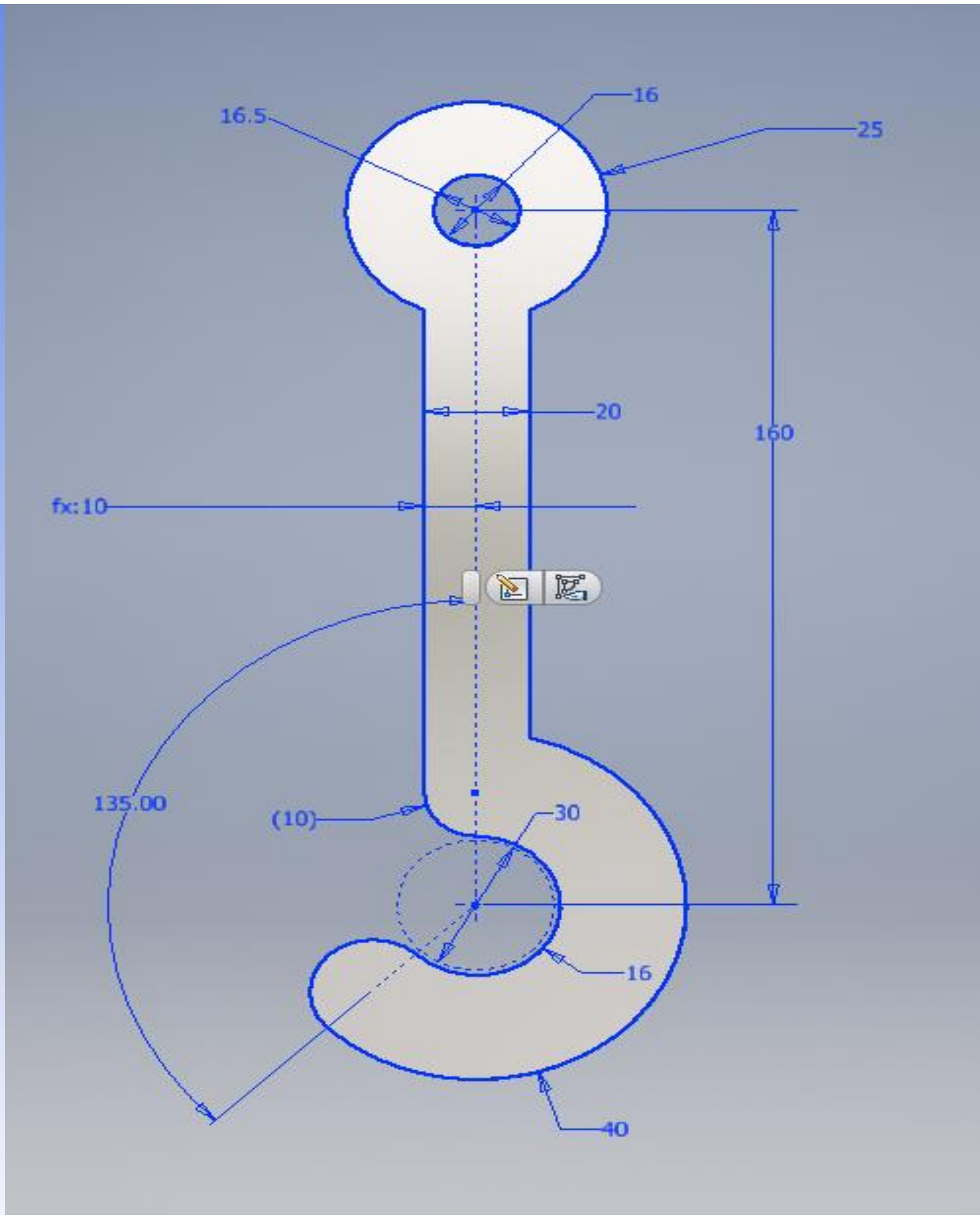
Name – David Stewart
Student Number - 180297339

Date – 10/11/20

Meshing of Hook v1



Dimensions of Hook v1



Steps taken to improve next design:

- Increase the thickness of the area to the right of the bottom pin to increase yield load and thus meet specification.
- Come up with a brand-new design so it's not the same as in tutorial lectures.

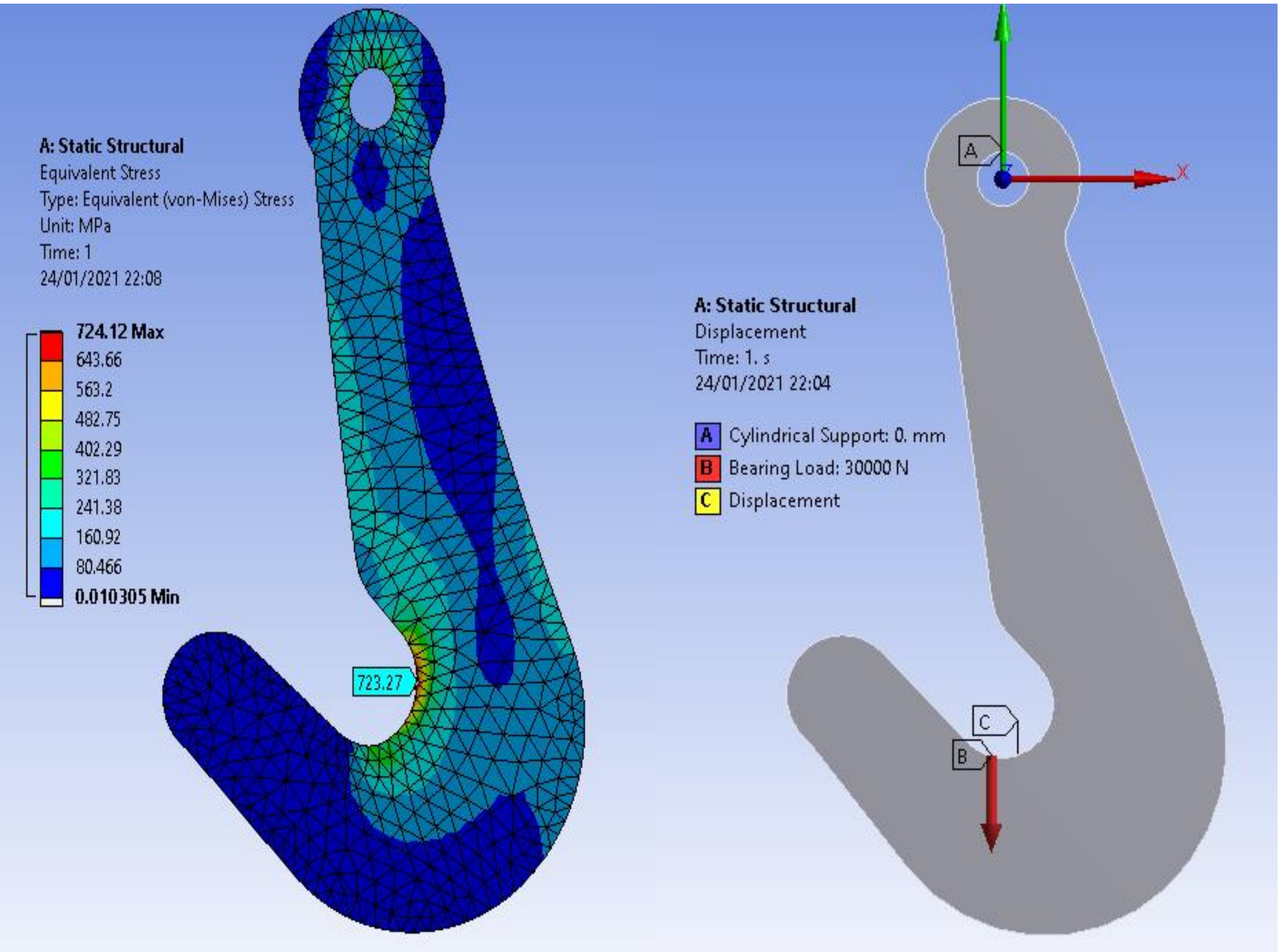
Name – David Stewart
Student Number - 180297339

Date – 10/11/20

Hook v2

Stress results of Hook 2

Constraints of Hook v2



Hook 2 Stress Analysis	
Yield Stress Used (MPa)	700
Failure Stress Used (MPa)	800
Max Stress (MPa)	723.27
Applied Load (kN)	30
Expected Yield Load (kN)	29.03
Mass (g)	1037
Yield Load/Mass Ratio	**28.00**

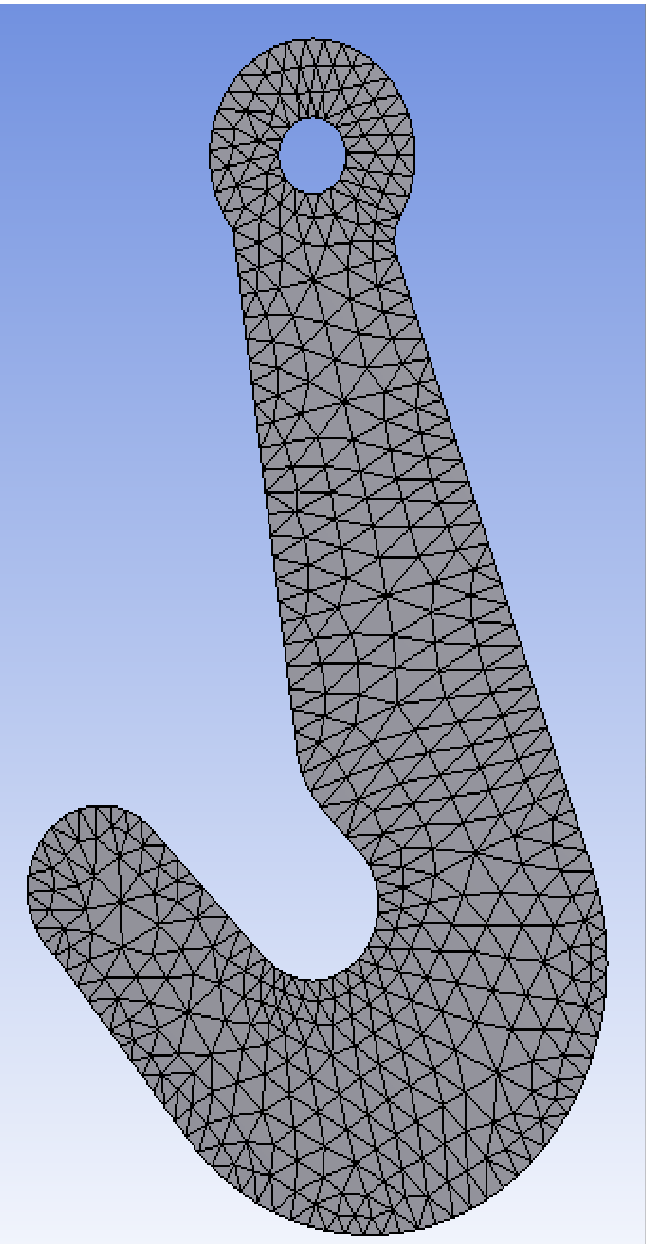
Hook 2 Contraints

Letter	Constraint	Value	Units
A	Cylindrical Support	(0,0,0)	mm
B	Bearing Load	(0.-30000,0)	N
C	Displacement	(0, Free, Free)	mm

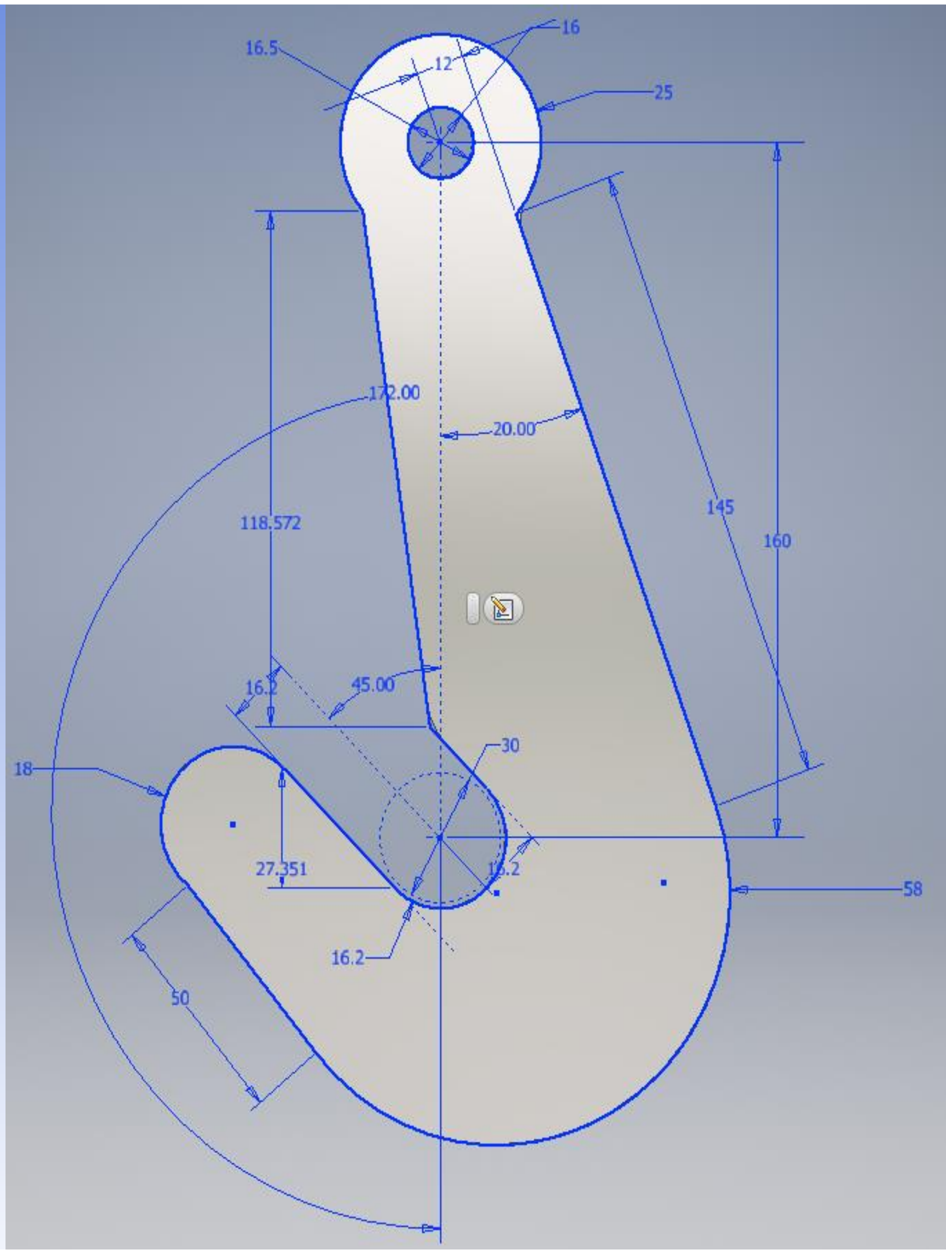
Name – David Stewart
Student Number - 180297339

Date – 10/11/20

Meshing of Hook v2



Dimensions of Hook v2



Steps taken to improve next design:

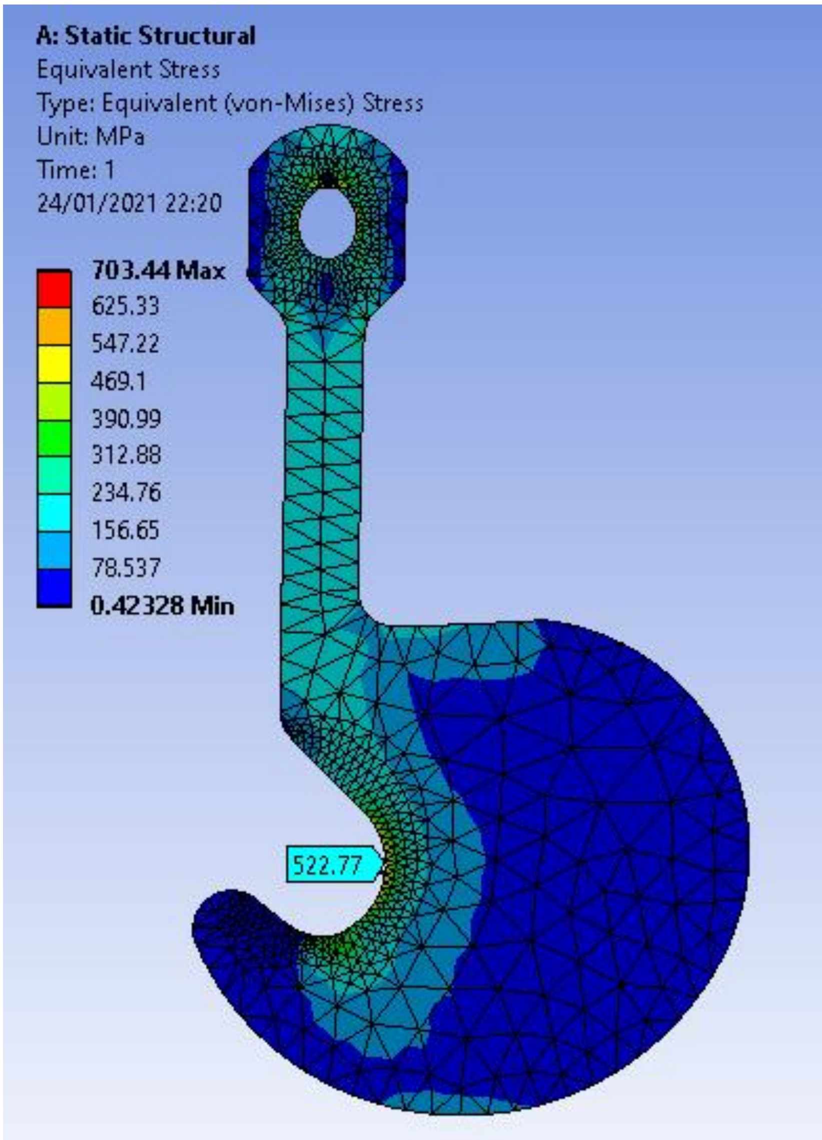
- Increase the thickness of the area to the right of the bottom pin to increase yield load and thus meet specification.
- Reduce length of hook tip as doesn't provide any increase to maximum yield load.
- Revert back to a straight and thinner neck to reduce mass.

Name – David Stewart
Student Number - 180297339

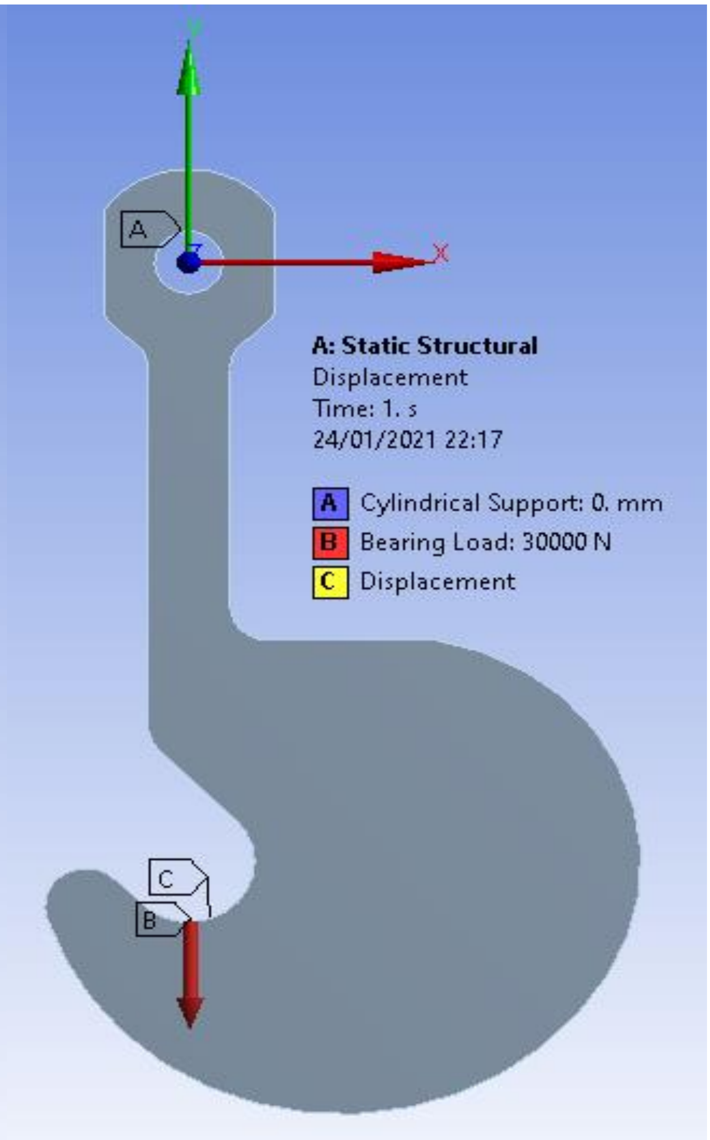
Date – 14/11/20

Hook v3

Stress results of Hook v3



Constraints of Hook v3



Hook 3 Stress Analysis

Yield Stress Used (MPa)	700
Failure Stress Used (MPa)	800
Max Stress (MPa)	522.72
Applied Load (kN)	30
Expected Yield Load (kN)	40.17
Mass (g)	1017
Yield Load/Mass Ratio	**39.50**

Hook 3 Contraints

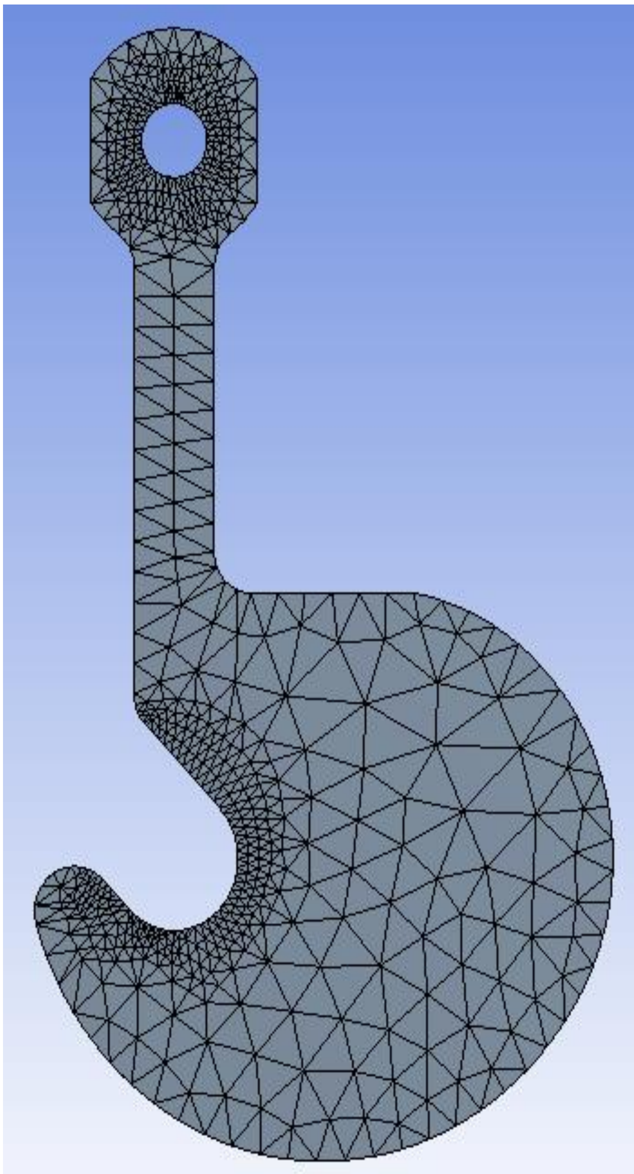
Letter	Constraint	Value	Units
A	Cylindrical Support	(0,0,0)	mm
B	Bearing Load	(0.-30000,0)	N
C	Displacement	(0, Free, Free)	mm

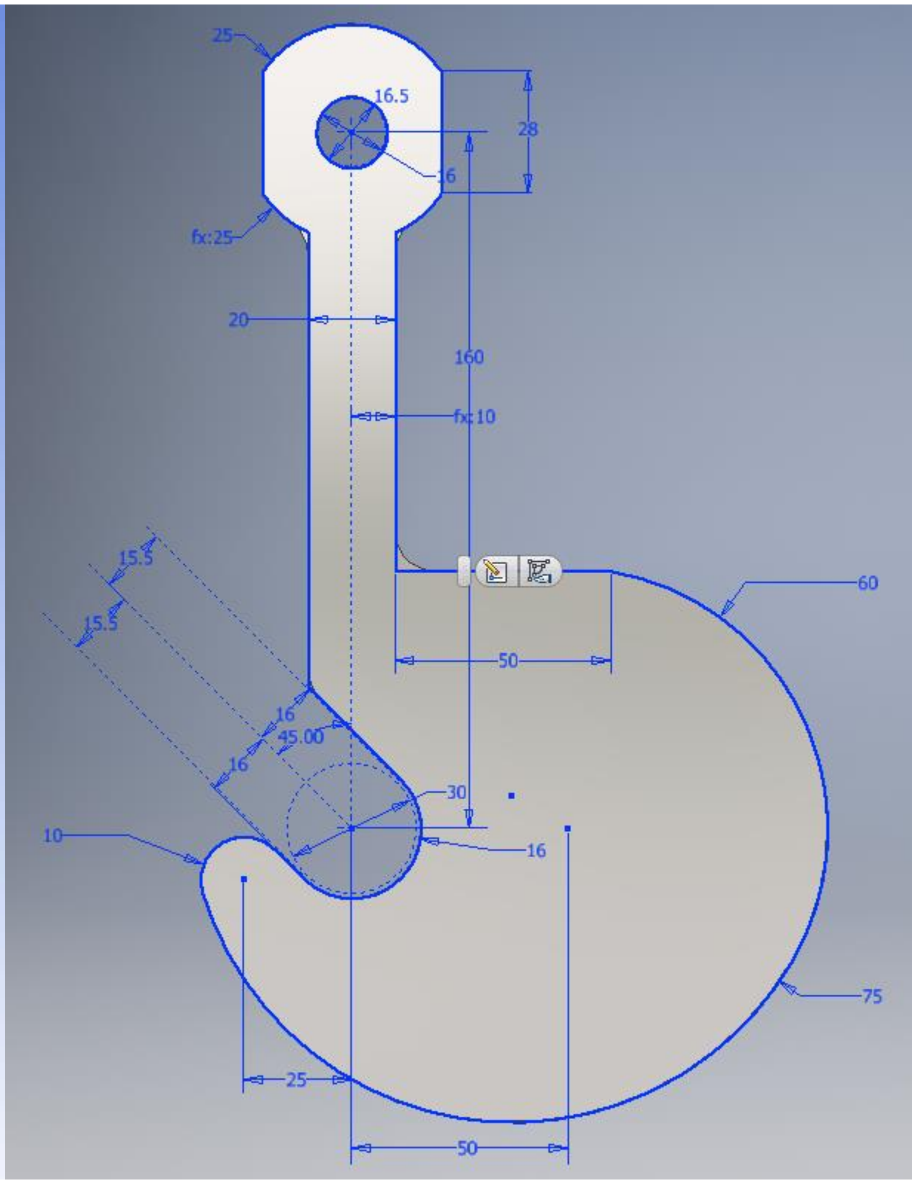
Name – David Stewart
Student Number - 180297339

Date – 14/11/20

Meshing of Hook v3

Dimensions of Hook v3





Steps taken to improve next design:

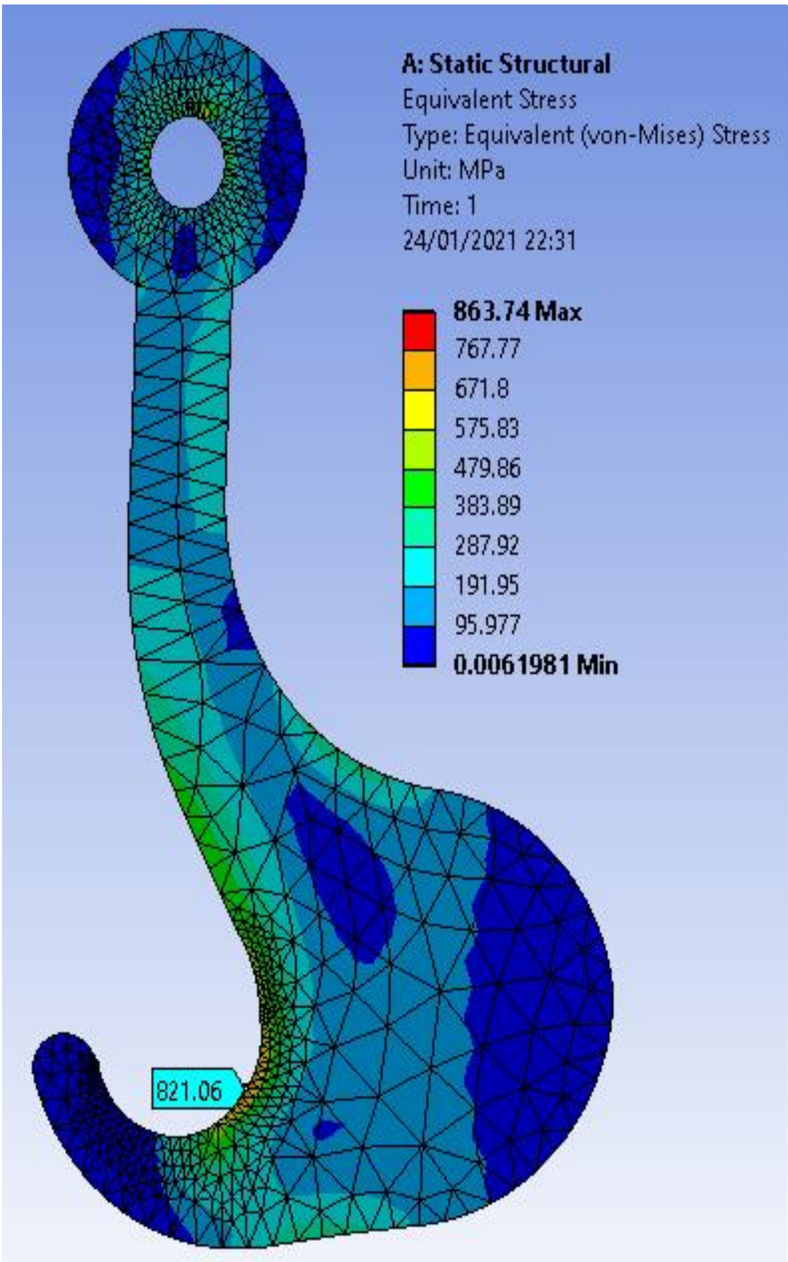
- Try a design with a much smaller mass
- Larger fillets to the left of the hook to reduce mass
- Larger fillets on the fight side of the hook to increase yield load.
- Less area at the tip of hook

Name – David Stewart
Student Number - 180297339

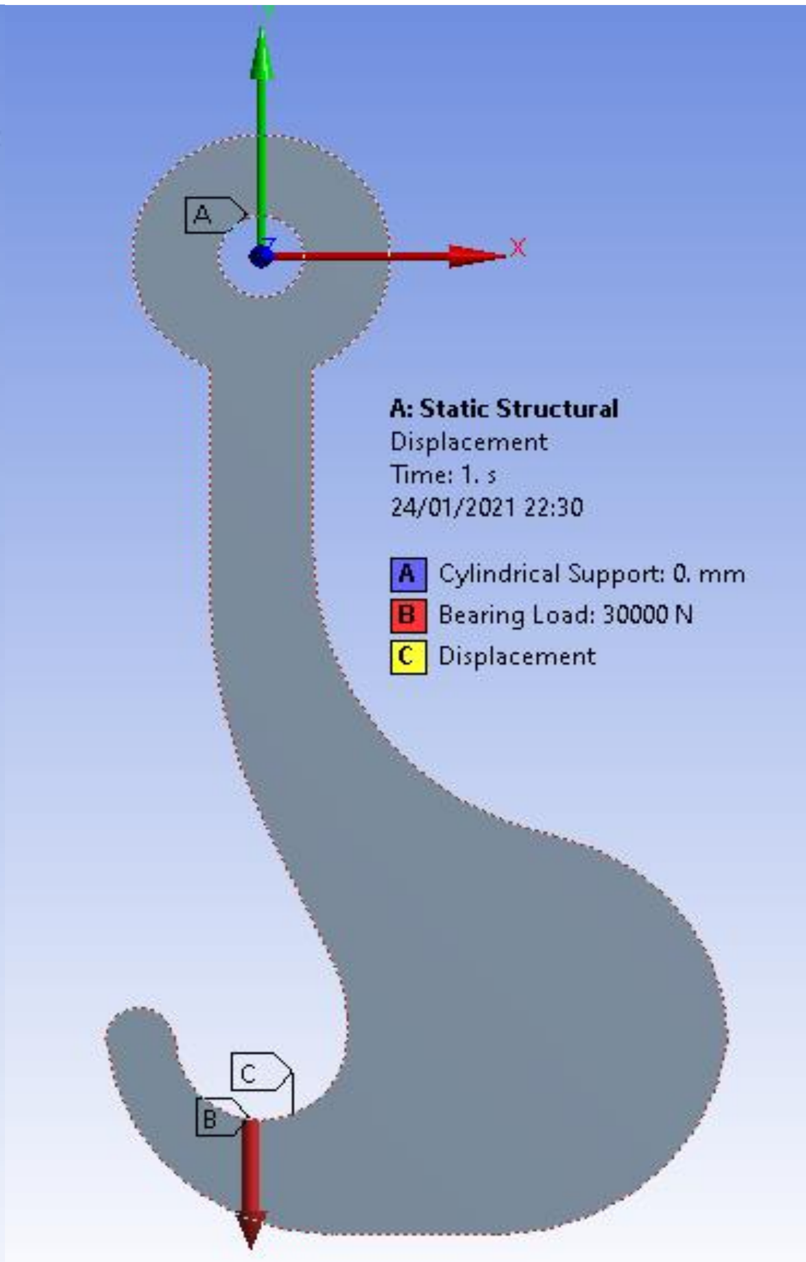
Date – 14/11/20

Hook v4

Stress results of Hook v4



Constraints of Hook v4



Hook 4 Stress Analysis

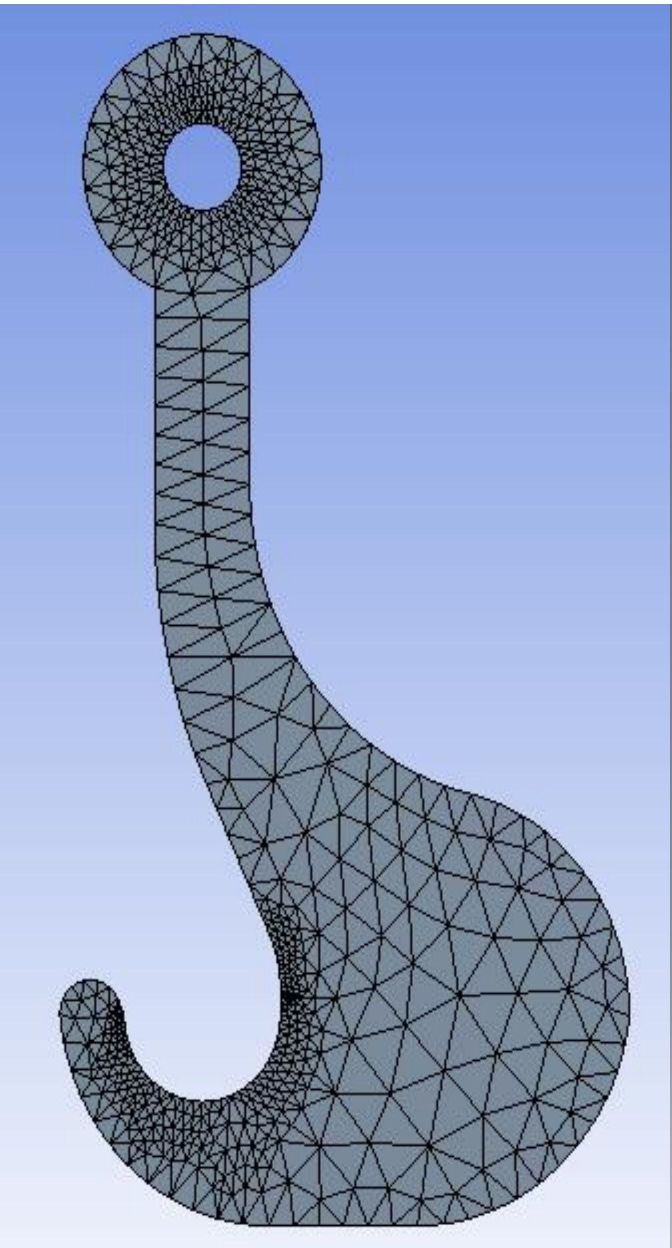
Yield Stress Used (MPa)	700
Failure Stress Used (MPa)	800
Max Stress (MPa)	821.06
Applied Load (kN)	30
Expected Yield Load (kN)	25.58
Mass (g)	670
Yield Load/Mass Ratio	**38.17**

Hook 4 Contraints

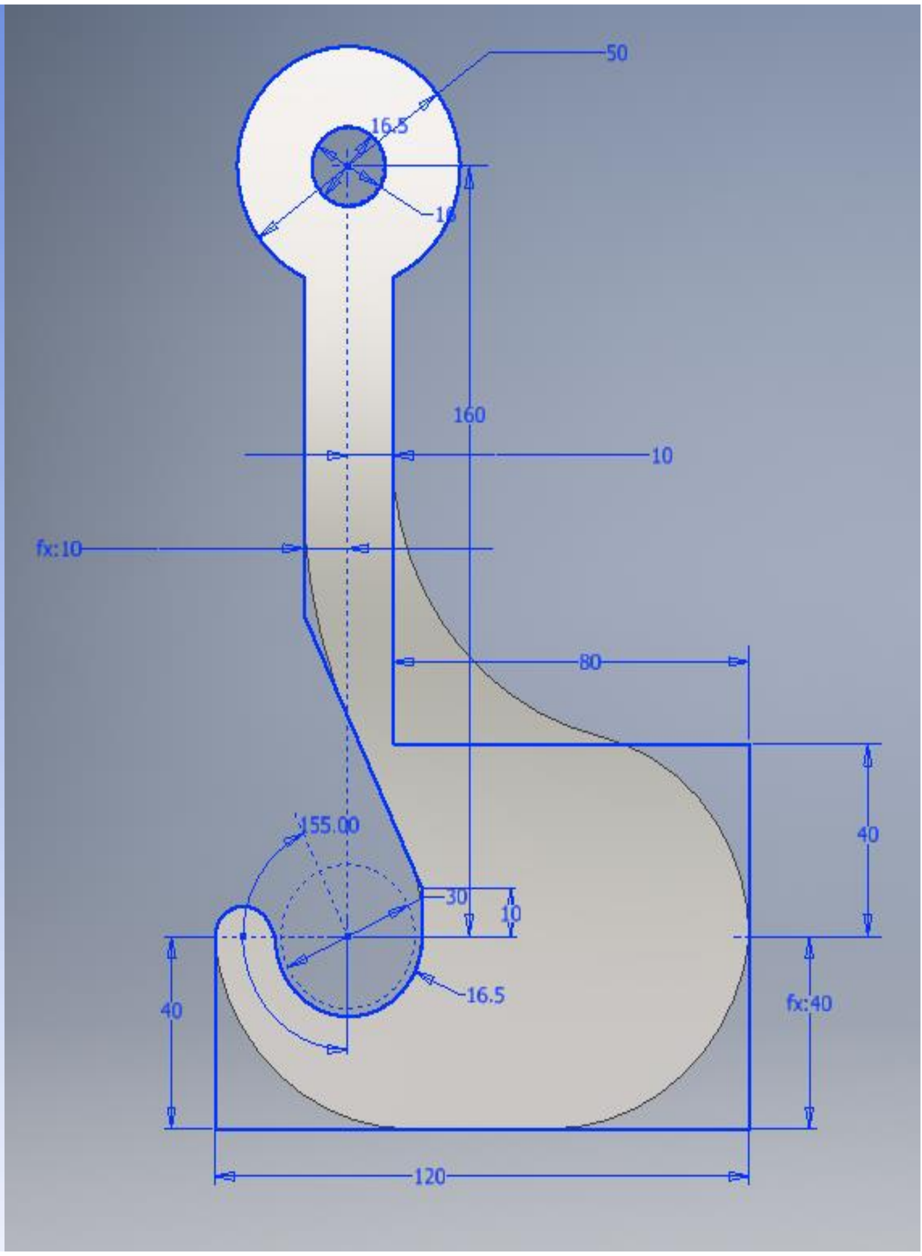
Letter	Constraint	Value	Units
A	Cylindrical Support	(0,0,0)	mm
B	Bearing Load	(0.-30000,0)	N
C	Displacement	(0, Free, Free)	mm

Date – 14/11/20

Meshing of Hook v4



Dimensions of Hook v4



Steps taken to improve next design:

- Revert back to old design and play with dimensions.
- Design a mechanical fail safe in the neck of the hook by reducing the area.
- Reduce the area around the top pin of the hook
- Reduce the hook tip dimensions
- Have the maximum width perpendicular to the centre point of the bottom pin

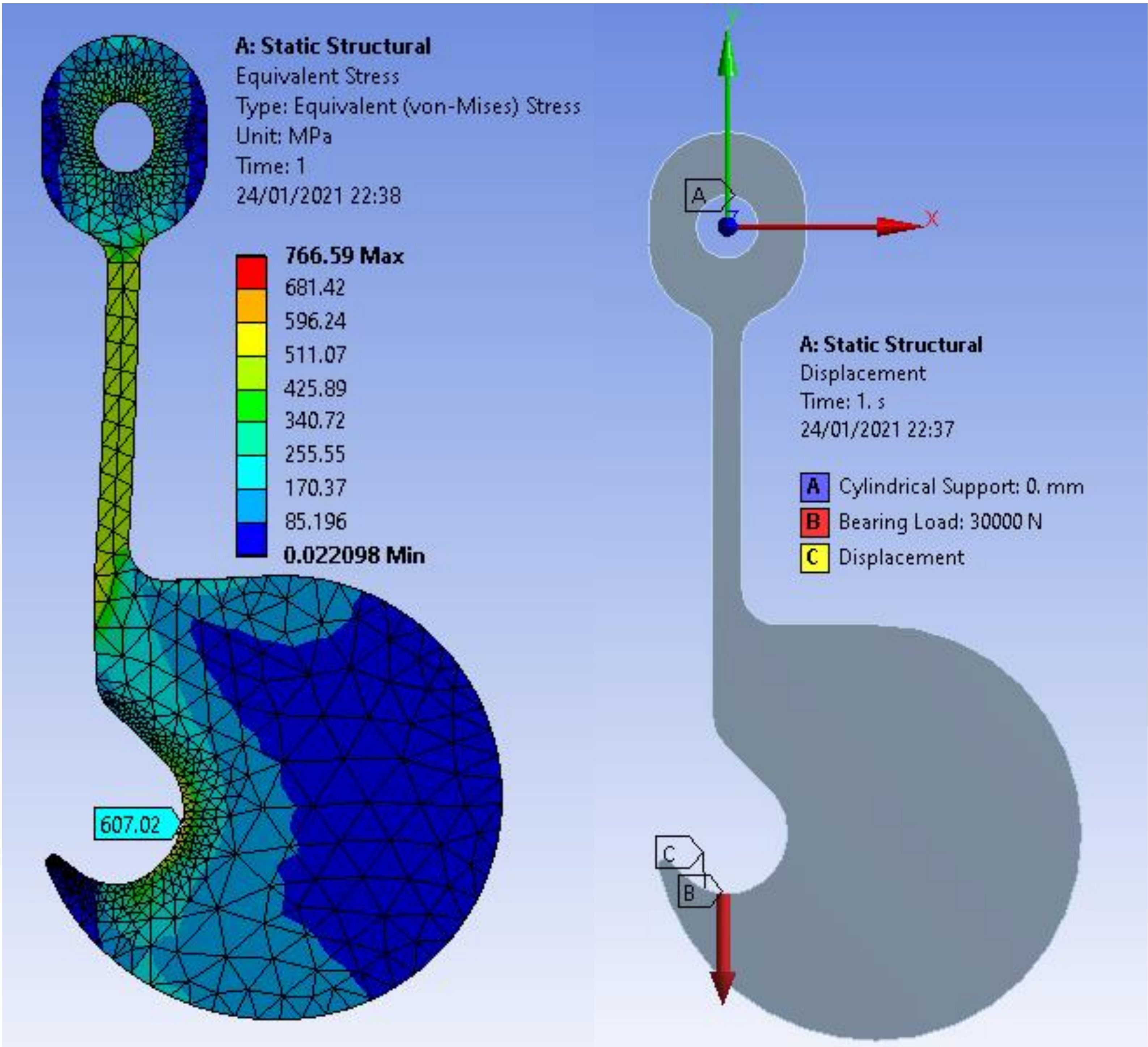
Name – David Stewart
Student Number - 180297339

Hook v5 (BEST DESIGN)

Date – 14/11/20

Stress results of Hook v5

Constraints of Hook v5



Hook 5 Stress Analysis

Yield Stress Used (MPa)	700
Failure Stress Used (MPa)	800
Max Stress (MPa)	607.02
Applied Load (kN)	30
Expected Yield Load (kN)	34.60
Mass (g)	700
Yield Load/Mass Ratio	**49.42**

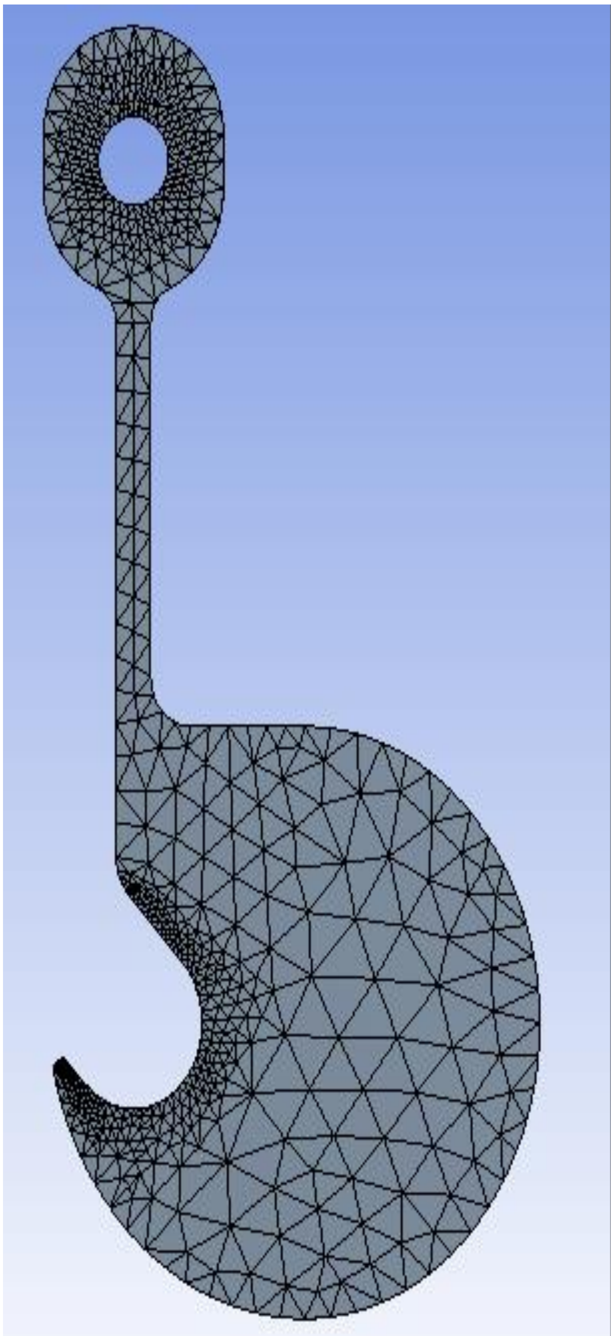
Hook 5 Contraints

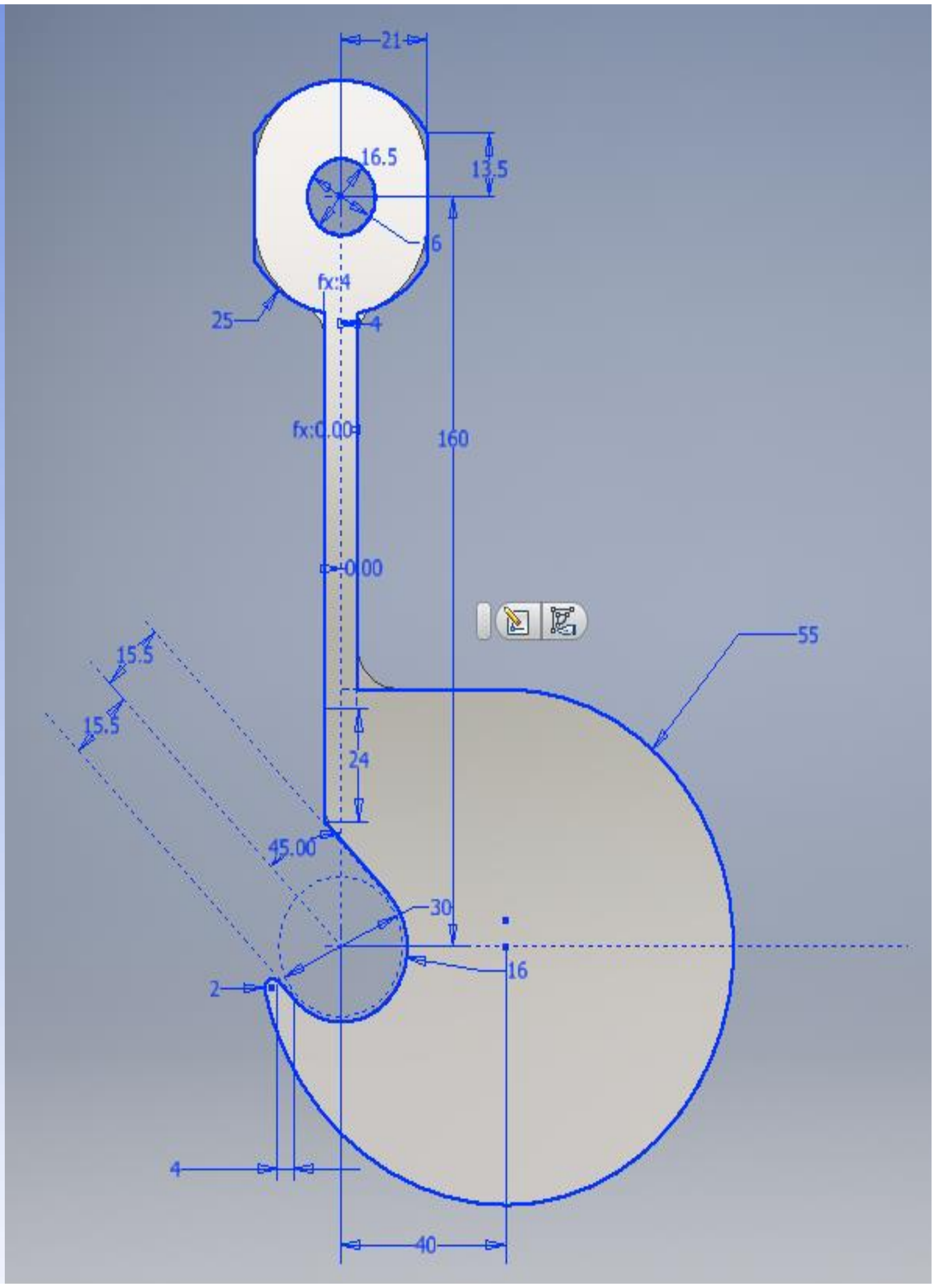
Letter	Constraint	Value	Units
A	Cylindrical Support	(0,0,0)	mm
B	Bearing Load	(0.-30000,0)	N
C	Displacement	(0, Free, Free)	mm

Date – 14/11/20

Meshing of Hook v5

Dimensions of Hook v5





Steps taken to improve next design:

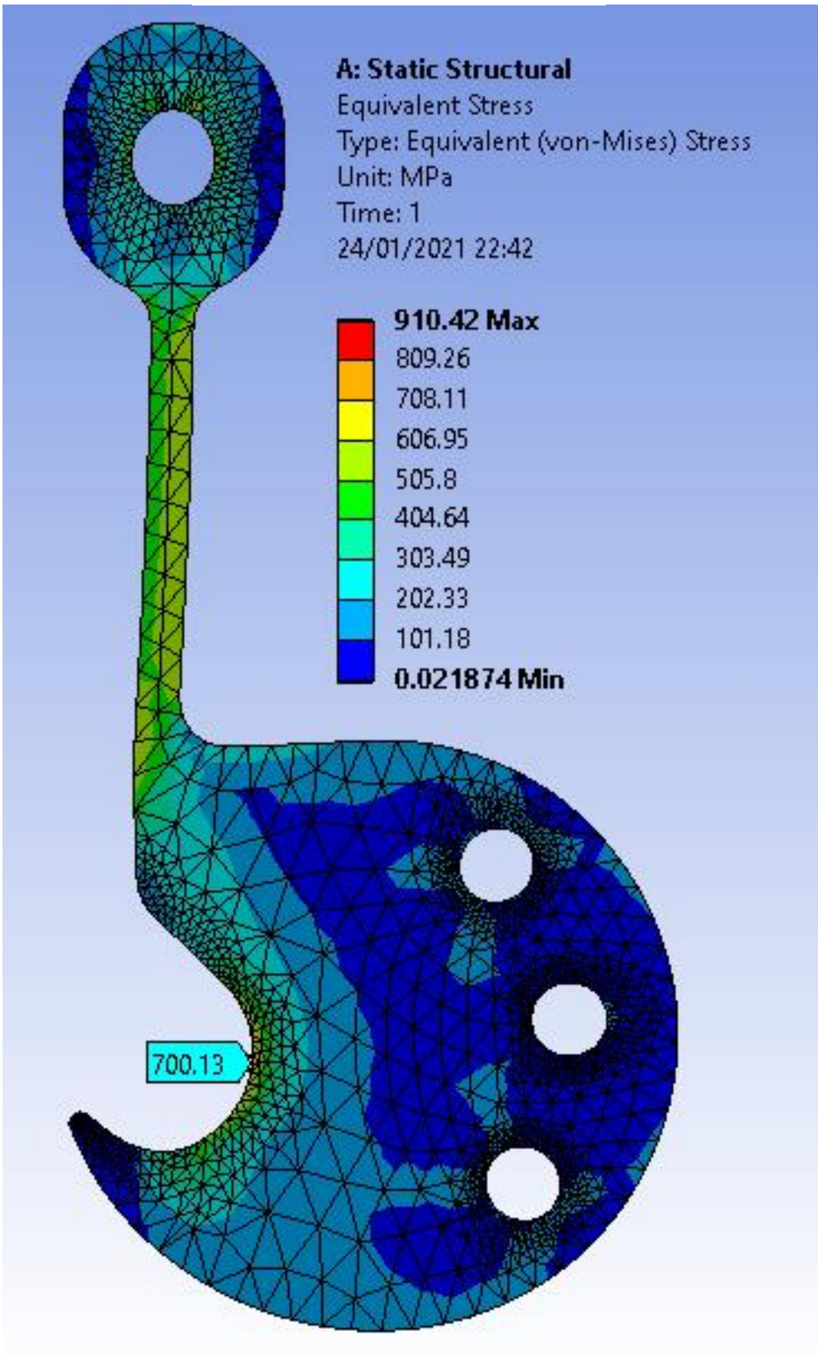
- Very good yield load to mass ratio relative to previous designs.
- Try to increase yield load to mass ratio by reducing mass of hook
- Design several holes in the blue area of the hook to reduce mass and not effect yield load.

Name – David Stewart
Student Number - 180297339

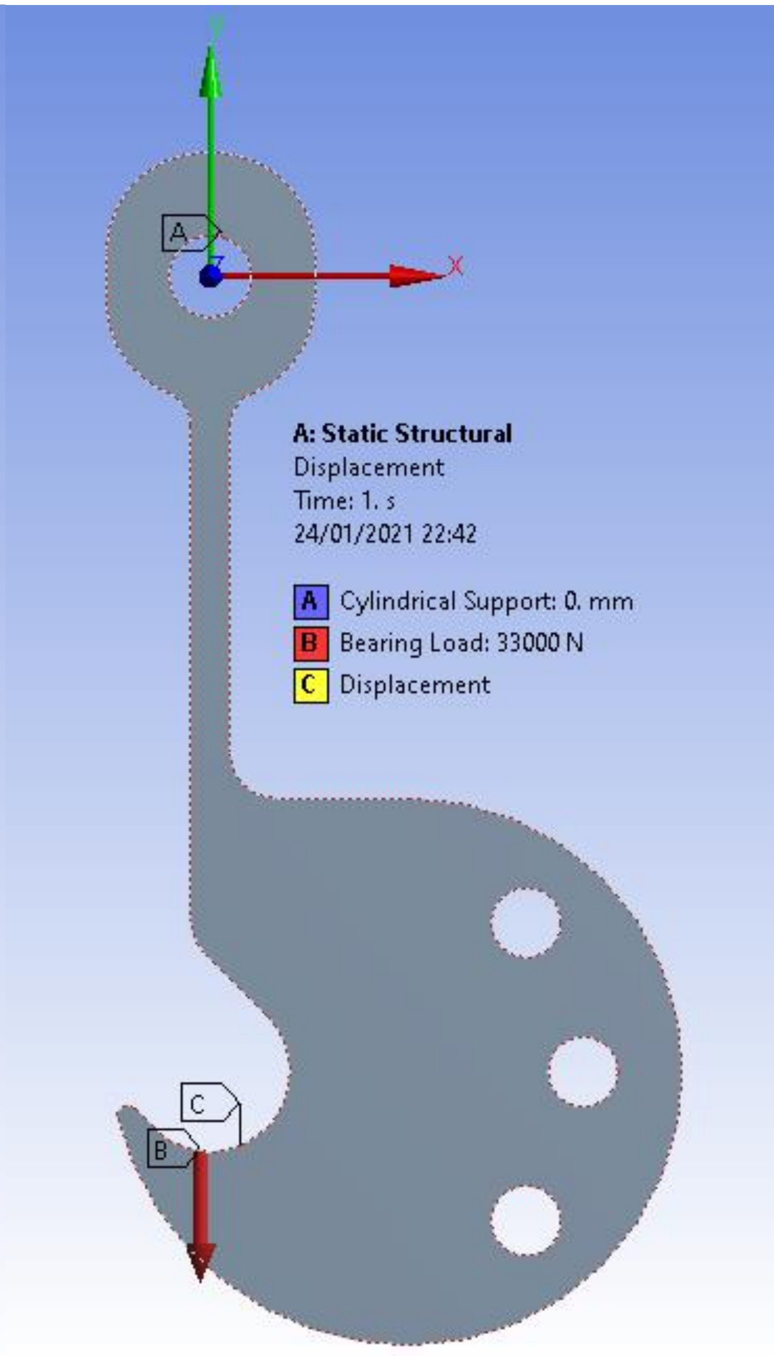
Date – 14/11/20

Hook v6

Stress results of Hook v6



Constraints of Hook v6



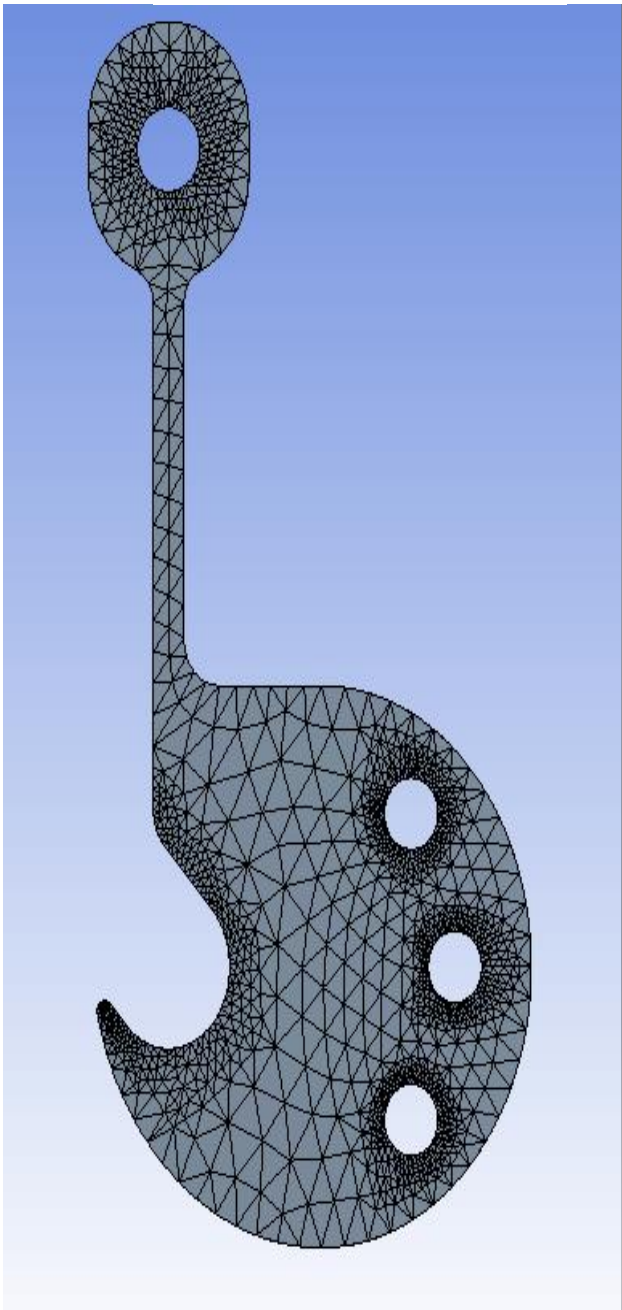
Hook 6 Stress Analysis	
Yield Stress Used (MPa)	700
Failure Stress Used (MPa)	800
Max Stress (MPa)	700.13
Applied Load (kN)	33
Expected Yield Load (kN)	32.99
Mass (g)	671
Yield Load/Mass Ratio	**49.17**

Hook 6 Contraints

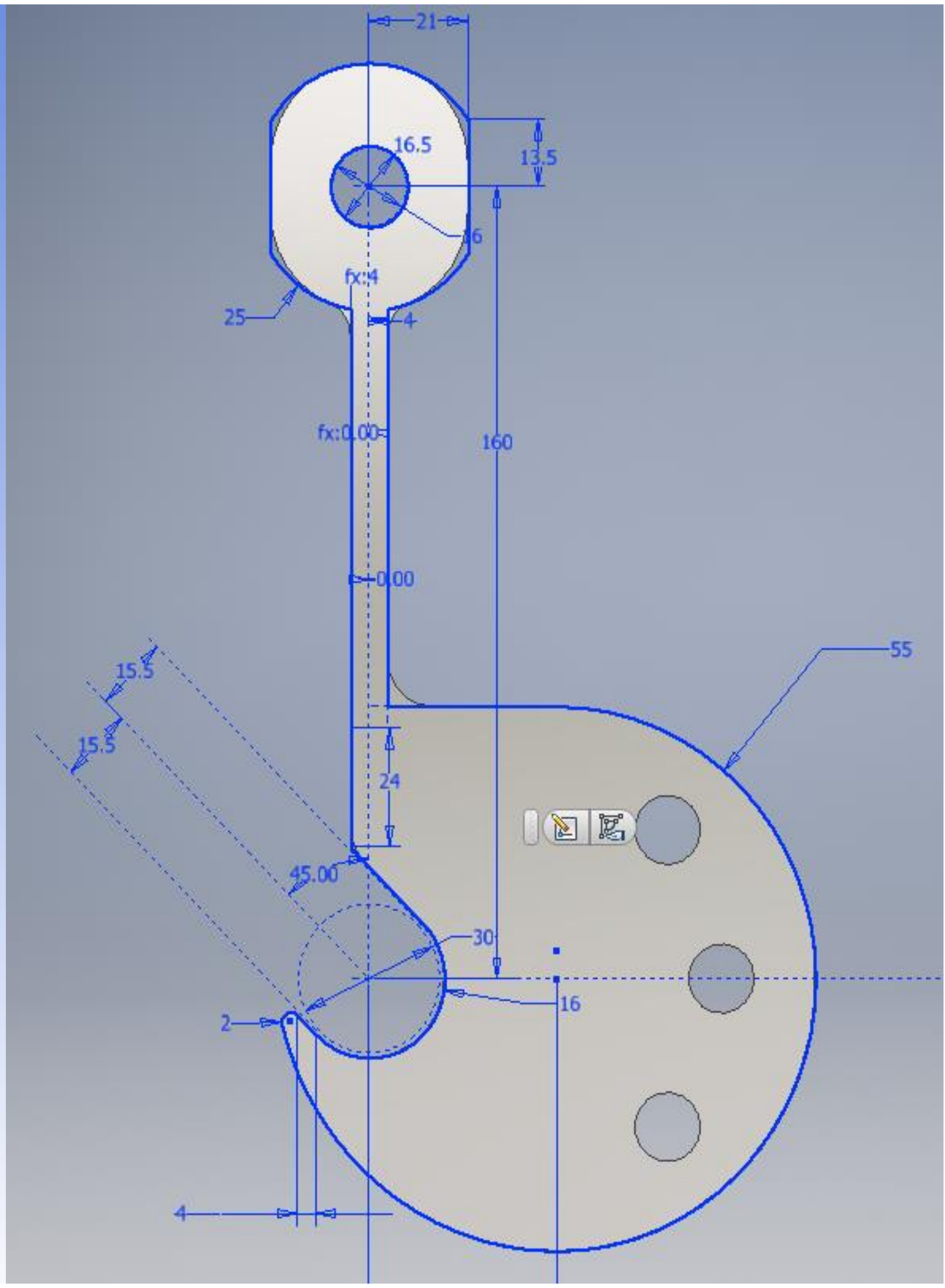
Letter	Constraint	Value	Units
A	Cylindrical Support	(0,0,0)	mm
B	Bearing Load	(0.-33000,0)	N
C	Displacement	(0, Free, Free)	mm

Date – 14/11/20

Meshing of Hook v6



Dimensions of Hook v6



Steps taken to improve next design:

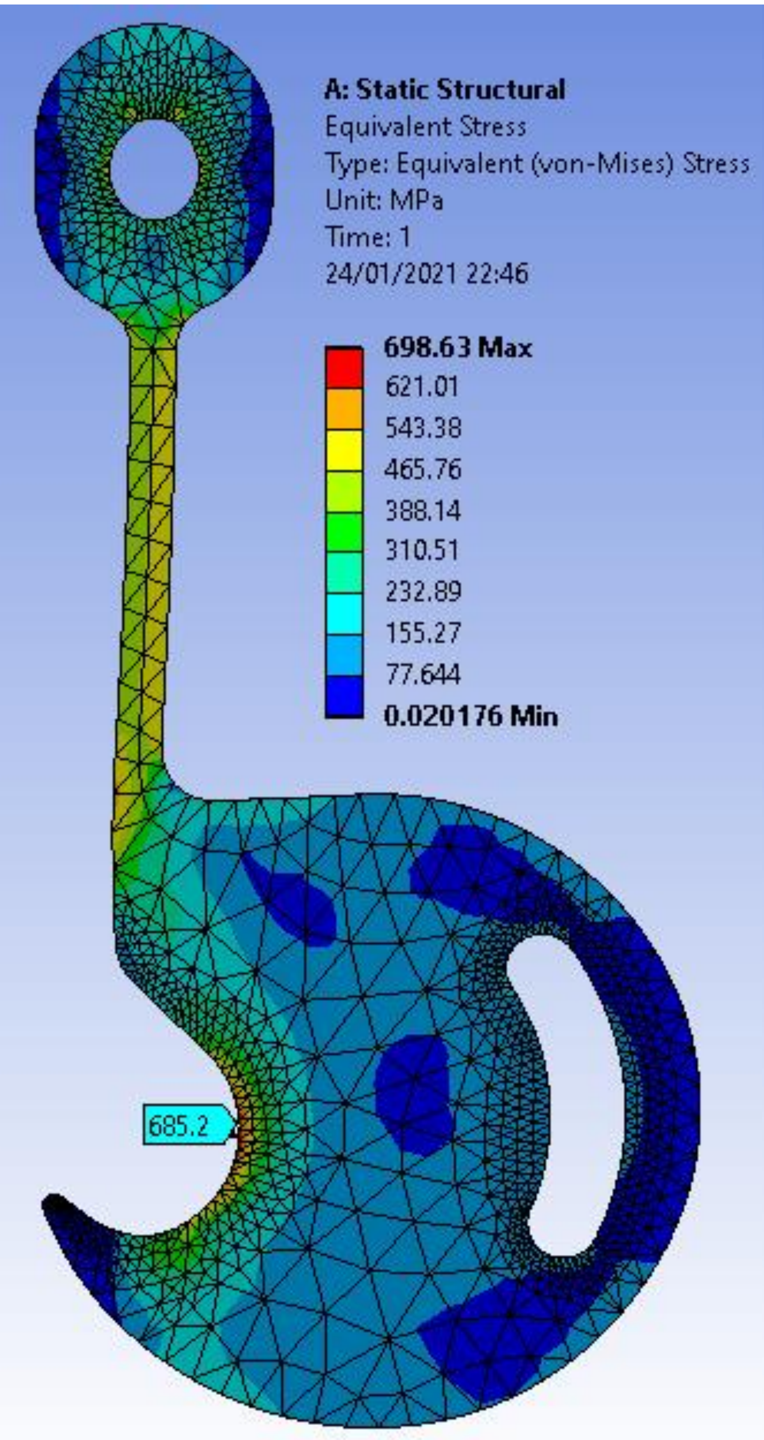
- A large drop in yield load observed along with a small drop in mass of hook.
- Slightly smaller yield load/mass ratio as pervious hook.
- Rearrange the holes to keep hook mass low and yield load high.

Name – David Stewart
Student Number - 180297339

Date – 14/11/20

Hook v7

Stress results of Hook v7



Constraints of Hook v7

Hook 7 Stress Analysis

Yield Stress Used (MPa)	700
Failure Stress Used (MPa)	800
Max Stress (MPa)	685.2
Applied Load (kN)	30
Expected Yield Load (kN)	30.65
Mass (g)	658
Yield Load/Mass Ratio	**46.58**

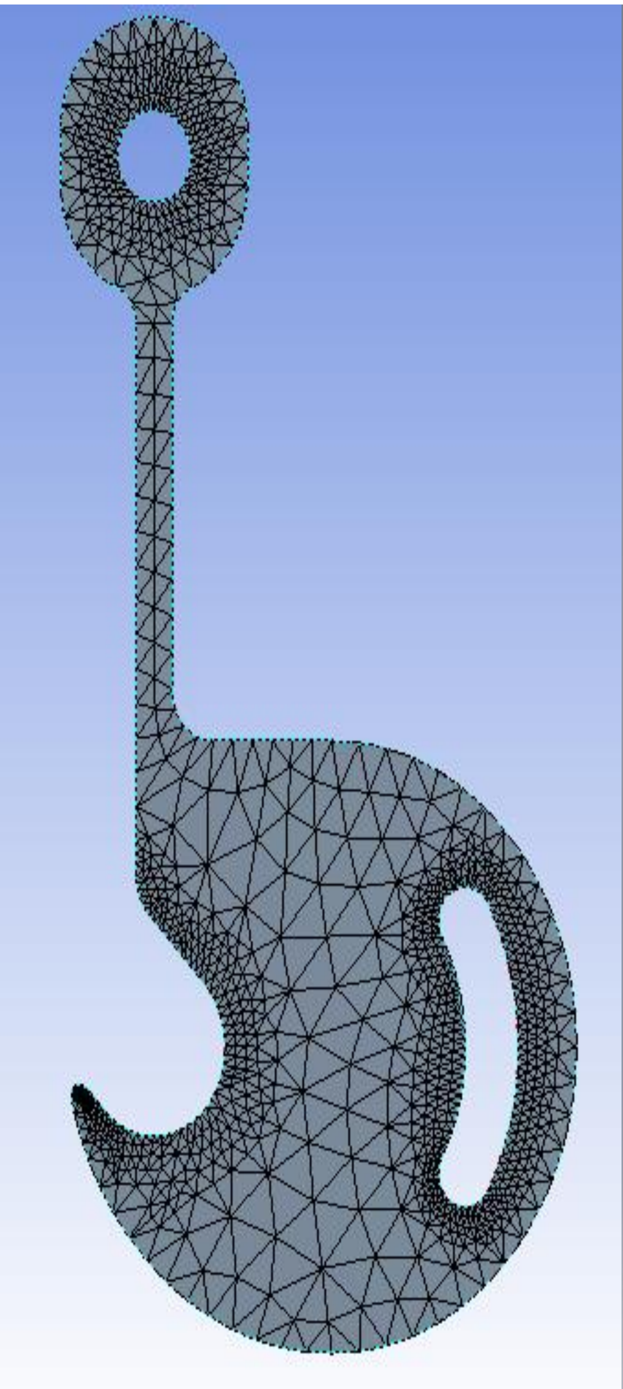
Hook 7 Contraints

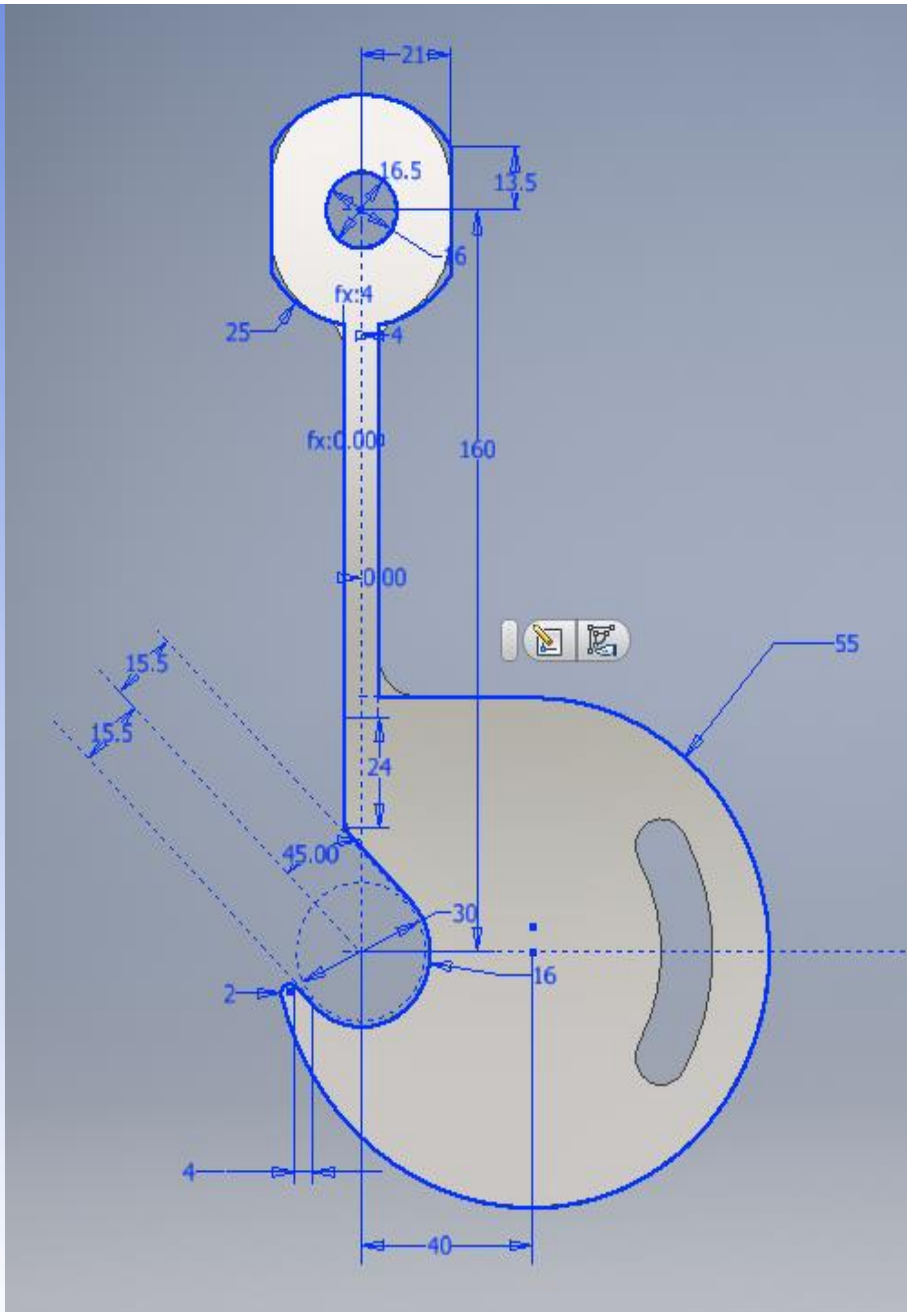
Letter	Constraint	Value	Units
A	Cylindrical Support	(0,0,0)	mm
B	Bearing Load	(0.-30000,0)	N
C	Displacement	(0, Free, Free)	mm

Date – 14/11/20

Meshing of Hook v7

Dimensions of Hook v7





Steps taken to improve next design:

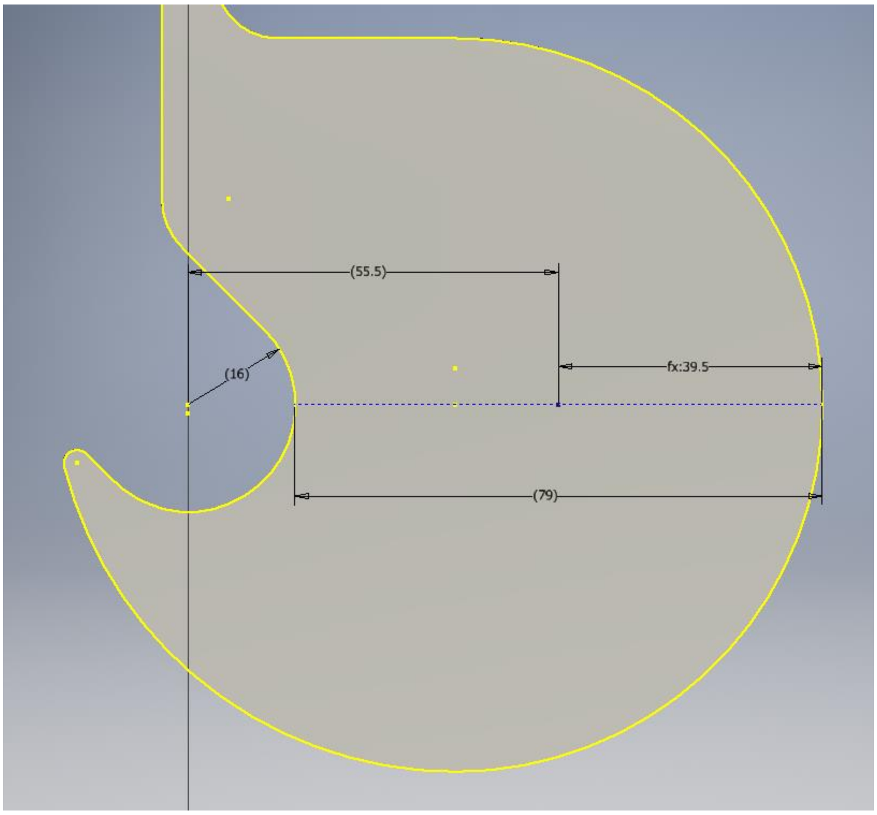
- Yield Load / mass ratio still not as high as hook v5's design.
- Finish analysis here and submit hook v5 as my final design.
- Conclusion – holes are not always beneficial.

Name – David Stewart
Student Number - 180297339

Date – 05/11/20

Hand Calculations for Final Design

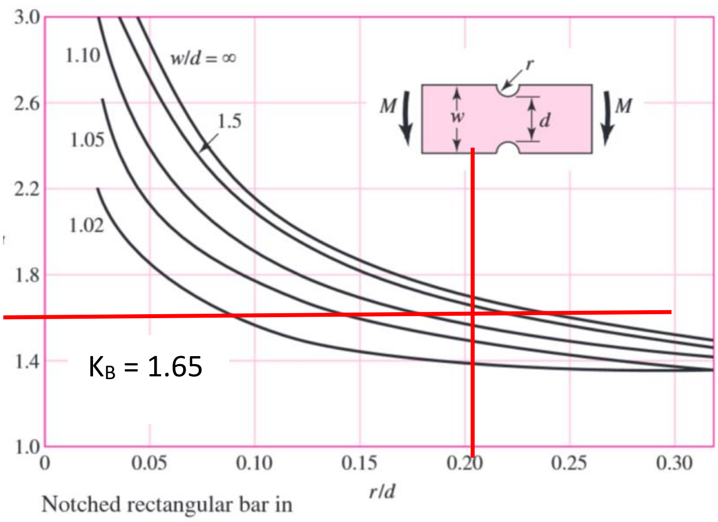
The following section describes how I carried out my hand calculations for the bending and tension stresses, the stress concentration factors and finally the maximum stress experience by the hook.



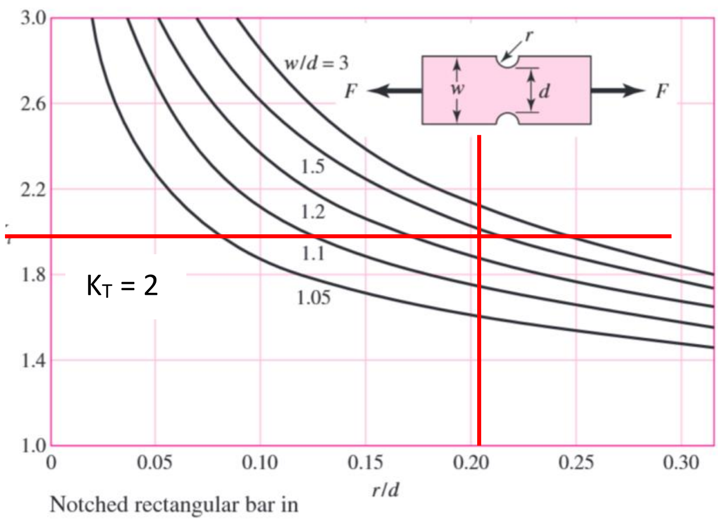
To the left is a screenshot showing the dimensions used for the area of maximum stress in the hook.

Where:
d = 79mm
r = 16mm
w = 111mm

Below are the two graphs used to estimate the stress concentration factors for a double notched flat plate in compression and bending.



Notched rectangular bar in bending. $\sigma_0 = Mc/I$, where $c = d/2$, $I = td^3/12$, and t is the thickness.



Notched rectangular bar in tension or simple compression. $\sigma_0 = F/A$, where $A = dt$ and t is the thickness.

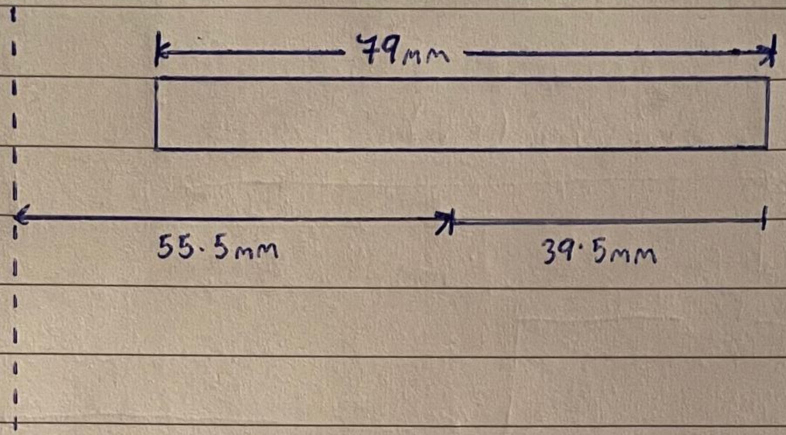
$K_B = 1.65$

$K_T = 2$

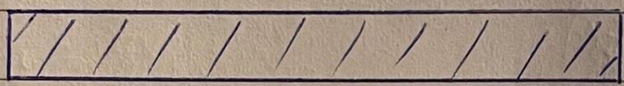
Name – David Stewart
Student Number - 180297339

Date – 05/11/20

Hand Calculations



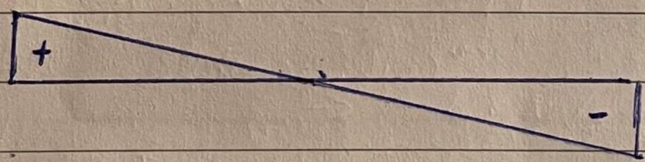
TENSION



$$\sigma_T = \left(\frac{\text{force}}{y \times \text{thickness}}\right) = \frac{30000}{79 \times 8} = 47.468\ N/mm^2$$

$$\sigma_T = 47.468\ N/mm^2$$

BENDING



$$\sigma_B = \frac{My}{I} = \frac{(30000 \times 0.0555 \times 0.0395) \times 12}{(0.008)(0.12)^3}$$

$$\sigma_B = 57.09\ N/mm^2$$

Date – 05/11/20

Stress Concentration Factors

Tension :

$d \simeq 79mm$ $\qquad$ $r/d = 0.2025$

$r \simeq 16mm$

$w \simeq 111mm$ $\qquad$ $w/d = 1.4051$

$K_t = 2$

Bending :

SAME VALUES

$K_B = 1.65$

$\therefore$ Max Stress $= K_t \sigma_T + K_B \sigma_B$

" " $= 2(47.468) + 1.65(57.09)$

$\boxed{\text{Max Stress by hand} = 192.5 \ N/mm^2}$

Max Stress by ansys $= 607.5 \ N/mm^2$

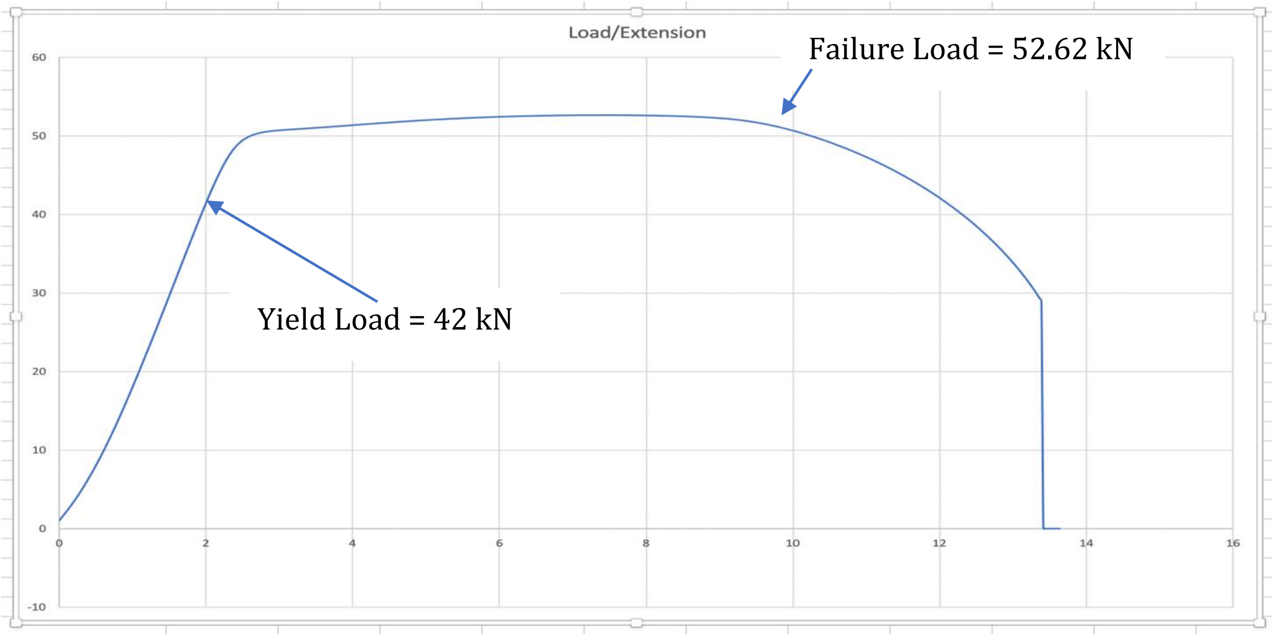
% deviation $= \left(\frac{192.5}{607.5}\right) \times 100 = 31.69..$

% descriepency $= 68.31\%$

Date – 14/01/21

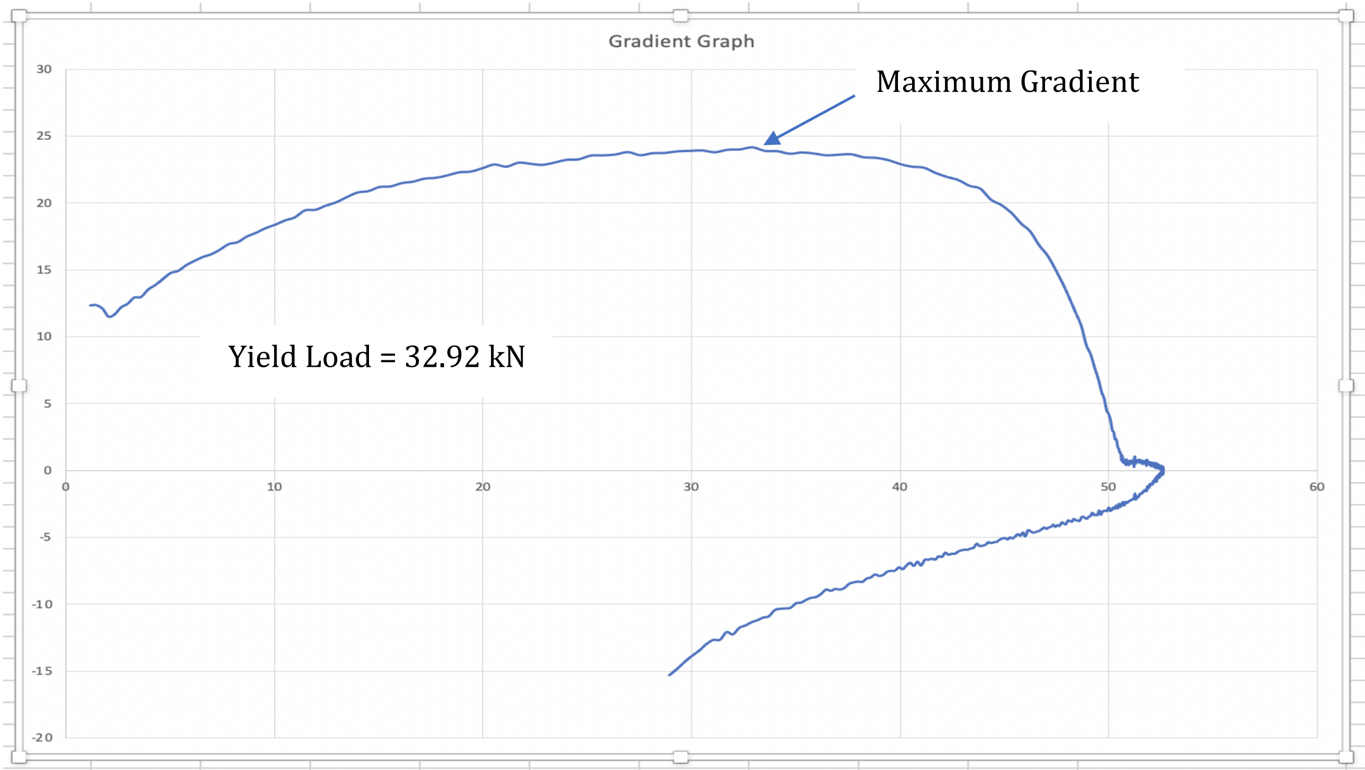
Results of Actual Test

Below shoes a graph of Load vs Extensions. Using this graph, we can estimate a maximum yield load of 42kN.



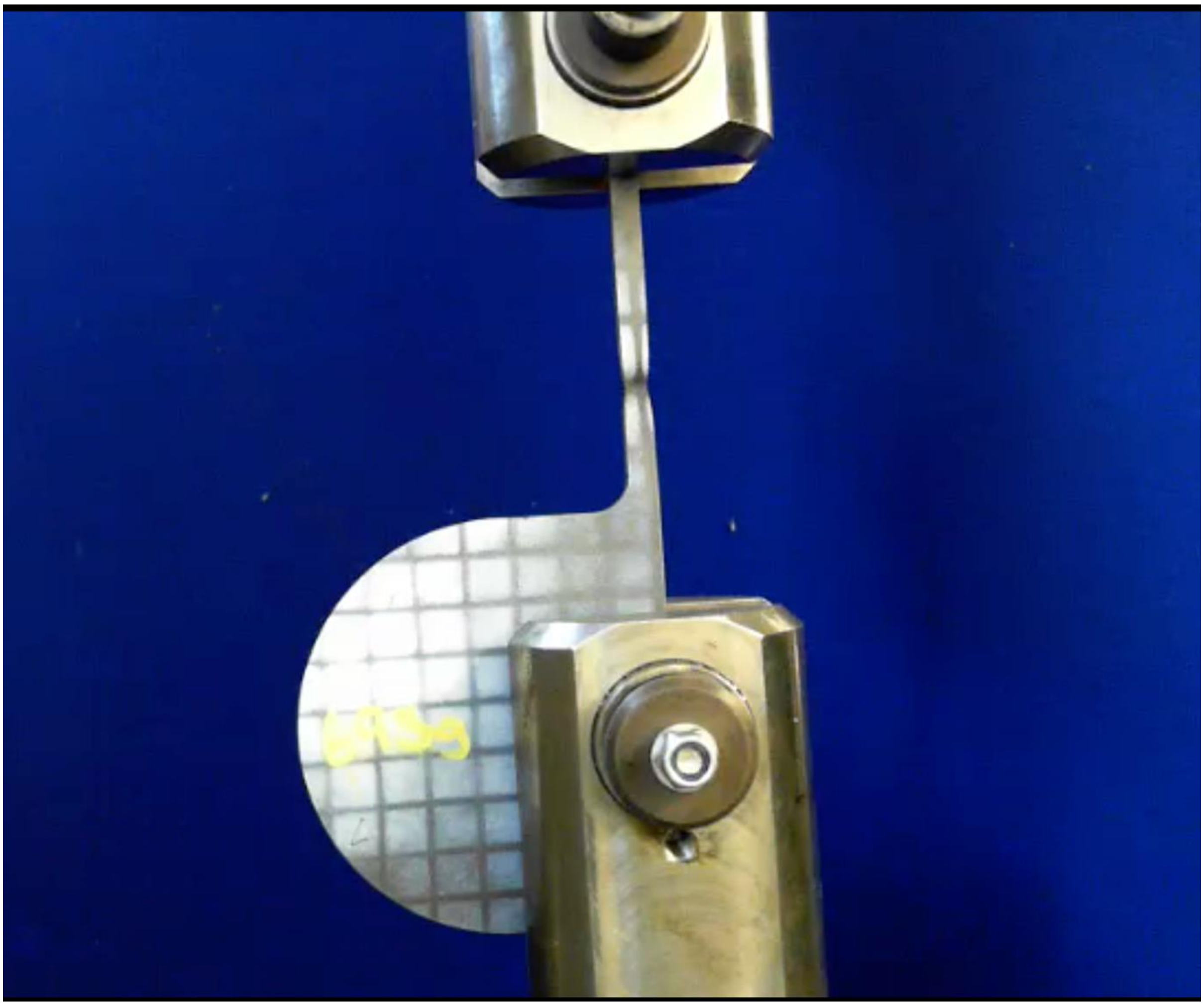
Below shoes a graph displaying the gradient of the above Load vs Extensions graph. By seeing where the gradient reaches a maximum, we can identify the first instance of yield at a load of 32.92 kN.

Time	Force	Stroke	Force	Gradient
sec	kN	mm	kN	kN/mm
6.5	32.30983	1.608604	32.30983	24.1917578
6.6	32.91564	1.633646	32.91564	24.1917578
6.7	33.5122	1.658583	33.5122	23.9226852



Name - David Stewart
Student Number - 180297339

Below shows the instance just before complete fracture at the mechanical fail safe designed in the neck of the hook. Failure occurred at 52.62 kN.



Reconciliation of Results to Analysis

Date – 22/01/21

The table below shows the discrepancies between my Ansys FEA result predictions and the actual test results for stress related values and hook mass.

Hook 5 Stress TEST Analysis			
	FEA Analysis	**Test**	**Descrepency**
Yield Load (kN)	31.375	32.91564	4.68%
Ultimate Tensile Strength (kN)	55	52.62	4.33%
Mass (g)	700	693	1.00%

For the Yield Load, the 4.68% difference in prediction to actual result may be due to the following reasons:

- The yield stress used on Ansys could range between 610kN to 740kN giving rise to a 17.6% uncertainty.
- Plate thickness could vary by ±0.02mm giving rise to a 0.25% uncertainty
- Plate width could vary by ±0.25mm giving rise to 2.5% uncertainty

CONCLUSION – The 4.68% variation in Analysis Vs Test results was due to choosing a yield stress in Ansys of 700MPa instead of an actual yield stress of 660MPa as observed in the test for the steel plate.

For the Ultimate Tensile Strength, the 4.33% difference in prediction to actual result may be due to the following reasons:

- The yield stress used on Ansys could range between 610kN to 740kN giving rise to a 17.6% uncertainty.
- Plate thickness could vary by ±0.02mm giving rise to a 0.25% uncertainty
- Plate width could vary by ±0.25mm giving rise to 2.5% uncertainty

CONCLUSION – The 4.33% variation in Analysis Vs Test results was due to choosing a yield stress in Ansys of 700MPa instead of an actual yield stress of 660MPa as observed in the test for the steel plate.

For the MASS of the hook, the 1 % difference in prediction to actual result may be due to the following reasons:

- Plate thickness could vary by ±0.02mm giving rise to a 0.25% uncertainty of mass leading to ±1.75 grams.
- Plate width could vary by ±0.25mm giving rise to 2.5% uncertainty of mass leading to ± 17.5 grams

CONCLUSION – The 1% variation in Analysis Vs Test results for the mass was due to error in the laser cutter or variations in the steel plates thickness.

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The table below shows the discrepancies between the Yield Load to Mass ratio by using different yield loads, comparing them with my initial predicted ratio.

Hook 5 Yield Load/Mass Ratio

Yield load Type	Value (kN)	Mass (g)	Yield Load/Mass ratio	Descrepency
Machine's YS1	42.78	697	61.38	24.17%
Gradient Graph	32.92		47.23	4.45%
FEA Analysis	34.6	700	49.43	0.00%
Hand Calculations	109.1		155.86	215.32%

My predicted yield load to mass ratio was 49.43 using a yield load of 34.6 kN and a mass of 700 grams.

Using the machines YS1 Yield Load of 42.78 kN, we get a Yield Load/Mass ratio of 61.38. This is a 24.17% increase over the predicted ratio of 49.43 and this may be because:

- The test machine allows for some plastic deformation before considering the hook to have yielded. It doesn't consider the hook to have yielded at the first instance of plastic deformation. This results in a higher value of yield force to be seen as the yield load, resulting in a higher yield load/mass ratio.

CONCLUSION – The 24.17% variation in yield load/mass ratio was due to the test rig allowing some yield to occur, not recording yield at the first instance.

Using the yield load from the gradient graph of 32.92 kN, we get a Yield Load/Mass ratio of 47.23. This is a 4.45% increase over the predicted ratio of 49.43 and this may be because:

- A variation in the dimensions of the hook due to errors in laser cutting or plate thickness causing a different yield load.
- My predicted yield load from Ansys may be incorrect because of constraining the hook incorrectly, due to poor meshing or due to using an inaccurate yield stress when editing the material properties.

CONCLUSION – The 4.45% variation in yield load/mass ratio was most likely due to not fine enough meshing or using an incorrect yield stress for the hooks material in ANSYS.

Using my hand calculations yield load of 109.1 kN, we get a Yield Load/Mass ratio of 61.38. This is a 215.32% increase over the predicted ratio of 49.43 and this may be because:

- Incorrect stress concentration factors have been used for the bending and tension stresses. The hook is not a flat plate with two notches, instead a flat plate with only one notch. This would cause huge changes to the yield load, thus to the yield load/mass ratio.
- The maximum stress calculated by hand was roughly three times smaller than that of the one calculated in ansys even after the stress concentration factors where considered.
- This is due to poor modelling of the shape but could be rectified by using more accurate model of the hook for the stress concentration factor.

CONCLUSION – The 24.17% variation in yield load/mass ratio was due to inaccurate stress concentration factors which could be rectified by using a more accurate model.

P.S - All relevant notes on lectures are in a handwritten logbook