

UWTSD

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Tensile Test

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Introduction

This assignment aims to test various materials for their stress, strain, and strength. To do this the materials will be placed in the tensile tester and a force will be applied through them until breakage.

Most Materials have a linear elasticity up until a certain point. After this, they no longer obey Hooke's law. This turning point is called yield stress. After a material has passed this point it will no longer return to its original size and shape (TecQuipment, 2012). This can be observed using a graph between stress and strain.

The maximum stress put through the material before breaking is called Tensile Strength or UTS (TecQuipment, 2012). This can be calculated by putting the force applied over the surface area.

Young's modulus which is the ratio of stress to strain, which is the gradient of the stress-strain graph.

Experimental Procedure

To begin this experiment, the tensile tester must be fitted to the work panel using the 4 screws (figure 3). To fit the specimen the tester, the load nut must be turned to align the top attachment with the bottom one for the specimen to fit.



Figure 1 Shows the complete setup of equipment

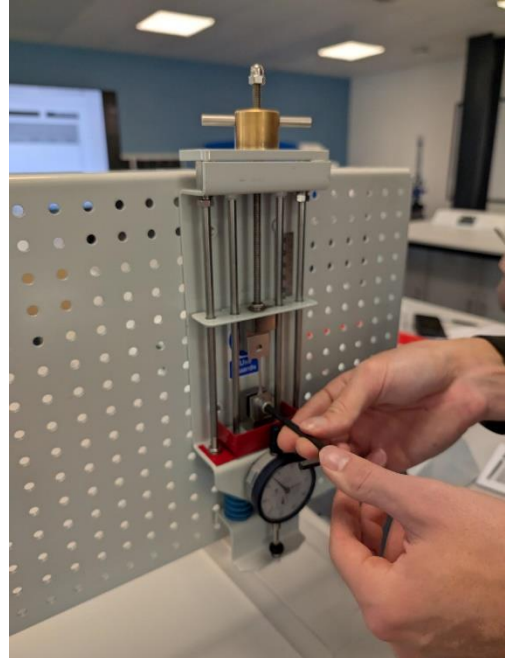


Figure 2 shows the fastening of material into attachment.

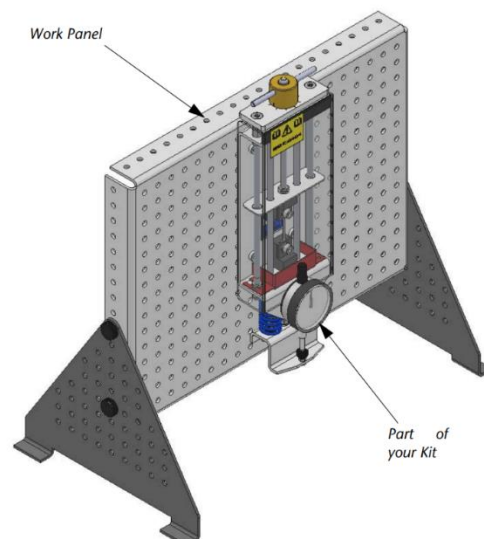
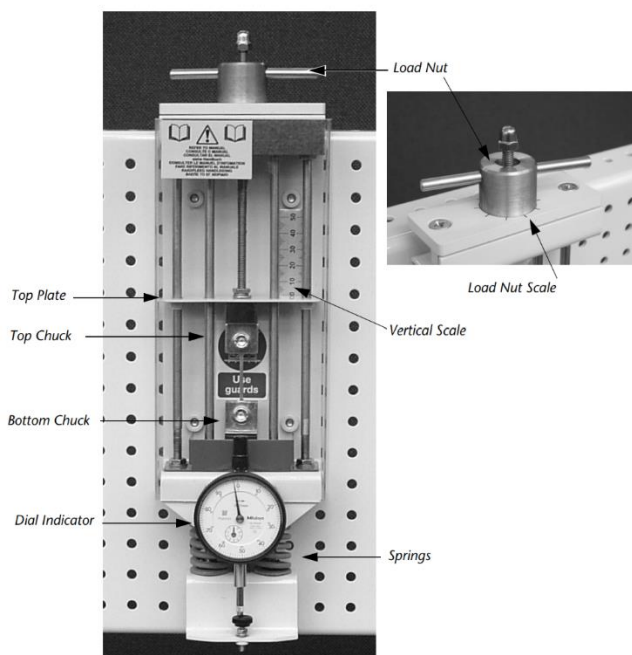


Figure 3 Shows the labelled diagram of components supplied by the kit (TecQuipment, 2012).

Before the material is fit, it must first be measured using a vernier for length and cross-sectional surface area (figure 4). Once the specimen has been fitted, the plastic shield must be placed. Next, turn the load nut until there is minute movement on the dti gauge, then align to zero. Atop the tensile tester, there are 10 notches around the load nut, each of these notches indicates 0.1mm of upward pull (TecQuipment, 2012).

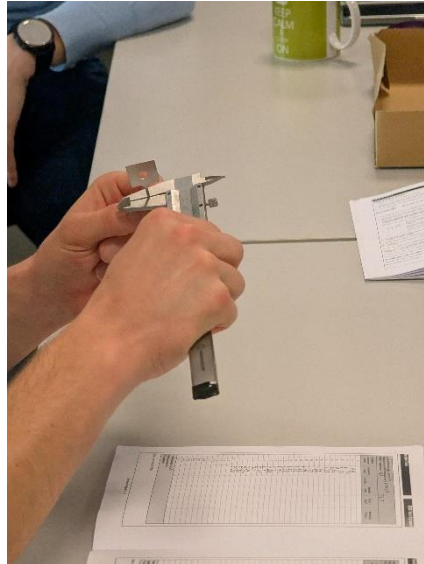


Figure 4 shows the measuring of the material.

This experiment asks for an increase of 0.2mm to 5mm at which point it is to be turned one full rotation at a time until 10mm where the increase will be in 10's, when turning the load nut turn with equal force and speed for accuracy. When reading the dial indicator, all measurements must be precise for accuracy. As the materials reach their breakpoint there will be a slight force pulling back causing the measurement to change.



Figure 5 shows the material after breakage.

Once the specimen has broken into two, remove it from the tester, align it back together with the broken ends touching, and use a vernier to measure the new length (Figure 6).



Figure 6 remeasuring the broken material.

Repeat this experiment with the other materials and record all data.

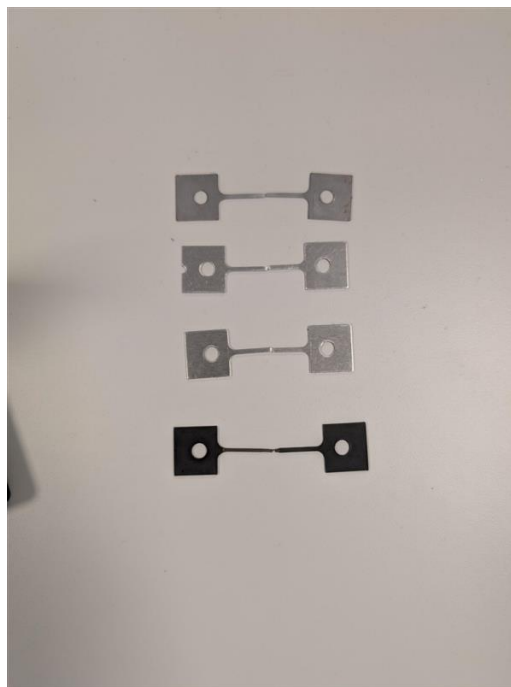


Figure 7 shows all materials together after breakage, showcasing different rates of elongation.

Results

Steel

Table 0-1 Shows the completed table with the measurements of material before and after the test.

Load nut movement (mm)	Dial indicator (mm)	Force (N)	Extension	Stress (N/m ²)	Stress (MPa)	Nominal Strain							
0.00	0.00	0.00	0.00	0.00	0.00	0.0000							
0.20	0.17	17.00	0.03	9444444.44	9.44	0.0010						Cross sectional area (mm ²)	(m ²)
0.40	0.35	35.00	0.05	19444444.44	19.44	0.0016						1.8	0.0000018
0.60	0.54	54.00	0.06	30000000.00	30.00	0.0019						Original length (mm)	
0.80	0.73	73.00	0.07	40555555.56	40.56	0.0023						30.9	
1.00	0.91	91.00	0.09	50555555.56	50.56	0.0029						New length (mm)	
1.20	1.11	111.00	0.09	61666666.67	61.67	0.0029						38.7	
1.40	1.29	129.00	0.11	71666666.67	71.67	0.0036							
1.60	1.48	148.00	0.12	82222222.22	82.22	0.0039							
1.80	1.64	164.00	0.16	91111111.11	91.11	0.0052							
2.00	1.84	184.00	0.16	102222222.22	102.22	0.0052							
2.20	2.02	202.00	0.18	112222222.22	112.22	0.0058							
2.40	2.22	222.00	0.18	123333333.33	123.33	0.0058							
2.60	2.39	239.00	0.21	132777777.78	132.78	0.0068							
2.80	2.56	256.00	0.24	142222222.22	142.22	0.0078							
3.00	2.75	275.00	0.25	152777777.78	152.78	0.0081							
3.20	2.91	291.00	0.29	161666666.67	161.67	0.0094							
3.40	3.09	309.00	0.31	171666666.67	171.67	0.0100							
3.60	3.21	321.00	0.39	178333333.33	178.33	0.0126							
3.80	3.35	335.00	0.45	186111111.11	186.11	0.0146							
4.00	3.48	348.00	0.52	193333333.33	193.33	0.0168							
4.20	3.62	362.00	0.58	201111111.11	201.11	0.0188							
4.40	3.75	375.00	0.65	208333333.33	208.33	0.0210							
4.60	3.86	386.00	0.74	214444444.44	214.44	0.0239							
4.80	3.98	398.00	0.82	221111111.11	221.11	0.0265							
5.00	4.09	409.00	0.91	227222222.22	227.22	0.0294							
6.00	4.54	454.00	1.46	252222222.22	252.22	0.0472							
7.00	4.89	489.00	2.11	271666666.67	271.67	0.0683							
8.00	5.14	514.00	2.86	285555555.56	285.56	0.0926							
9.00	5.28	528.00	3.72	293333333.33	293.33	0.1204							
10.00	5.38	538.00	4.62	298888888.89	298.89	0.1495							
20.00													
30.00													
40.00													
50.00													
60.00													

Aluminum

Table 0-2 Shows all the data required for this test for aluminium.

Load nut movement (mm)	Dial indicator (mm)	Force (N)	Extension	Stress (N/m ²)	Stress (MPa)	Nominal Strain					
0.00	0.00	0.00	0.00	0.00	0.00	0.0000					
0.20	0.16	16.00	0.04	9356725.15	9.36	0.0013				Cross sectional area (mm ²)	(m ²)
0.40	0.35	35.00	0.05	20467836.26	20.47	0.0016				1.71	0.00000171
0.60	0.53	53.00	0.07	30994152.05	30.99	0.0023					
0.80	0.71	71.00	0.09	41520467.84	41.52	0.0029				Original length (mm)	
1.00	0.89	89.00	0.11	52046783.63	52.05	0.0036				30.9	
1.20	1.08	108.00	0.12	63157894.74	63.16	0.0039				New length (mm)	
1.40	1.26	126.00	0.14	73684210.53	73.68	0.0045				33.7	
1.60	1.44	144.00	0.16	84210526.32	84.21	0.0052					
1.80	1.70	170.00	0.10	99415204.68	99.42	0.0032					
2.00	1.86	186.00	0.14	108771929.82	108.77	0.0045					
2.20	2.02	202.00	0.18	118128654.97	118.13	0.0058					
2.40	2.15	215.00	0.25	125730994.15	125.73	0.0081					
2.60	2.25	225.00	0.35	131578947.37	131.58	0.0113					
2.80	2.34	234.00	0.46	136842105.26	136.84	0.0149					
3.00	2.42	242.00	0.58	141520467.84	141.52	0.0188					
3.20	2.51	251.00	0.69	146783625.73	146.78	0.0223					
3.40	2.58	258.00	0.82	150877192.98	150.88	0.0265					
3.60	2.61	261.00	0.99	152631578.95	152.63	0.0320					
3.80	2.70	270.00	1.10	157894736.84	157.89	0.0356					
4.00	2.71	271.00	1.29	158479532.16	158.48	0.0417					
4.20	2.76	276.00	1.44	161403508.77	161.40	0.0466					
4.40	2.77	277.00	1.63	161988304.09	161.99	0.0528					
4.60	2.80	280.00	1.80	163742690.06	163.74	0.0583					
4.80	2.78	278.00	2.02	162573099.42	162.57	0.0654					
5.00											
6.00											
7.00											
8.00											
9.00											
10.00											
20.00											
30.00											
40.00											
50.00											
60.00											

Duralumin

Table 0-3 Highlights the data calculated from the tensile strength test. Including conversion from N/m² to MPa.

Load nut movement (mm)	Dial indicator (mm)	Force (N)	Extension	Stress (N/m ²)	Stress (MPa)	Nominal Strain						
0.00	0.00	0.00	0.00	0.00	0.00	0.0000						
0.20	0.17	17.00	0.03	8947368.42	8.95	0.0010						
0.40	0.35	35.00	0.05	18421052.63	18.42	0.0016						
0.60	0.54	54.00	0.06	28421052.63	28.42	0.0019						
0.80	0.72	72.00	0.08	37894736.84	37.89	0.0026						
1.00	0.91	91.00	0.09	47894736.84	47.89	0.0029						
1.20	1.09	109.00	0.11	57368421.05	57.37	0.0036						
1.40	1.27	127.00	0.13	66842105.26	66.84	0.0042						
1.60	1.45	145.00	0.15	76315789.47	76.32	0.0049						
1.80	1.63	163.00	0.17	85789473.68	85.79	0.0055						
2.00	1.82	182.00	0.18	95789473.68	95.79	0.0058						
2.20	2.00	200.00	0.20	105263157.89	105.26	0.0065						
2.40	2.18	218.00	0.22	114736842.11	114.74	0.0071						
2.60	2.36	236.00	0.24	124210526.32	124.21	0.0078						
2.80	2.54	254.00	0.26	133684210.53	133.68	0.0084						
3.00	2.72	272.00	0.28	143157894.74	143.16	0.0091						
3.20	2.89	289.00	0.31	152105263.16	152.11	0.0100						
3.40	3.06	306.00	0.34	161052631.58	161.05	0.0110						
3.60	3.24	324.00	0.36	170526315.79	170.53	0.0117						
3.80	3.41	341.00	0.39	179473684.21	179.47	0.0126						
4.00	3.57	357.00	0.43	187894736.84	187.89	0.0139						
4.20	3.72	372.00	0.48	195789473.68	195.79	0.0155						
4.40	3.89	389.00	0.51	204736842.11	204.74	0.0165						
4.60	4.07	407.00	0.53	214210526.32	214.21	0.0172						
4.80	4.23	423.00	0.57	222631578.95	222.63	0.0184						
5.00	4.41	441.00	0.59	232105263.16	232.11	0.0191						
6.00	4.95	495.00	1.05	260526315.79	260.53	0.0340						
7.00	5.27	527.00	1.73	277368421.05	277.37	0.0560						
8.00	5.30	530.00	2.70	278947368.42	278.95	0.0874						
9.00												
10.00												
20.00												
30.00												
40.00												
50.00												
60.00												

PVC

Table 0-4 Shows the complete data table for PVC.

Load nut movement (mm)	Dial indicator (mm)	Force (N)	Extension	Stress (N/m ²)	Stress (MPa)	Nominal Strain				
0.00	0.00	0.00	0.00	0.00	0.00	0.0000				
0.20	0.09	9.00	0.11	4736842.11	4.74	0.0036			Cross sectional area (mm ²)	(m ²)
0.40	0.11	11.00	0.29	5789473.68	5.79	0.0095			1.9	0.00000190
0.60	0.19	19.00	0.41	10000000.00	10.00	0.0134			Original length (mm)	
0.80	0.24	24.00	0.56	12631578.95	12.63	0.0183			30.6	
1.00	0.26	26.00	0.74	13684210.53	13.68	0.0242			New length (mm)	
1.20	0.25	25.00	0.95	13157894.74	13.16	0.0310			43	
1.40	0.16	16.00	1.24	8421052.63	8.42	0.0405				
1.60	0.14	14.00	1.46	7368421.05	7.37	0.0477				
1.80	0.18	18.00	1.62	9473684.21	9.47	0.0529				
2.00	0.18	18.00	1.82	9473684.21	9.47	0.0595				
2.20	0.17	17.00	2.03	8947368.42	8.95	0.0663				
2.40	0.16	16.00	2.24	8421052.63	8.42	0.0732				
2.60	0.16	16.00	2.44	8421052.63	8.42	0.0797				
2.80	0.16	16.00	2.64	8421052.63	8.42	0.0863				
3.00	0.17	17.00	2.83	8947368.42	8.95	0.0925				
3.20	0.17	17.00	3.03	8947368.42	8.95	0.0990				
3.40	0.16	16.00	3.24	8421052.63	8.42	0.1059				
3.60	0.16	16.00	3.44	8421052.63	8.42	0.1124				
3.80	0.16	16.00	3.64	8421052.63	8.42	0.1190				
4.00	0.17	17.00	3.83	8947368.42	8.95	0.1252				
4.20	0.17	17.00	4.03	8947368.42	8.95	0.1317				
4.40	0.15	15.00	4.25	7894736.84	7.89	0.1389				
4.60	0.16	16.00	4.44	8421052.63	8.42	0.1451				
4.80	0.17	17.00	4.63	8947368.42	8.95	0.1513				
5.00	0.16	16.00	4.84	8421052.63	8.42	0.1582				
6.00	0.22	22.00	5.78	11578947.37	11.58	0.1889				
7.00	0.22	22.00	6.78	11578947.37	11.58	0.2216				
8.00	0.20	20.00	7.80	10526315.79	10.53	0.2549				
9.00	0.19	19.00	8.81	10000000.00	10.00	0.2879				
10.00	0.18	18.00	9.82	9473684.21	9.47	0.3209				
20.00										
30.00										
40.00										
50.00										
60.00										

Analysis

The springs have a combined spring rate of 100n/mm, the dial indicator measures the change in spring length so each mm it changes shows a force of 100N (TecQuipment, 2012). So to find the overall force you need to use the equation

$$Force (N) = Dial Indicator Reading (mm) \times 100.$$

In Excel, this was represented as =SUM(Cx*100) where x represents the row and C references the column with the dial indicator results.

The next measurement the table asks to be worked out is the extension, this is as simple as taking the load nut movement and taking away the dial indicator movement (TecQuipment, 2012). This is shown as

$$Extension (mm) = Load Nut Movement (mm) - Dial Indicator movement (mm).$$

In Excel, this is represented as =sum(Bx-Cx). Where x represents the row, B represents the column of Load nut Movement.

Stress is the next column on this table to work out. This can be calculated using the formula

$$Stress (\sigma) = \frac{Force (N)}{Area acted on by force (m^2)}$$

otherwise known as $\sigma = \frac{F}{A}$. In Excel this is represented as =SUM(Dx/\$M\$5), where D represents the column of force, and \$M\$5 is the cell containing the cross sectional area in M². This can also be converted into MPa, to do this swap the area from m² to mm².

The final column; nominal strain. This can be worked out using the formula

$$\varepsilon = \frac{Change in Length}{Original Length}$$

Otherwise known as $\varepsilon = \frac{l}{L}$. In Excel, this is represented as =SUM(Ex/\$K\$8) where E is the column for elongation and \$K\$8 is the cell with the original length in mm.

To calculate the Young's Modulus a graph plotting the correlation between stress and strain must be made. The gradient of the elastic region equates to the Young's Modulus.

Graphs for Stress vs Strain

Steel

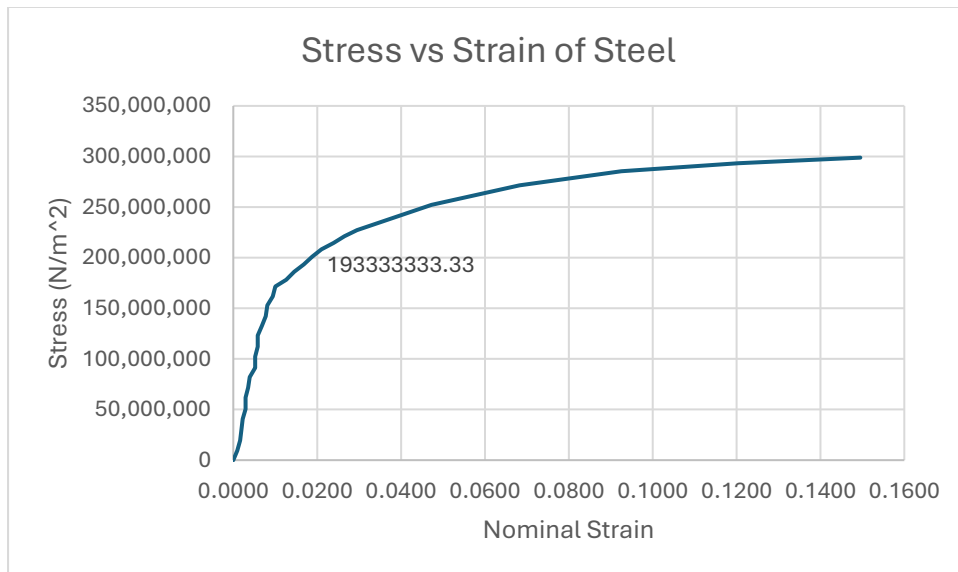


Figure 8 Shows the Stress vs Strain of Steel whilst highlighting the yield point.

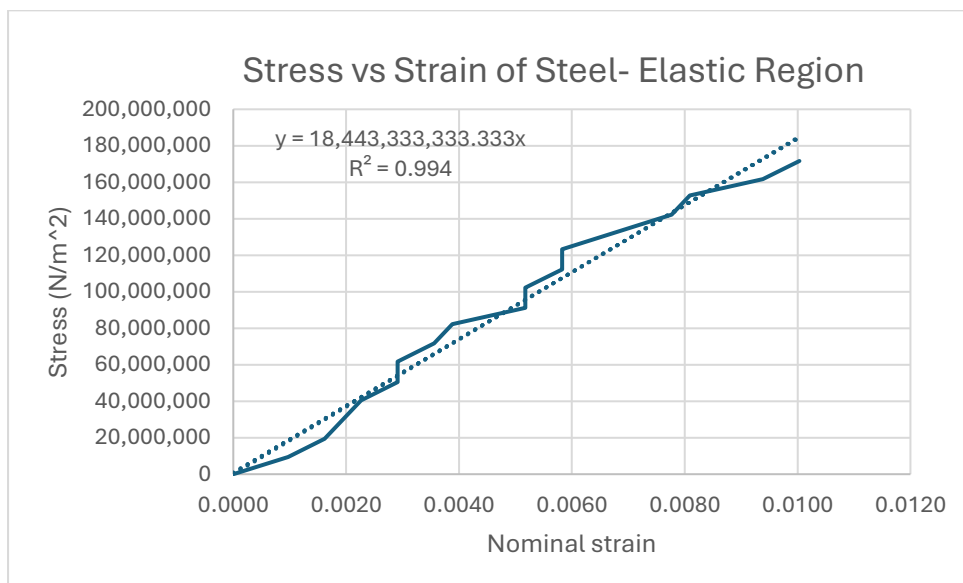


Figure 9 Shows the Elastic region stress vs strain graph where the gradient is Youngs Modulus.

Aluminium

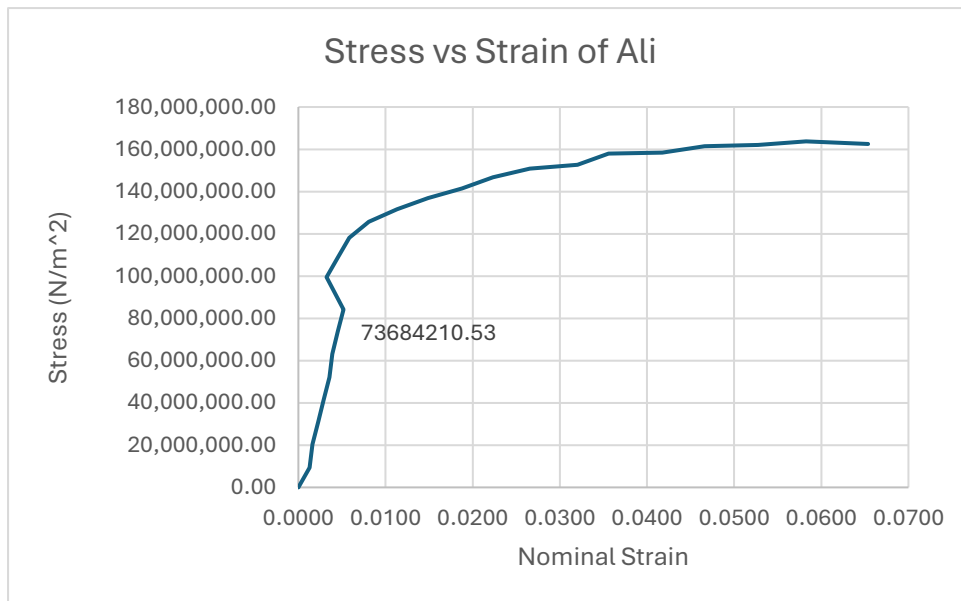


Figure 10 Highlights the anomaly in the stress and strain graph of Aluminium.

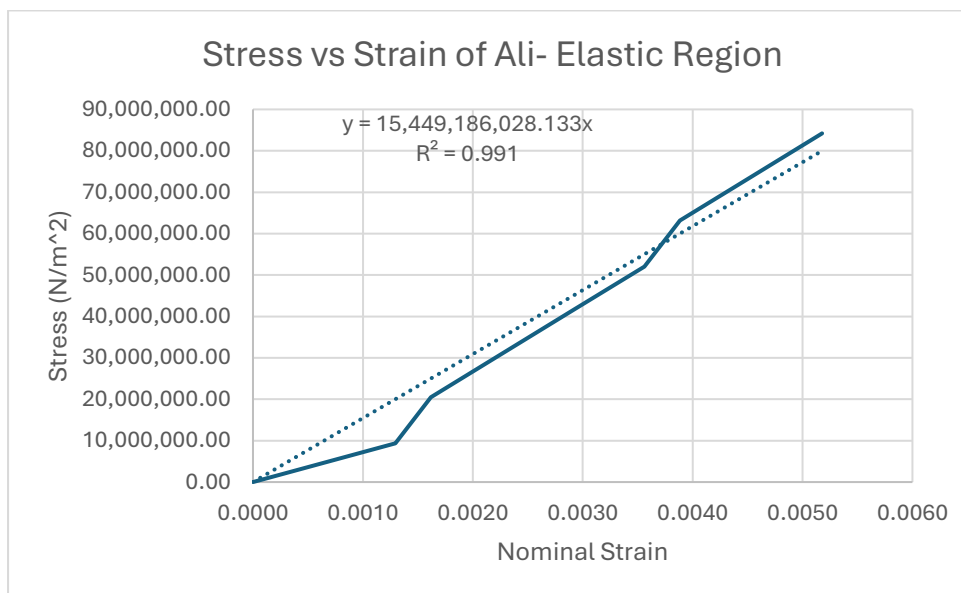


Figure 11 Shows the Young's Modulus for Aluminium in the elastic region.

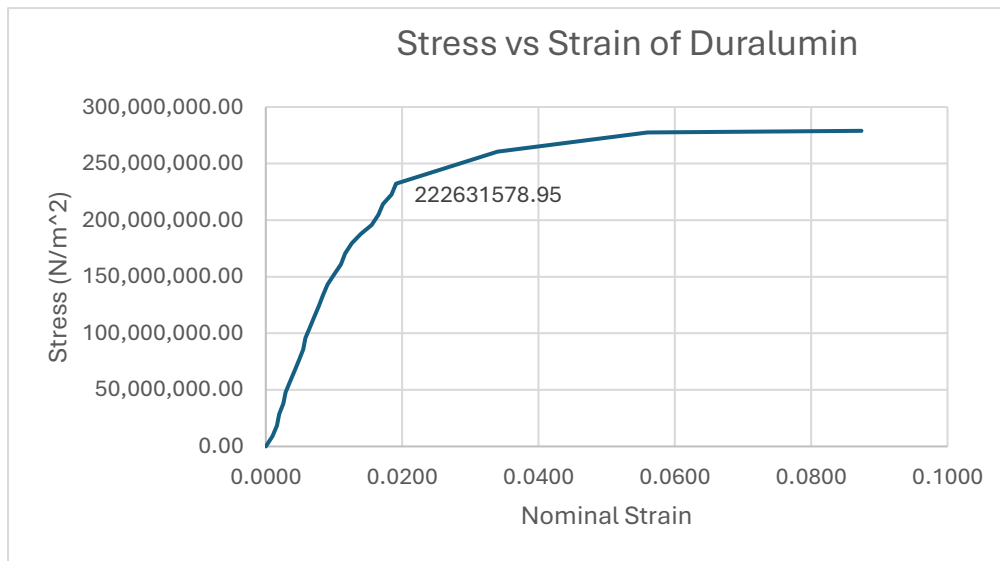
Duralumin

Figure 12 Shows the Stress vs Strain of Duralumin.

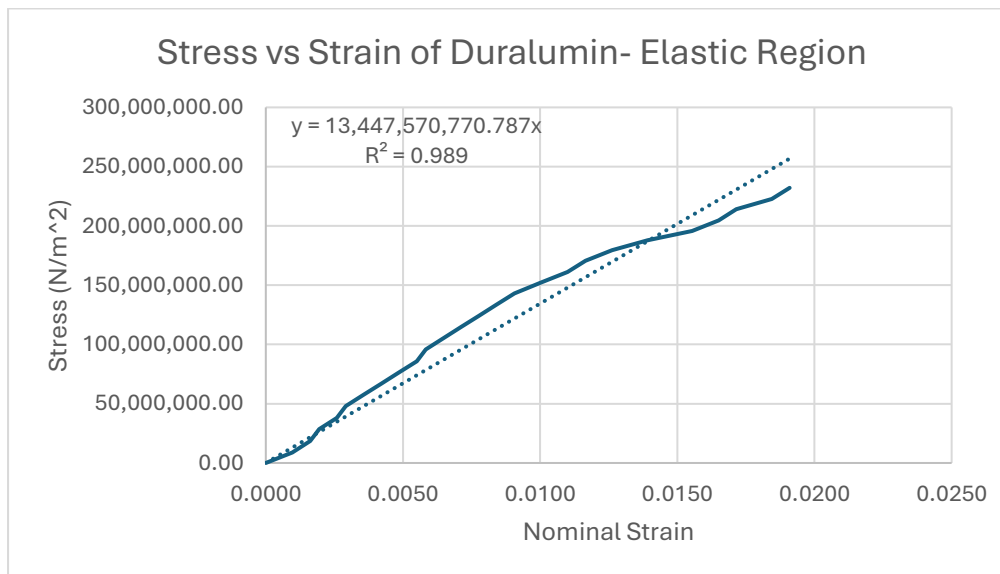


Figure 13 Shows the elastic region of Duralumin highlighting the gradient (E)

PVC

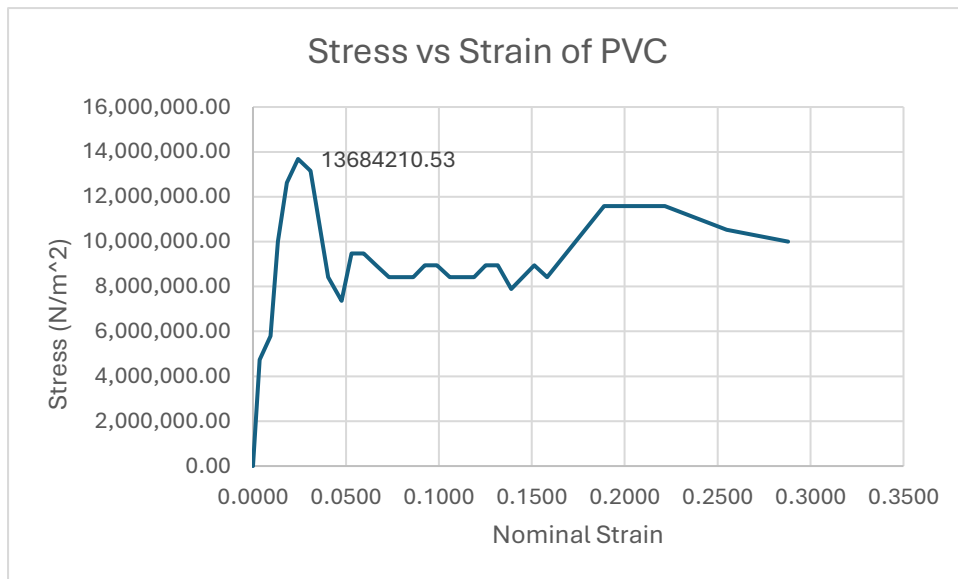


Figure 14 Stress and Strain of PVC highlighting the yield point.

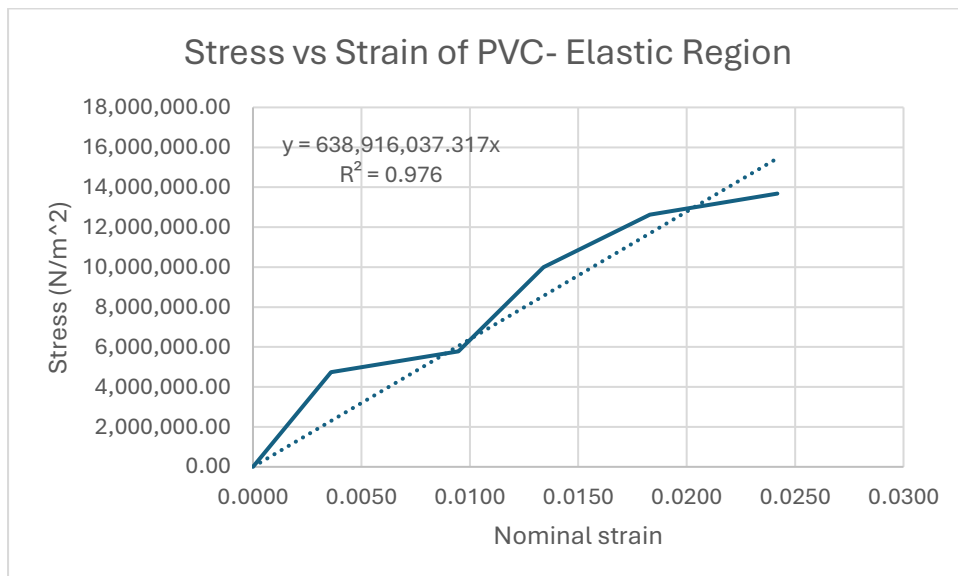


Figure 15 shows the Young's modulus of PVC in the elastic region.

Conclusion

Steel

Youngs Modulus

The Young's Modulus for steel typically ranges from 180-200 GPa ($18-20 \times 10^{10} \text{ N/m}^2$) (Mouser Electronics, 2003). In this experiment, a resultant Young's modulus was $18 \times 10^9 \text{ n/m}^2$, 10x smaller than anticipated. The discrepancy could have many factors contributing to it such as the quality of steel. Temperature, however, can be ruled out due to the experiment being at room temperature.

Tensile Stress

The maximum tensile stress recorded for the steel piece was 298.89 MPa after which it snapped. Due to the break, we were unable to record the exact stress put through the material before the break. The UTS of mild steel varies from 400-550 MPa and medium Carbon Steel has a UTS of 500-700 MPa (Callister.W.D, 2007). Comparing these results I can determine that it was a very low quality of steel that was used.

Yield Stress

For Steel, I determined this point to be at the 4.00mm of load nut travel. The total stress on the workpiece at this time was 193,333,333 N/m² or 193.3 MPa. Steel has a typical Yield stress of roughly 40,000 psi or 2.757×10^8 (CNCLATHING, 2020). Due to my result being equivalent to 1.9×10^8 , I feel that is result correlates.

Aluminum

Youngs Modulus

For the aluminum results in the elastic region, I got a gradient of 15.45×10^9 . For this material, an expected outcome would be in the range of 68-88.5 GPa ($68-88.5 \times 10^9$) (Kahn, 2024). Therefore my result was between 4.4 and 5.7 times smaller than this. Due to the Young's modulus decreasing at a rate of 5 GPa per 100 degrees C I can determine that the temperature was not the cause of this.

Tensile Strength

The largest tensile strength was recorded at 4.60 mm of load nut movement. At this time 280N of force was being put through the material. Resulting in a UTS of 163.74 MPa. Pure Aluminum has a UTS of 90 MPa and a lower quality of aluminum alloy has a UTS of 310 MPa. So the material used is a poor quality aluminum alloy.

Yield Stress

Pure aluminum has a yield stress point of 30 MPa, whereas a lower quality alloy such as 1100 has a yield stress of 76MPa. The result returned from the experiment was 73.68MPa so I can verify that this material must be of an 1100 grade.

Duralumin

Young's Modulus

The Young's Modulus of duralumin is 73.1 GPa (True geometry, 2024). Using the gradient of the graph for the elastic region I determined that my Youngs Modulus equated to 13.4 GPa therefore my reading was 5.4x smaller than the data provided online.

Tensile Stress

The maximum stress recorded for duralumin was 278.95 MPa which it hit just before breaking at 530N. the average UTS of duralumin is 483 MPa, therefore my results are roughly half (True geometry, 2024).

Yield Stress

Duralumin has a yield stress of 345 MPa (True geometry, 2024). For this experiment, I got a result of 222.63 MPa at 423N of force. Which shows that my result was 0.6 the scale expected.

PVC

Young's Modulus

Rigid PVC has a Youngs modulus value of 3.7 GPa and flexible PVC has a Young's modulus of 1.4 GPa (Atkins, 2019). Using the gradient on the graph I have determined the result of 0.639 GPa. Which is less than half the expected result for flexible PVC

Tensile Stress

The maximum tensile stress put through the PVC was 13.68 MPa which was recorded at 1mm of load nut travel. The expected UTS was 16 MPa so this result is accurate (Atkins, 2019).

Yield Stress

The yield stress of PVC has a large range which is dependent on the application. This range is 3.45-73.1 MPa (Matweb, No Date). My result of 13.68 MPa recorded at the same time as UTS is well within this range.

Evaluation

To help minimize errors as much as possible we had one person dedicated to each role, for focus. Unfortunately, there was one anomaly picked up for Aluminum. Looking at the Stress-Stain graph it is apparent that the load nut was turned too far, at the 1.8mm mark, due to the results continuing from this point. We also ensured the reader sat level with DTI for clear vision. Breaks were also taken in between tests to increase alertness.

Further work

To make this experiment better, I would use sensors and a digital data logging DTI to accurately measure when each material breaks. Alternatively using a slo-mo camera to read the DTI and the load nut at the time of the break. I would also repeat the test and use an average for the results. Using a digital vernier caliper would also help to remove any human error with measurements.

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