



Tensile Strength
Engineering Science ACHA4002

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1 Introduction

This paper will be looking at a tensile test experiment and analysis of the tensile strength and stiffness of different specimen materials using the 'Tensile Tester Kit ES6'. This paper will provide a detailed analysis of the experimental procedure, and the data found from the results into the conclusion to better understand materials under stress and strain.

2 Experiment Procedure

2.1 Setting Up

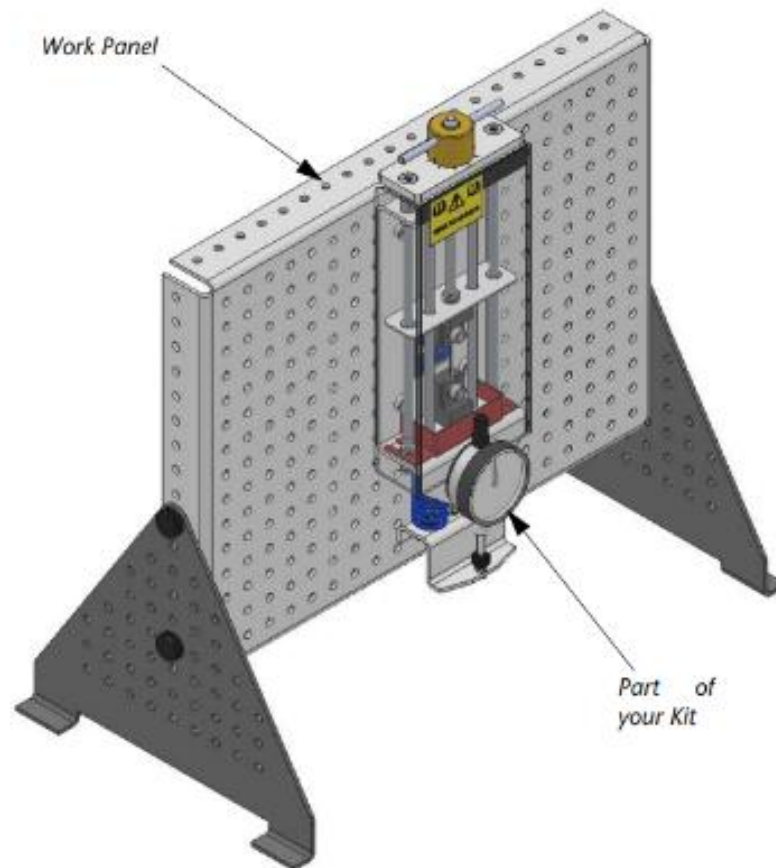


Figure 2-1: A Typical Experiment set up (TecQuipment, 2012)

Firstly, the work panel and the experiment kit must be assembled together as seen above in Figure 2-1. The experiment kit has many different features as seen below in Figure 2-3; the load nut, load nut scale (can only be seen in figure 2-1), top plate, vertical scale, top chuck, bottom chuck, dial indicator and springs. To begin remove the safety guard and use a hexagon tool supplied to unlock both chucks ready to fit a specimen piece.

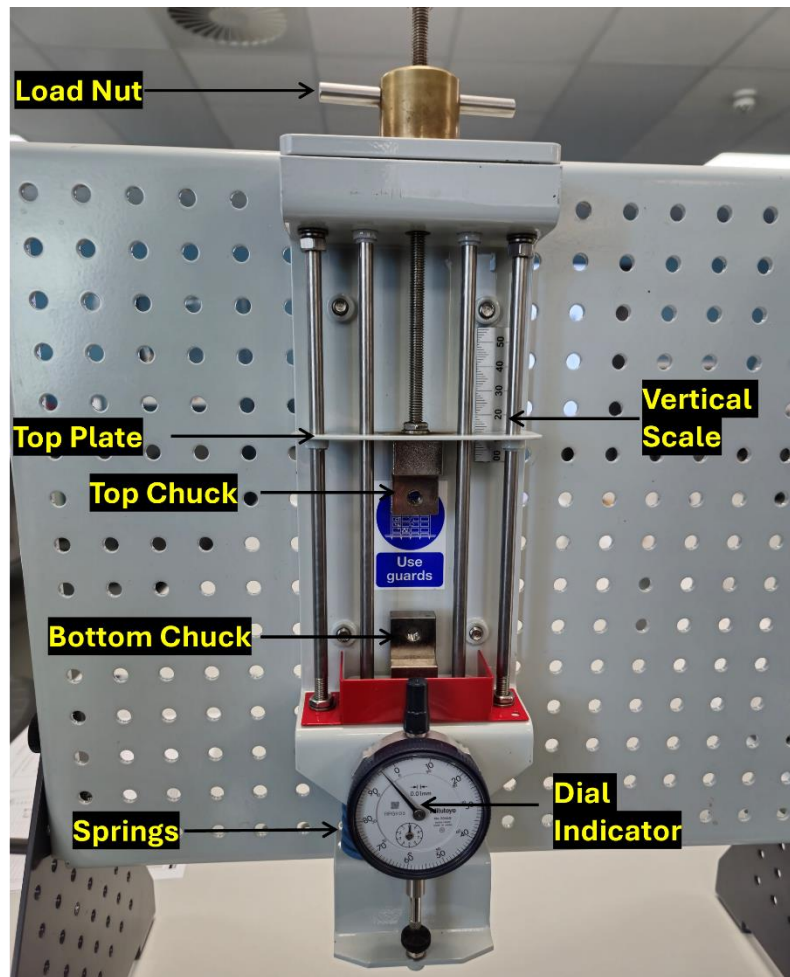


Figure 2-2: Labelled Experiment Kit (Ethan Davies, 2024)

With the experiment kit set up, guard removed and chucks loose the first specimen may be fitted. To do so place the specimen in between both chuck and tighten the chucks using the hexagon tool then refit the guard accordingly.

Specimens used will consist of:

A basic aluminium alloy

Duralumin – a high specification aluminium alloy

Mild steel – a basic steel alloy

PVC (polyvinyl chloride) – a common thermoplastic

Make sure you measure the dimensions of each specimen being the gauge length, width and depth to then work out the cross-sectional area.



*Figure 2-3 Experiment Kit Set with Guard and Specimen
(Ethan Davies, 2024)*

2.2 Experimentation & Measurement

To start the experiment, turn the load nut until the dial indicator starts to show movement, this means the specimen is now tight between both chucks, then set the dial indicator to zero. Begin moving the load nut in the designated increments on the work sheet and write down the readings on the dial indicator, repeat this until the specimen breaks.

3 Results

3.1 Steel

Table 3-1: Raw Data of Steel

Load Nut Movement (mm)	Dial Indicator (mm)
0	0
0.2	0.17
0.4	0.36
0.6	0.55
0.8	0.74
1	0.93
1.2	1.11
1.4	1.3
1.6	1.49
1.8	1.67
2	1.85
2.2	2.03
2.4	2.22
2.6	2.4
2.8	2.57
3	2.73
3.2	2.9
3.4	3.05
3.6	3.28
3.8	3.29
4	3.42
4.2	3.54
4.4	3.67
4.6	3.78
4.8	3.88
5	3.99
6	4.48
7	4.8
8	5.04
9	5.2
10	5.28

Table 3-2: Measured Values of Steel

Original Cross Sectional Area (mm ²)	Original Length (mm)	Final Length (mm)
1.818	31	39.1
Elongation (mm)	Elongation (%)	
8.1	26.12903226	

3.2 Aluminium

Table 3-3: Raw Data of Aluminium

Load Nut Movement (mm)	Dial Indicator (mm)
0	0
0.2	0.07
0.4	0.24
0.6	0.42
0.8	0.61
1	0.79
1.2	0.96
1.4	1.15
1.6	1.32
1.8	1.5
2	1.66
2.2	1.78
2.4	1.89
2.6	2.02
2.8	2.13
3	2.27
3.2	2.33
3.4	2.44
3.6	2.49
3.8	2.59
4	2.62
4.2	2.71
4.4	2.74
4.6	2.76
4.8	2.79
5	2.82

Table 3-4: Measured Values of Aluminium

Original Cross Sectional Area (mm ²)	Original Length (mm)	Final Length (mm)
1.824	31	33.95
Elongation (mm)	Elongation (%)	
2.95	9.516129032	

3.3 Duralumin

Table 3-5: Raw Data of Duralumin

Load Nut Movement (mm)	Dial Indicator (mm)
0	0
0.2	0.13
0.4	0.29
0.6	0.46
0.8	0.64
1	0.81
1.2	0.98
1.4	1.16
1.6	1.34
1.8	1.52
2	1.69
2.2	1.87
2.4	2.05
2.6	2.34
2.8	2.41
3	2.59
3.2	2.77
3.4	2.94
3.6	3.12
3.8	3.3
4	3.48
4.2	3.65
4.4	3.83
4.6	4.01
4.8	4.18
5	4.35
6	5.02
7	5.37

Table 3-6: Measured Values of Duralumin

Original Cross Sectional Area (mm ²)		Original Length (mm)	Final Length (mm)
1.8914		31	33.5
Elongation (mm)	Elongation (%)		
2.5	8.064516129		

3.4 PVC

Table 3-7 Raw Data of PVC

Load Nut Movement (mm)	Dial Indicator (mm)
0	0
0.2	0.05
0.4	0.11
0.6	0.16
0.8	0.19
1	0.21
1.2	0.06
1.4	0.09
1.6	0.1
1.8	0.09
2	0.09
2.2	0.09
2.4	0.09
2.6	0.09
2.8	0.09
3	0.1
3.2	0.1
3.4	0.1
3.6	0.1
3.8	0.09
4	0.09
4.2	0.09
4.4	0.1
4.6	0.09
4.8	0.08
5	0.09
6	0.09
7	0.08

Table 3-8: Measured Values of PVC

Original Cross Sectional Area (mm ²)	Original Length (mm)	Final Length (mm)
1.9602	31.2	69.51
Elongation (mm)	Elongation (%)	
38.31	122.7884615	

8	0.03
9	0.05
10	0.08
20	0.04
30	0.05
40	0.05

4 Analysis

4.1 Stress & Strain

To begin to understand the stiffness of each specimen Young's Modulus must be calculated through a Young's Modulus stress and strain graph. Firstly, the extension of the specimen and force applied to each specimen must be calculated.

$$\text{Extension (mm)} = \text{Load Nut Movement (mm)} - \text{Dial Indicator Reading (mm)}$$

$$\text{Force (N)} = \text{Dial indicator Reading (mm)} * 100$$

Moving onto stress also known as Greek letter σ we must use the formula

$$\sigma \left(\frac{\text{N}}{\text{mm}^2} \right) = \frac{\text{Force (N)}}{\text{Area acted on by force (mm}^2\text{)}}$$

The units of stress are usually $\left(\frac{\text{N}}{\text{m}^2} \right)$ or (Pa) but to ensure that the results are not giant numbers working in $\left(\frac{\text{N}}{\text{mm}^2} \right)$ and (MPa) the results will be numbers of a reasonable size for

$$1 \text{ MPa} = 1 \frac{\text{N}}{\text{mm}^2}.$$

Similarly, strain also known as Greek letter ϵ is calculated from the formula

$$\epsilon = \frac{\text{Change in Length}}{\text{Original Length}}$$

The change in length in this formula will be the extension of the specimen labelled in the Tables 4-1 through to 4-4

4.2 Calculated Values

Table 4-2: Calculated Values of Steel

Force (N)	Extension (mm)	Stress σ (N/mm ²)	Nominal Strain ϵ
0	0	0	0
17	0.03	9.350935094	0.000967742
36	0.04	19.8019802	0.001290323
55	0.05	30.2530253	0.001612903
74	0.06	40.70407041	0.001935484
93	0.07	51.15511551	0.002258065
111	0.09	61.05610561	0.002903226
130	0.1	71.50715072	0.003225806
149	0.11	81.95819582	0.003548387
167	0.13	91.85918592	0.004193548
185	0.15	101.760176	0.00483871
203	0.17	111.6611661	0.005483871
222	0.18	122.1122112	0.005806452
240	0.2	132.0132013	0.006451613
257	0.23	141.3641364	0.007419355
273	0.27	150.1650165	0.008709677
290	0.3	159.5159516	0.009677419
305	0.35	167.7667767	0.011290323
328	0.32	180.4180418	0.010322581
329	0.51	180.9680968	0.016451613
342	0.58	188.1188119	0.018709677
354	0.66	194.7194719	0.021290323
367	0.73	201.870187	0.023548387
378	0.82	207.9207921	0.026451613
388	0.92	213.4213421	0.029677419
399	1.01	219.4719472	0.032580645
448	1.52	246.4246425	0.049032258
480	2.2	264.0264026	0.070967742
504	2.96	277.2277228	0.095483871
520	3.8	286.0286029	0.122580645
528	4.72	290.4290429	0.152258065

Table 4-3: Calculated Values of Aluminium

Force (N)	Extension (mm)	Stress σ (N/mm ²)	Nominal Strain ϵ
0	0	0	0
7	0.13	3.837719298	0.004193548
24	0.16	13.15789474	0.00516129
42	0.18	23.02631579	0.005806452
61	0.19	33.44298246	0.006129032
79	0.21	43.31140351	0.006774194
96	0.24	52.63157895	0.007741935
115	0.25	63.04824561	0.008064516
132	0.28	72.36842105	0.009032258
150	0.3	82.23684211	0.009677419
166	0.34	91.00877193	0.010967742
178	0.42	97.5877193	0.013548387
189	0.51	103.6184211	0.016451613
202	0.58	110.745614	0.018709677
213	0.67	116.7763158	0.021612903
227	0.73	124.4517544	0.023548387
233	0.87	127.7412281	0.028064516
244	0.96	133.7719298	0.030967742
249	1.11	136.5131579	0.035806452
259	1.21	141.995614	0.039032258
262	1.38	143.6403509	0.044516129
271	1.49	148.5745614	0.048064516
274	1.66	150.2192982	0.053548387
276	1.84	151.3157895	0.059354839
279	2.01	152.9605263	0.06483871
282	2.18	154.6052632	0.070322581

Table 4-1: Calculated Values of Duralumin

Force (N)	Extension (mm)	Stress σ (N/mm ²)	Nominal Strain ϵ
0	0	0	0
13	0.07	6.873215607	0.002258065
29	0.11	15.33255789	0.003548387
46	0.14	24.32060907	0.004516129
64	0.16	33.83736914	0.00516129
81	0.19	42.82542032	0.006129032
98	0.22	51.8134715	0.007096774
116	0.24	61.33023157	0.007741935
134	0.26	70.84699165	0.008387097
152	0.28	80.36375172	0.009032258
169	0.31	89.3518029	0.01
187	0.33	98.86856297	0.010645161
205	0.35	108.385323	0.011290323
224	0.36	118.430792	0.011612903
241	0.39	127.4188432	0.012580645
259	0.41	136.9356033	0.013225806
277	0.43	146.4523633	0.013870968
294	0.46	155.4404145	0.01483871
312	0.48	164.9571746	0.015483871
330	0.5	174.4739347	0.016129032
348	0.52	183.9906947	0.016774194
365	0.55	192.9787459	0.017741935
383	0.57	202.495506	0.018387097
401	0.59	212.012266	0.019032258
418	0.62	221.0003172	0.02
435	0.65	229.9883684	0.020967742
502	0.98	265.4118642	0.031612903
537	1.63	283.9166755	0.052580645

Table 4-4: Calculated Values of PVC

Force (N)	Extension (mm)	Stress σ (N/mm ²)	Nominal Strain ϵ
0	0	0	0
5	0.15	2.550760127	0.004807692
11	0.29	5.611672278	0.009294872
16	0.44	8.162432405	0.014102564
19	0.61	9.692888481	0.019551282
21	0.79	10.71319253	0.025320513
6	1.14	3.060912152	0.036538462
9	1.31	4.591368228	0.041987179
10	1.5	5.101520253	0.048076923
9	1.71	4.591368228	0.054807692
9	1.91	4.591368228	0.061217949
9	2.11	4.591368228	0.067628205
9	2.31	4.591368228	0.074038462
9	2.51	4.591368228	0.080448718
9	2.71	4.591368228	0.086858974
10	2.9	5.101520253	0.092948718
10	3.1	5.101520253	0.099358974
10	3.3	5.101520253	0.105769231
10	3.5	5.101520253	0.112179487
9	3.71	4.591368228	0.118910256
9	3.91	4.591368228	0.125320513
9	4.11	4.591368228	0.131730769
10	4.3	5.101520253	0.137820513
9	4.51	4.591368228	0.144551282
8	4.72	4.081216202	0.151282051
9	4.91	4.591368228	0.157371795
9	5.91	4.591368228	0.189423077
8	6.92	4.081216202	0.221794872
3	7.97	1.530456076	0.255448718
5	8.95	2.550760127	0.286858974
8	9.92	4.081216202	0.317948718
4	19.96	2.040608101	0.63974359
5	29.95	2.550760127	0.959935897
5	39.95	2.550760127	1.280448718

4.3 Graphs

Having now calculated all the essential values needed to create a stress v strain graph input all stress values onto the Y axis and strain onto the X axis. This type of graph is also known as a Young's Modulus graph. This creates the Young's Modulus graphs seen below in Figures 4-1 through to 4-4. There will also be a secondary graph displaying the elastic region where the gradient of such will equate to the stiffness of each specimen.

4.3.1 Steel

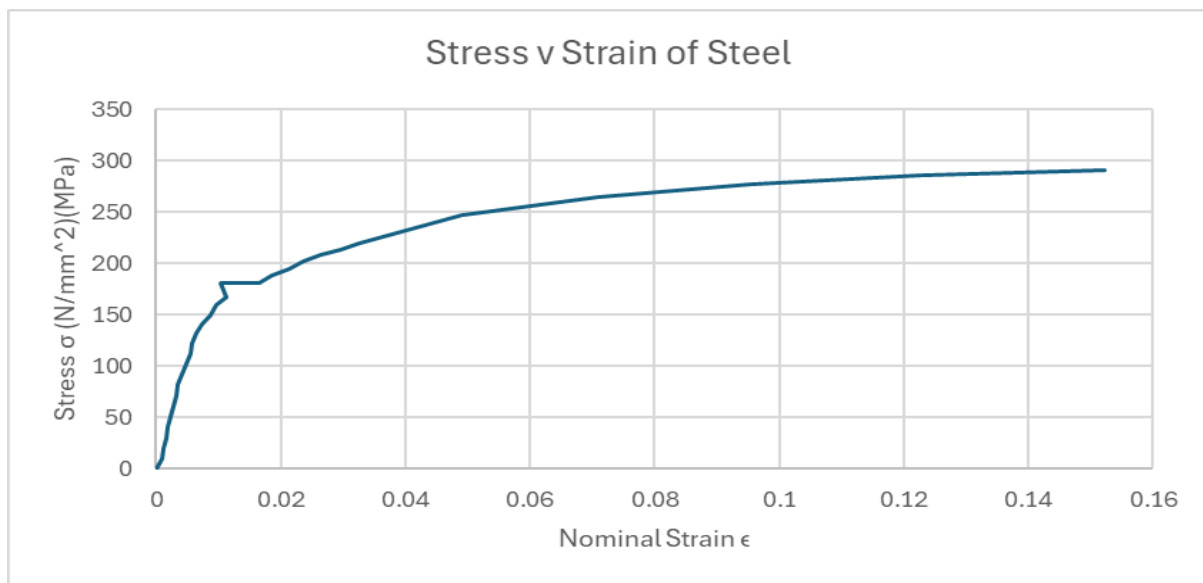


Figure 4-2: Stress & Strain Graph of Steel

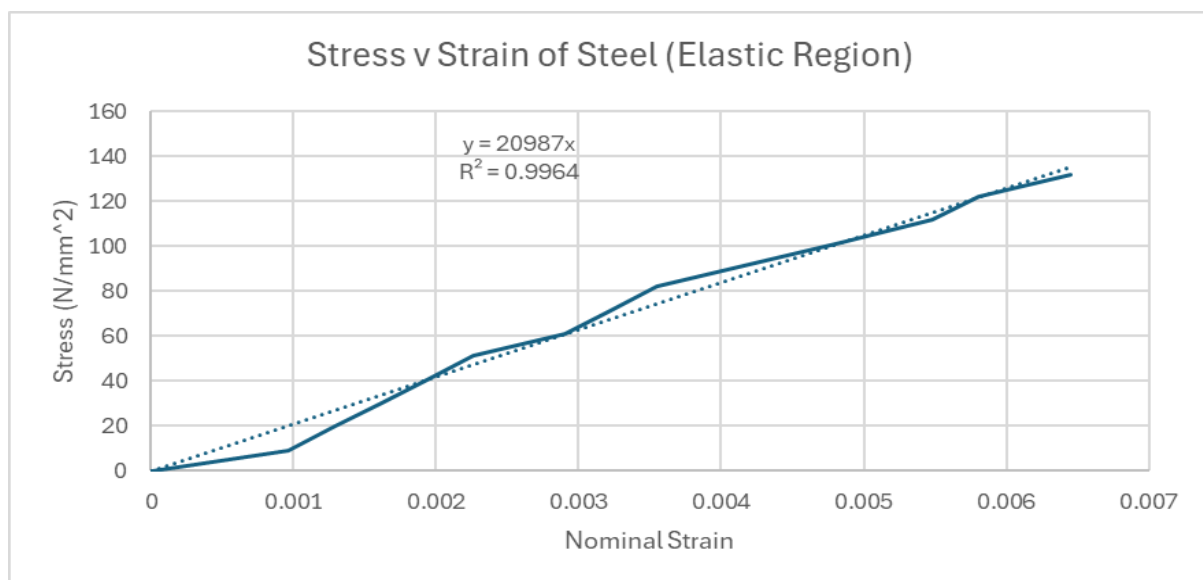


Figure 4-1: Stress & Strain Graph of Steel's Elastic Region

4.3.2 Aluminium

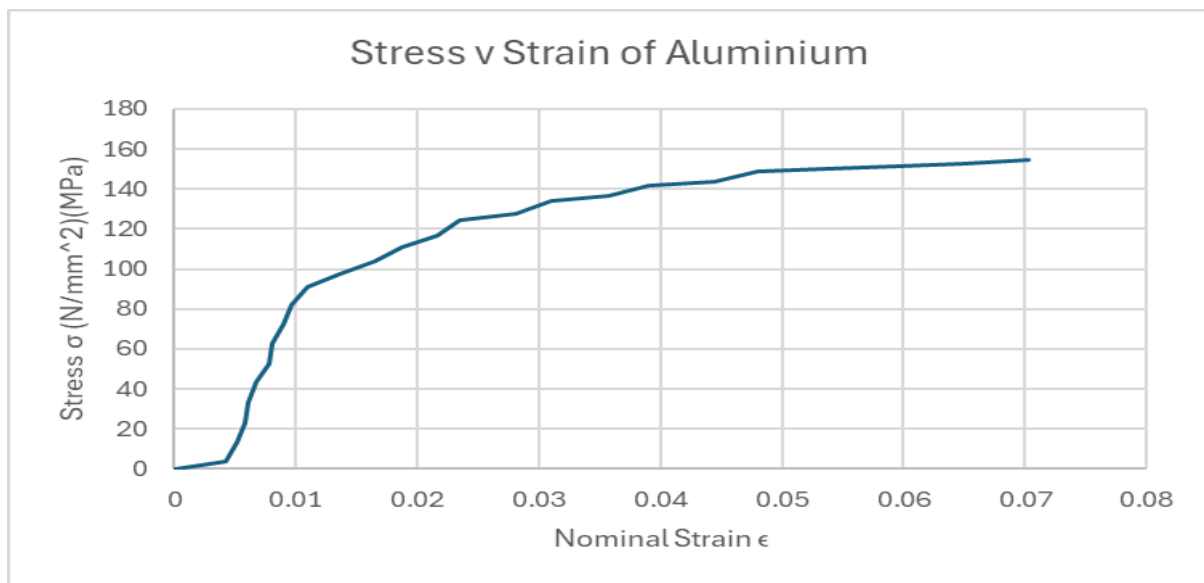


Figure 4-4: Stress & Strain Graph of Aluminium

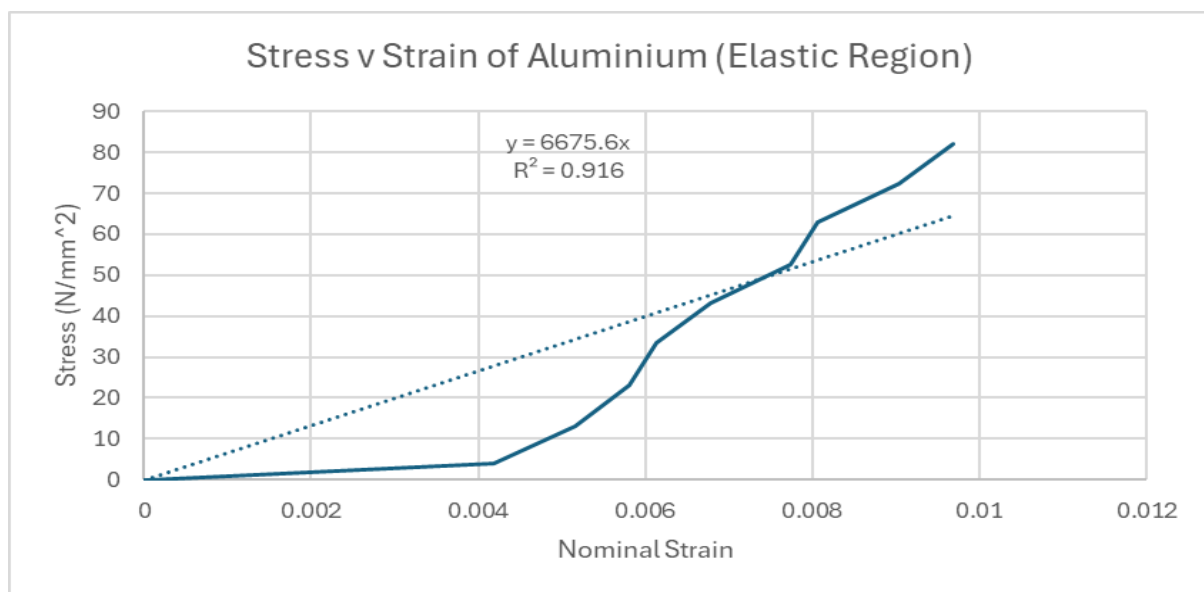
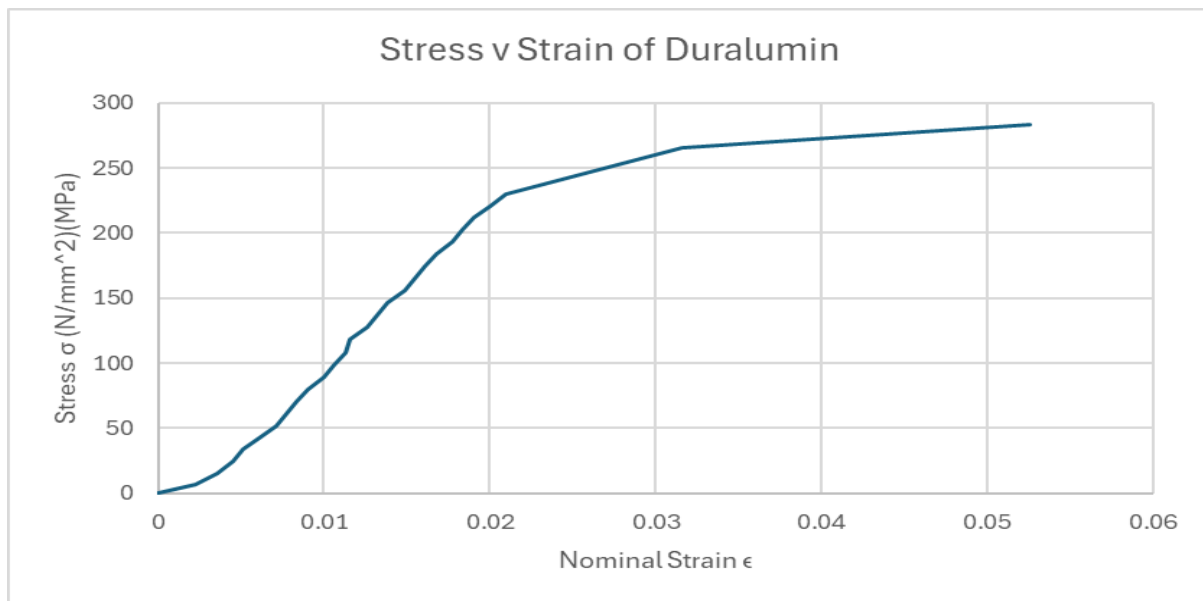
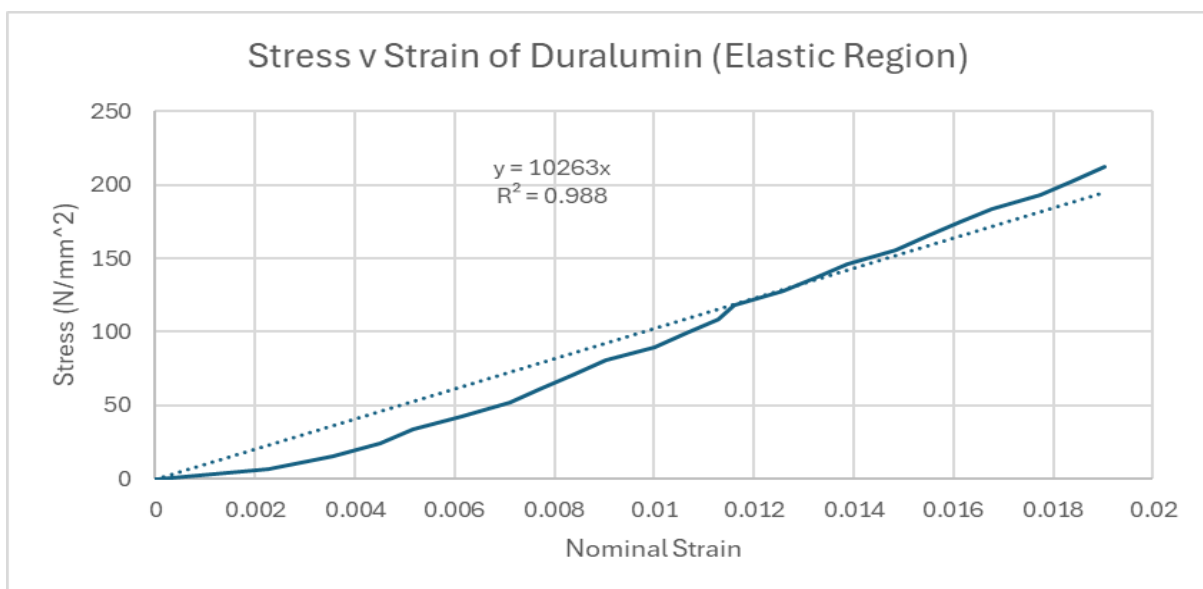


Figure 4-3 Stress & Strain Graph of Aluminium's Elastic Region

4.3.3 Duralumin

*Figure 4-6: Stress & Strain Graph of Duralumin**Figure 4-5: Stress & Strain Graph of Duralumin's Elastic Region*

4.3.4 PVC

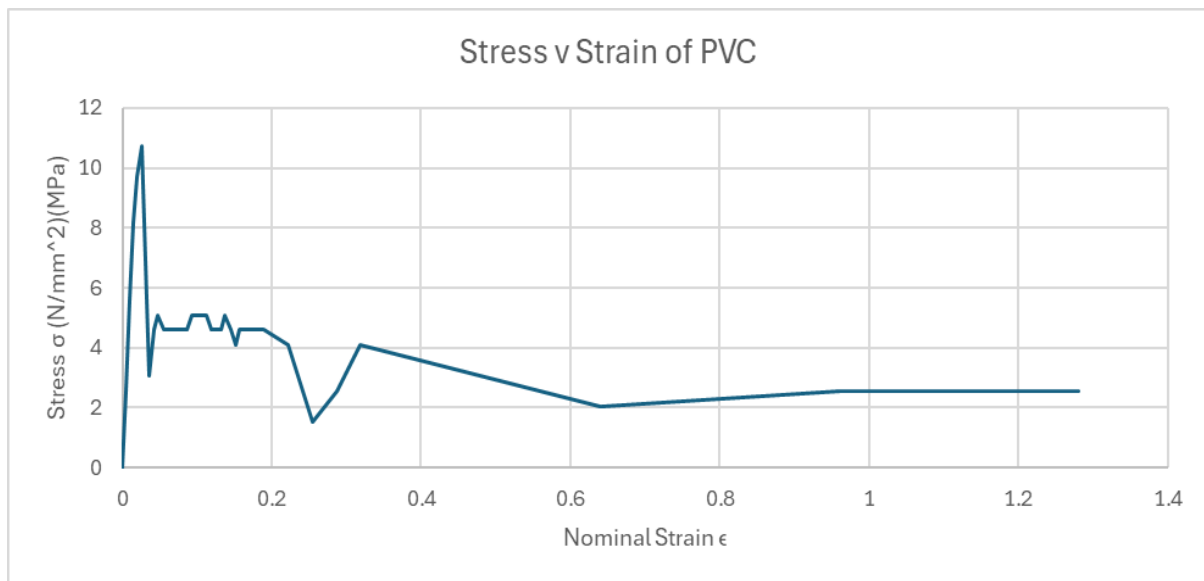


Figure 4-7: Stress & Strain Graph of PVC

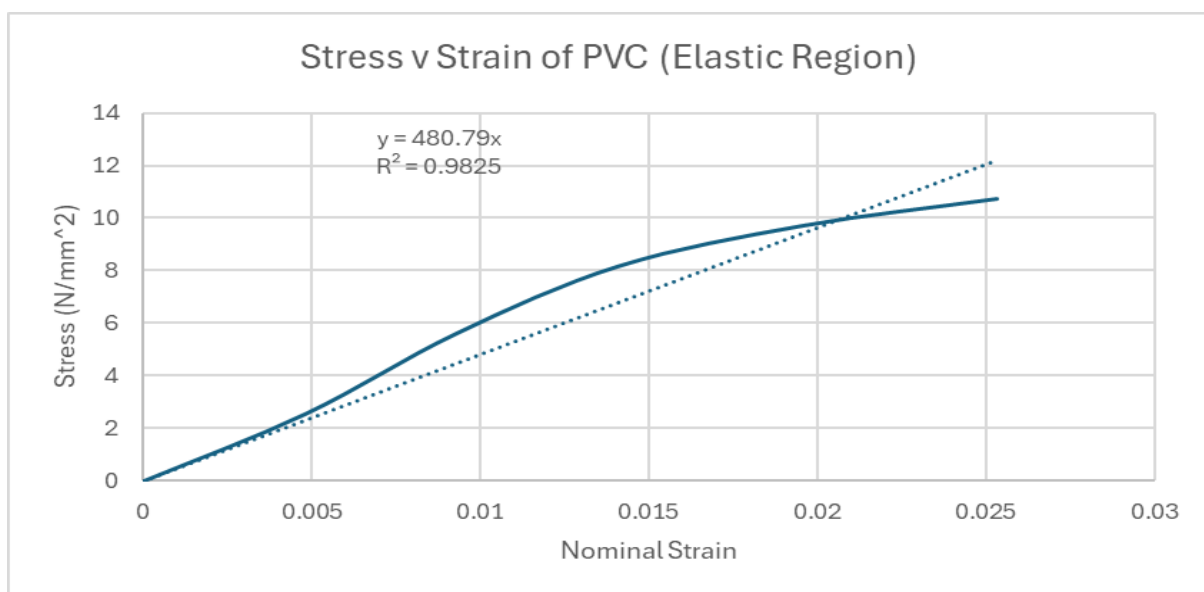


Figure 4-8: Stress & Strain Graph of PVC's Elastic Region

5 Conclusion

5.1 Tensile Strength & Yield Stress

5.1.1 Tensile Strength

From the graphs produced in this report the highest recorded tensile stress of the steel specimen provided is 290 MPa as seen in Table 4-1. The average maximum tensile strength for a basic steel alloy is between 400-550 MPa (Meister Nicholas [no date]). With the next measurement being 10mm of load nut movement essentially doubling the stress applied, it can be assumed that the specimen would have reached the maximum tensile stress to cause breakage.

For the specimen of aluminium, the maximum recorded tensile stress applied to the specimen was 154MPa. The ultimate tensile strength of aluminium varies between 70MPa to 700MPa depending on the specification of the alloy, it can be assumed from Table 4-3 that our specimen reached its ultimate tensile stress point at approximately 160MPa which fits in the specification of aluminium alloy 356.0. (Callister.W.D, 2007)

For specimen duralumin the maximum recorded tensile stress applied was noted at 283MPa. Duralumin being a higher specificized alloy of aluminium it is expected to have a higher ultimate tensile strength which from data in Table 4-2 would approximately be 300MPa

Lastly for specimen PVC the maximum recorded tensile stress applied was noted at 10.7MPa. However, this is quite different to the other three specimens for PVC elongated as stress was applied rendering that stress ineffective providing a very small elastic region of data in the 1mm load nut movement compared to Duralumin which had 4.4mm of load nut movement in its elastic region with minimal elongation.

5.1.2 Yield Stress

Yield stress or the yield point will be noted to show where the specimen's elastic region becomes its plastic region when a certain value of stress is applied this will vary for each specimen.

For specimen steel the yield stress is at 141 MPa before entering the plastic region. Whereas compared to other sources the yield point for steel is usually between 160 and 250 MPa.

This hints at inaccuracies in the experiment process and to further reinforce the theory there are inaccuracies in the data as Figure 4-1 displays an obvious outlier. (Davis J R, 1998)

For the specimen Aluminium the yield point is at 91MPa. Aluminium has many different specifications but the yield point for aluminium is generally around 90MPa, this confirms the data for this specimen (The Engineering Toolbox 2003).

Specimen Duralumin has a yield stress of 212MPa it again would be expected to have a higher yield point than aluminium which is a good inclination that this is an accurate result.

Specimen PVC however has the lowest yield stress of all the specimens which is 10.7MPa. For this type of PVC, the yield stress is usually between 10-25MPa which would lead to the understanding that this result is accurate. (Chavan et al. 2017)

5.2 Young's Modulus & Elongation

Young's Modulus denoted by symbol E can be calculated by formula

$$E = \frac{\sigma}{\epsilon}$$

Young's Modulus can be calculated in a stress v strain graph as the gradient of the elastic region seen in the graphs of Figures 4-2,4,6 and 8. Where the gradient is $y = mx + c$ 'm' is the value of Young's Modulus.

For the specimen steel the gradient is $y = 20987x$

For aluminium the gradient is $y = 6675.6x$

For specimen Duralumin the gradient is $y = 10263x$

Lastly, for specimen PVC the gradient is $y = 480.79x$

From this data steel is outright the stiffest specimen out of all four, whereas PVC expectedly has the lowest stiffness. Building on this point steel being the stiffest also has the highest elongation out of the metals which is 26.13% meaning it is more ductile than the aluminium specimens. Furthermore, both aluminium and duralumin have a low elongation of 9.51% and 8.06% revealing they are brittle. However, PVC is the most interesting as its elongation is 122.79% more than doubling its original length.

This leads onto how important a constant force application rate is to specimen PVC. In Figure 4-7 the stress rate is inconsistent and pairing that with the high elongation it almost resets the stress applied to itself every increment of the load nut movement. The temperature would also affect the PVC experimentation as if the specimen were to be below room temperature it would be found to be more fragile but with a higher tensile strength and stiffness but if it were to be above room temperature it would be softer with a lower tensile strength and stiffness. (Amorim et al. 2022)

Two specimens have quite similar stiffness being duralumin and aluminium, this is to be expected as duralumin is 95% aluminium but reinforced with other elements such as copper and magnesium (Material-Properties, [no date]) which is why duralumin has a higher stiffness, tensile strength and yield stress.

6 Evaluation

To eliminate errors there were many precautions undertaken to ensure the data would be as accurate as possible these consisted of

- Using the same person for each task undergone in the experiment to eliminate any change in the way each task was undertaken.
- Ensuring there were two people reading measurements to ensure the data received was correct
- Comparing every measurement written down with each other to ensure everyone had the same result
- Ensuring each specimen was mounted properly to avoid misalignment errors
- Ensuring each specimen was tight in each chuck
- Taking breaks in between the test of each specimen to reduce fatigue

7 Further Work

As there were some inaccuracies in the data if there were unlimited resources available to do this experiment again it would be useful to

- Test each specimen three times which will help eliminate outliers
- Using a digital dial indicator eliminating chance of a reading error when data is being collected
- Use machines to automate the collection of data with sensors for more precision and consistency
- Include other specifications of the specimens to be able to compare more data
- Using high quality cameras to be able to track the elongation and breakage of the specimen in real time and slow motion

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