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Tensile Testing Laboratory Report

Engineering Science 1 and Lab Skills (ACMA4033)

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June 2026

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1 Introduction

1.1 What is Tensile Testing

Tensile testing is a widely used method for determining the mechanical properties of engineering materials. The test involves applying a tensile force to a specimen until failure occurs, enabling important properties such as yield stress, ultimate tensile strength (UTS), and Young's modulus to be measured (Callister and Rethwisch, 2020). These properties are essential in engineering design as they provide information about a material's ability to withstand applied loads without experiencing excessive deformation or sudden failure.

The behaviour of a material under tensile loading is represented by a stress-strain curve. Initially, materials deform elastically, meaning they return to their original dimensions when the load is removed. As the applied load increases beyond the yield point, plastic deformation occurs, resulting in permanent changes to the material's shape. Continued loading eventually leads to necking and fracture (Ashby and Jones, 2018). Stress is defined as the force applied per unit area, while strain is the ratio of extension to the original length of the specimen. The relationship between stress and strain in the elastic region is used to determine Young's modulus, a measure of material stiffness (Budynas and Nisbett, 2020).

1.2 Aim of Experiment

The aim of this experiment was to perform tensile tests on a range of engineering material specimens using the Tensile Tester Kit ES6. Load and extension data were collected and used to calculate stress and strain values. The resulting stress-strain curves were analysed to determine key mechanical properties and compare the experimental results with published material data to assess the validity of the experiment.

2 Experimental Procedure

2.1 Equipment Used in Experiment

Before starting the physical experiment, the first step was to gather all equipment needed to conduct the test. This equipment included:

- The Tensile Tester Kit ES6, the user manual and work panel
- Specimens of the four different materials being tested
- Thermometer to measure ambient temperature throughout
- A laptop to record the results during the experiment
- Vernier callipers to measure the dimensions before and after the test
- Safety glasses for eye protection

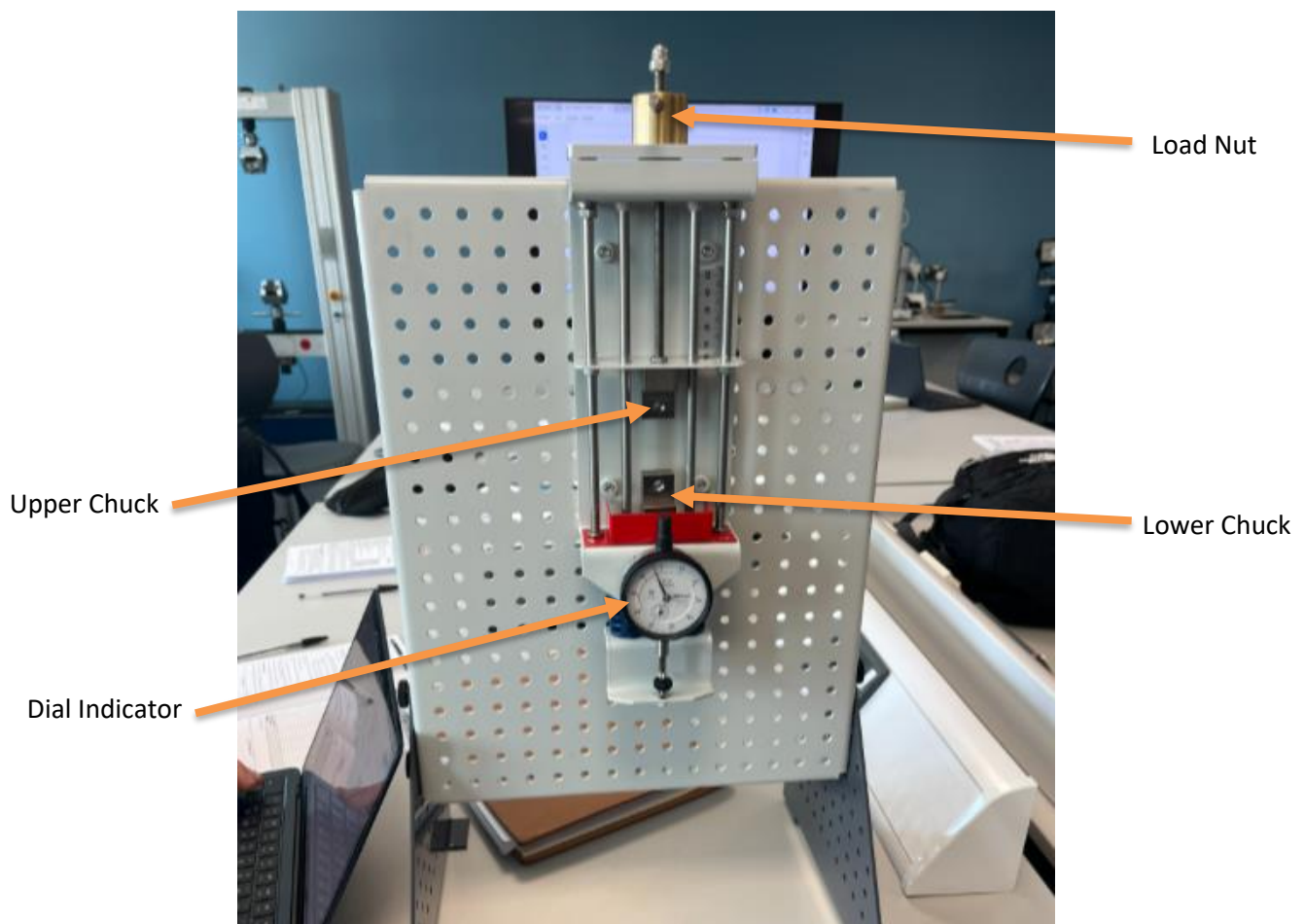


Figure 1: Tensile Tester Kit ES6 mounted on work panel

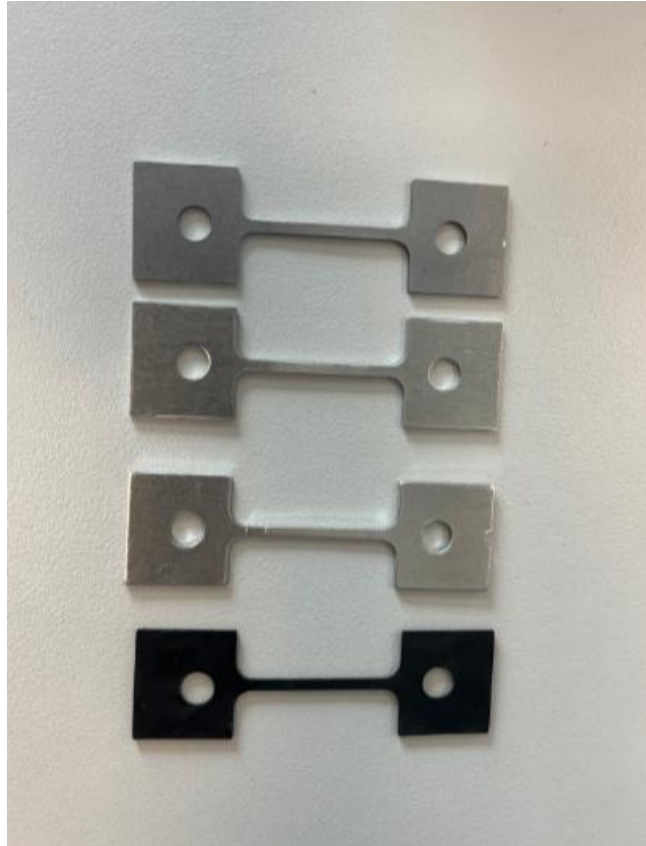


Figure 2: Test specimens for steel, aluminium, duralumin and PVC plastic

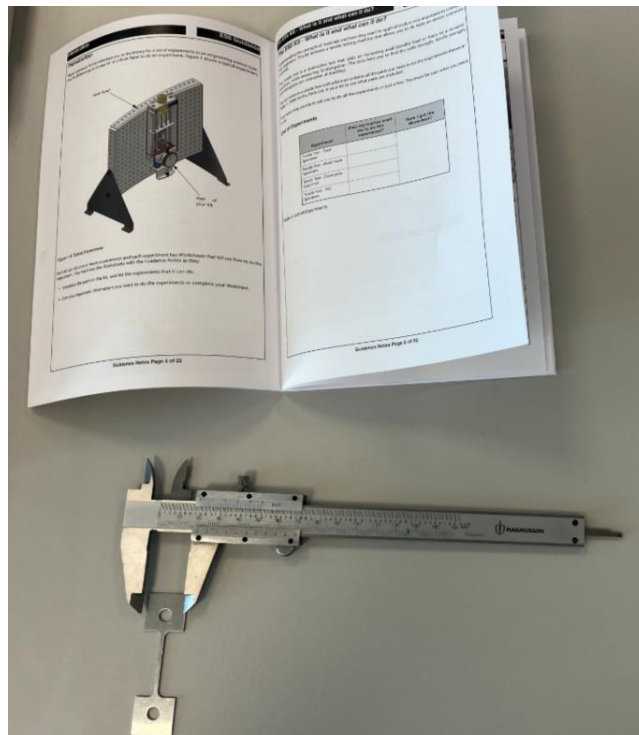


Figure 3: Tensile test manual and vernier callipers



Figure 4: Safety glasses

2.2 Step by Step Methodology

The first material to be tested was the steel specimen. After measuring and recording the original dimensions using Vernier callipers, the specimen was mounted between the upper and lower chucks, with an emphasis on being as straight as possible, as shown in Figure 5. When lined up straight, the chucks were tightened by hand and then using the provided Allen key to ensure the piece was secure.

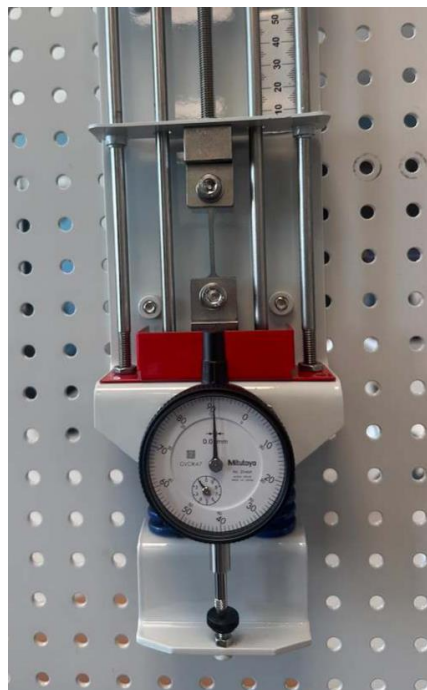


Figure 5: Steel specimen secured in tester kit

To allow for more accurate, consistent readings, the starting point for the load nut was established in line with a black mark that would be used as a zero point. With that datum set, the dial indicator was set to zero to match the position of the load nut.

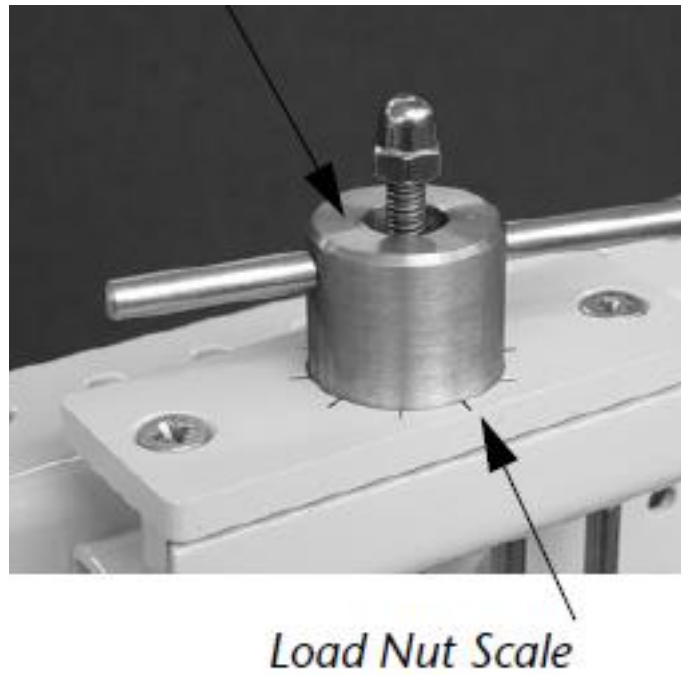


Figure 6: Scale system used on load nut (TecQuipment Ltd, 2012)

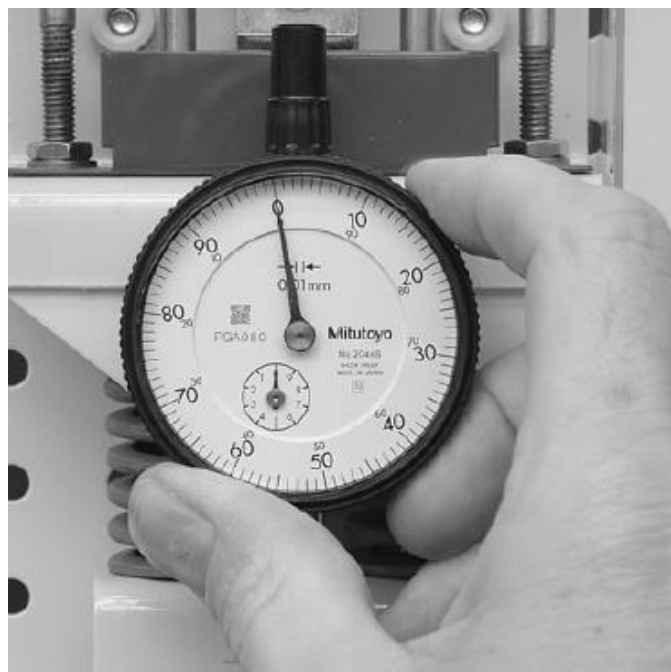


Figure 7: Dial indicator being set at zero (TecQuipment Ltd, 2012)

The next step of the test was to start turning the load nut to apply tensile load. For repetitive and fair testing, the amount of rotation put on the load nut was predetermined. Up to 5mm, the intervals for recording the dial indicator reading would be every 0.2mm, which is two notches on the load nut. From 5mm to 10mm, it would be every 1mm or 10 notches, which is a complete rotation. From 10mm and upwards, the nut would be rotated 10 full times for 10mm of movement until fracture. At each interval, the movement of the load nut and dial indicator reading were recorded into a table, as shown in Table 1.

Table 1: Example of load nut movement and dial readings being recorded

	A	B
1	Load nut movement (mm)	Dial indicator (mm)
2	0	0
3	0.2	0.175
4	0.4	0.37
5	0.6	0.56
6	0.8	0.74
7	1	0.935
8	1.2	1.1
9	1.4	1.295
10	1.6	1.475
11	1.8	1.64
12	2	1.78
13	2.2	1.9
14	2.4	2
15	2.6	2.09
16	2.8	2.2
17	3	2.28
18	3.2	2.33
19	3.4	2.4
20	3.6	2.45
21	3.8	2.49
22	4	2.56
23	4.2	2.56
24	4.4	2.56
25	4.6	2.575
26	4.8	2.59
27	5	
28	6	

The procedure was repeated for the aluminium, duralumin and PVC specimens under identical testing conditions.

3 Results

The raw data collected during tensile testing of the steel, aluminium, duralumin and PVC specimens are summarised in Table 2. Full datasets, including load nut movement, dial indicator readings, calculated extension, stress and strain values, are provided in Appendix A.

Table 2: Summary of tensile test results for all specimens

Material	Original Gauge Length(mm)	Final Gauge Length (mm)	Maximum Stress (Mpa)	Maximum Extension Recorded (mm)
Steel	31	38	335	6.3
Aluminium	31	34.5	130	2.21
Duralumin	31	33	275	2.51
PVC	31	55	13	27.28

The complete raw datasets for each specimen are included in Appendix A to support the calculations and graphical analysis presented in the Analysis section.

4 Analysis

4.1 Stress-Strain Analysis of Steel Specimen

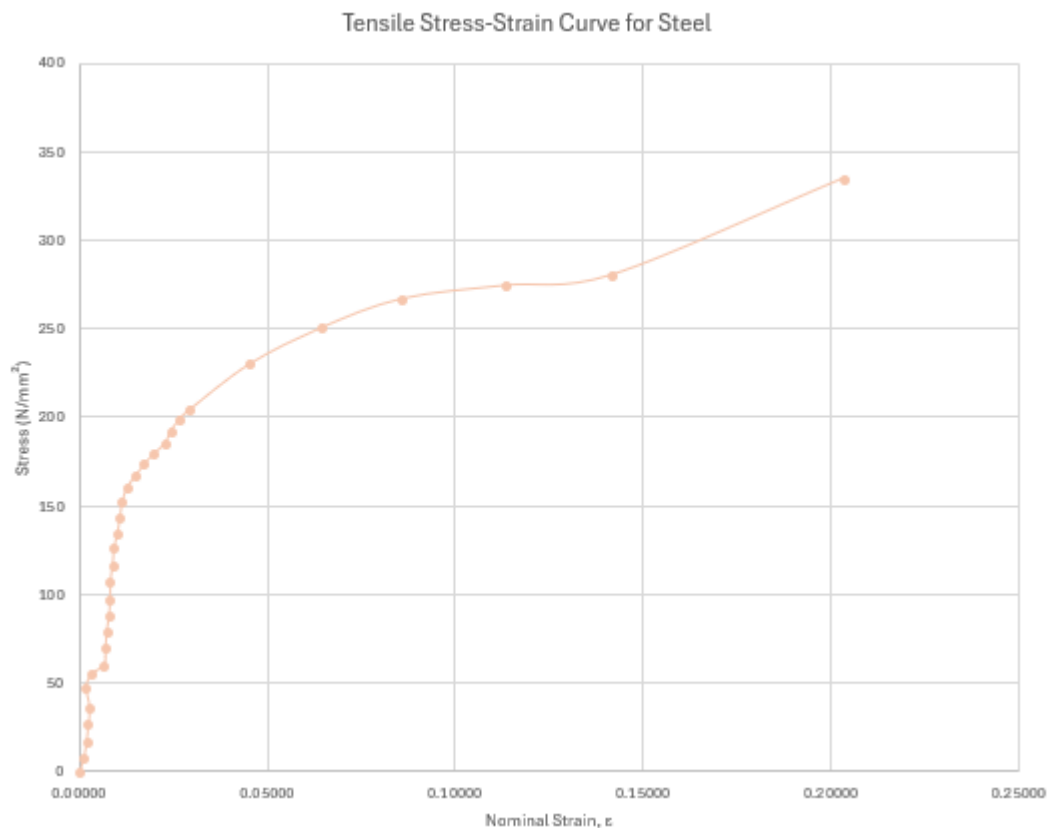


Figure 8: Stress-Strain curve for steel

Figure 8 shows the stress-strain curve obtained for the steel specimen during tensile testing. The yield point was identified as the point at which the curve first deviated from the initial linear elastic region. This represents the transition from elastic deformation, where the material returns to its original shape when unloaded, to plastic deformation, where permanent deformation occurs (Hibbeler, 2020).

From Figure 8, the yield stress was determined to be approximately 205 MPa. Beyond this point, the specimen continued to deform under increasing strain, indicating that plastic deformation had begun. The ultimate tensile strength (UTS) was determined from the maximum stress reached on the stress-strain curve before fracture occurred. The highest stress recorded during testing was approximately 335 MPa, which corresponds to the maximum load-carrying capacity of the material. Following this point, the specimen experienced necking prior to fracture.

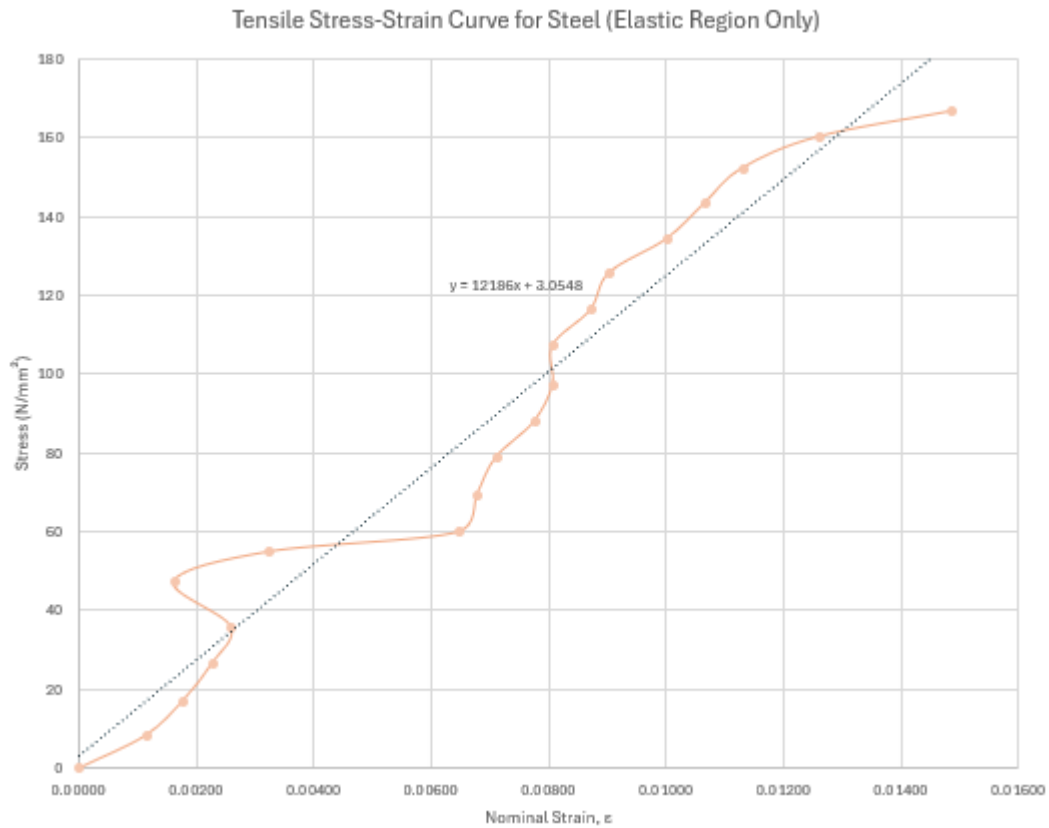


Figure 9: Elastic region Stress-Strain graph for steel

Young's modulus is defined as the gradient of the stress-strain curve within the elastic region and represents the stiffness of a material (Budynas and Nisbett, 2020). To determine the Young's modulus of the steel specimen, a graph of the elastic region was plotted using all data points up to the yield point, as instructed. A linear trendline was fitted to the data, producing the equation $y = 1218.6x + 3.0548$, as shown in Figure 9. The gradient of the trendline therefore gives a Young's modulus of approximately 1218.6 MPa (1.22 GPa).

4.2 Stress-Strain Analysis for Aluminium Specimen

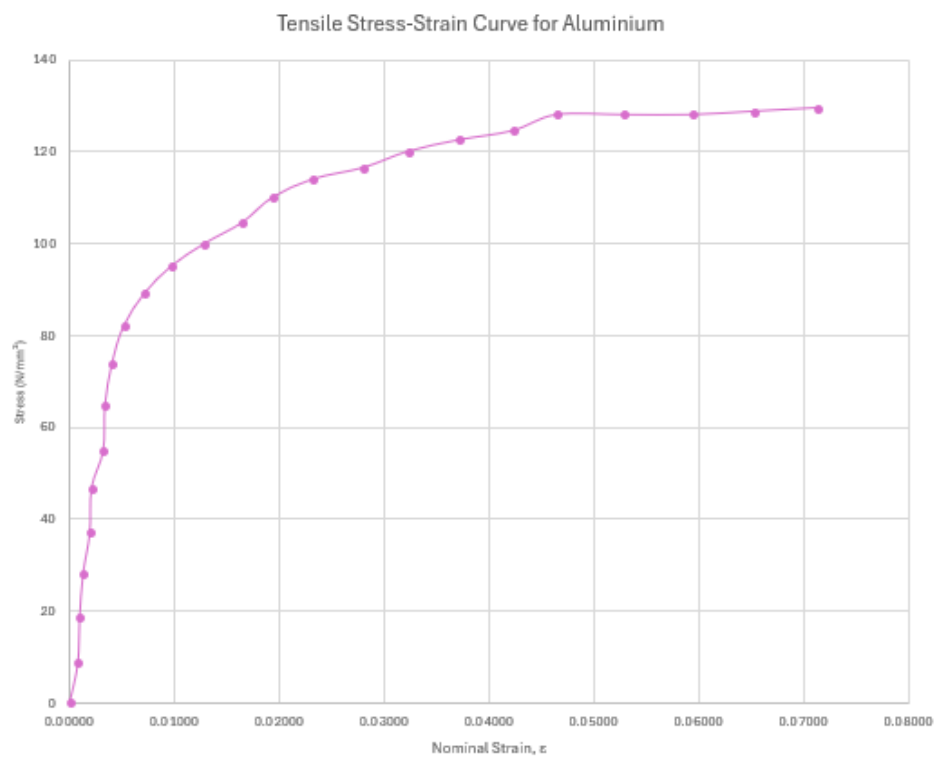


Figure 10: Stress-Strain curve for aluminium

Figure 10 shows the stress-strain curve obtained for the aluminium specimen. Using the same methodology described for the steel specimen, the yield stress was determined to be approximately 89 MPa, while the ultimate tensile strength was approximately 130 MPa.

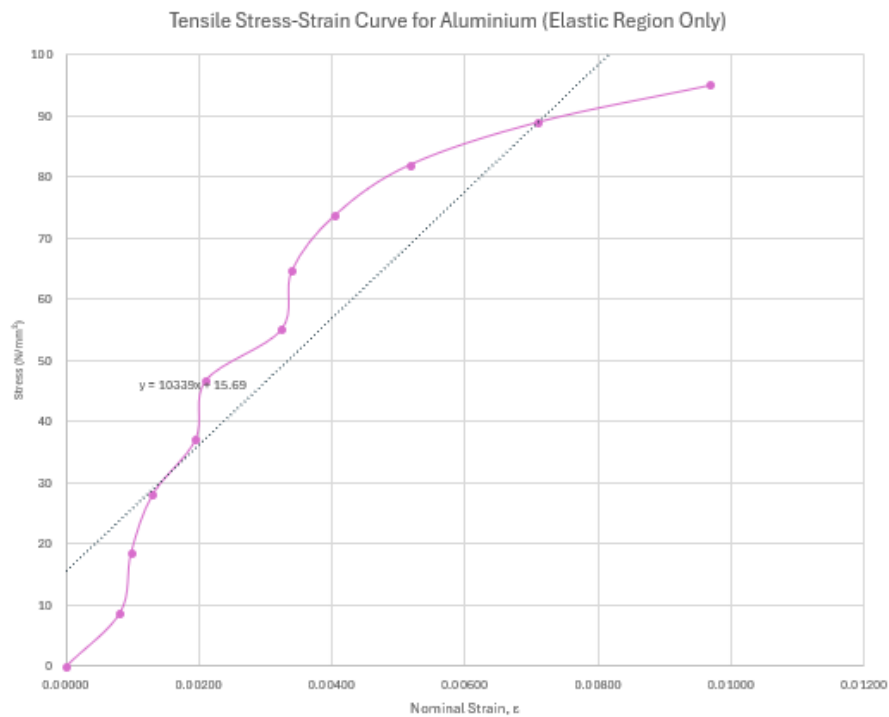


Figure 11: Elastic region Stress-Strain graph for aluminium

The Young's modulus was calculated from the gradient of the elastic region trendline shown in Figure 11. The equation $y = 1023.3x + 15.69$ gave a Young's modulus of 1023.3 MPa (1.02 GPa).

Compared with the steel specimen, aluminium exhibited a lower yield stress and ultimate tensile strength, indicating a reduced resistance to plastic deformation and failure. However, the material experienced a greater degree of strain prior to fracture, demonstrating increased ductility.

4.3 Stress-Strain Analysis of Duralumin Specimen

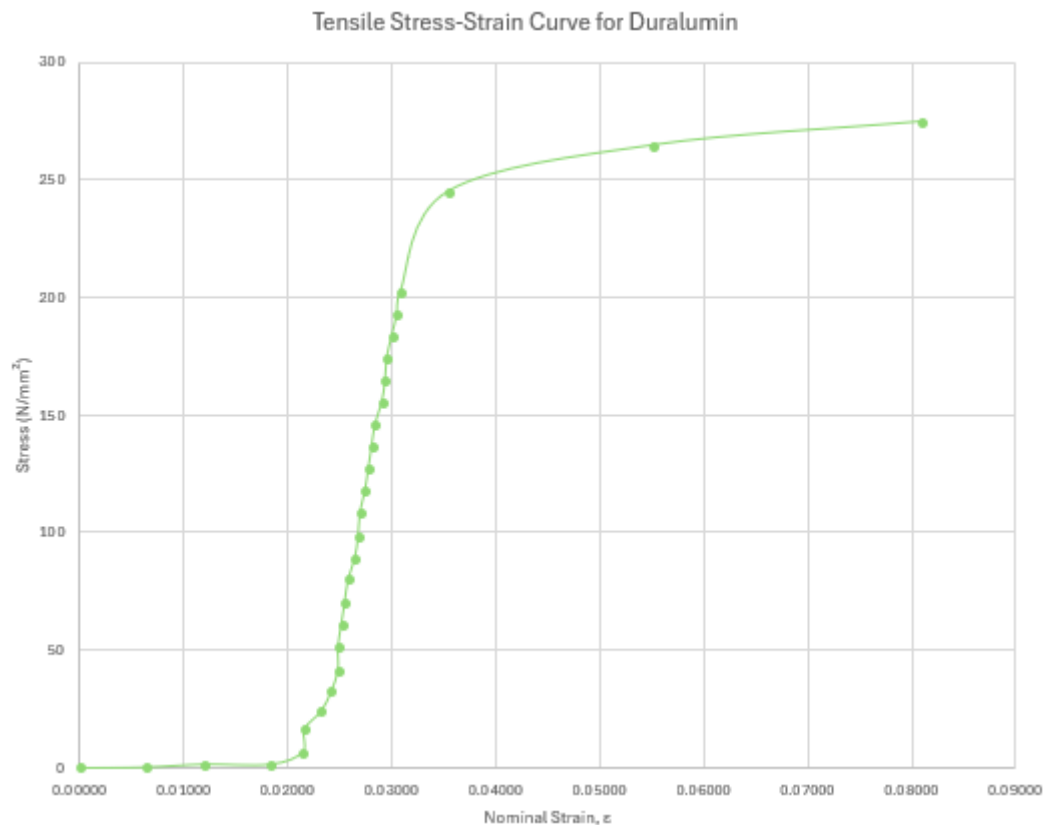


Figure 12: Stress-Strain curve for duralumin

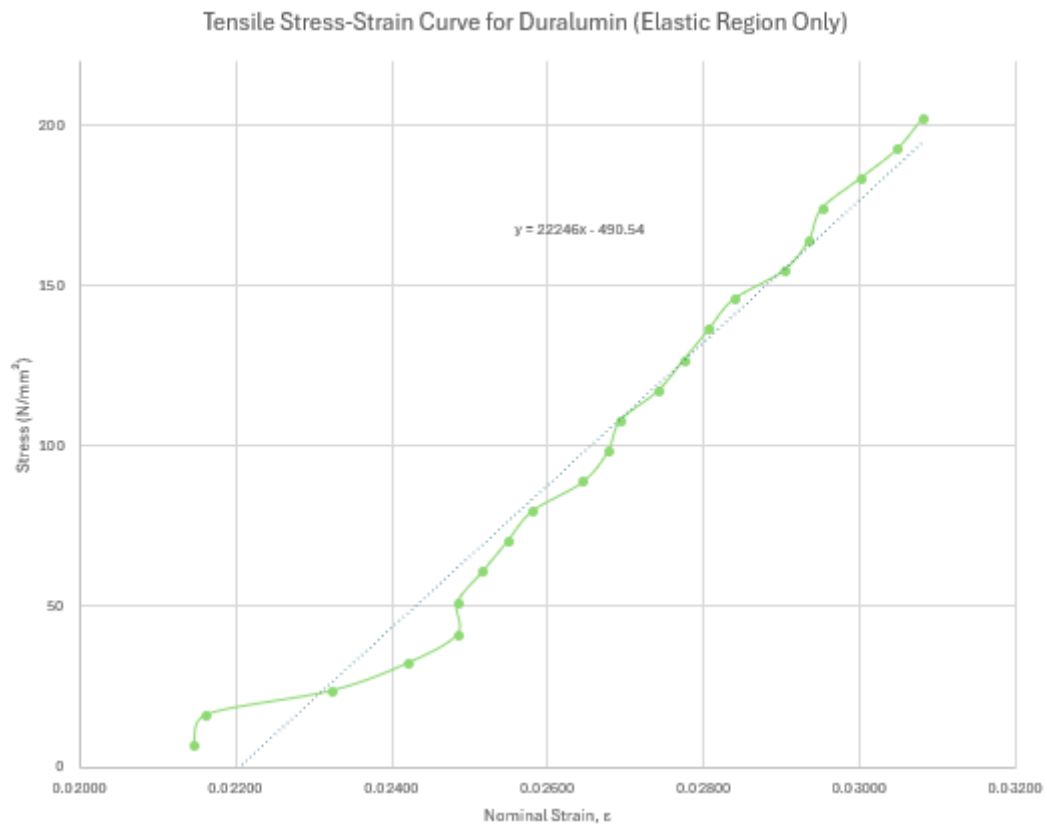


Figure 13: Elastic region Stress-Strain graph for duralumin

The stress-strain curve for the duralumin specimen is shown in Figure 12 and specifically the elastic region of the curve is shown in Figure 13. Applying the same analysis method used previously, the yield stress, ultimate tensile strength and Young's modulus were determined to be 202 MPa, 275 MPa and 22.25 GPa respectively.

The results indicate that duralumin possessed greater strength than aluminium while maintaining relatively high ductility. This behaviour is consistent with precipitation-hardened aluminium alloys commonly used in aerospace applications.

4.4 Stress-Strain Analysis of PVC Specimen

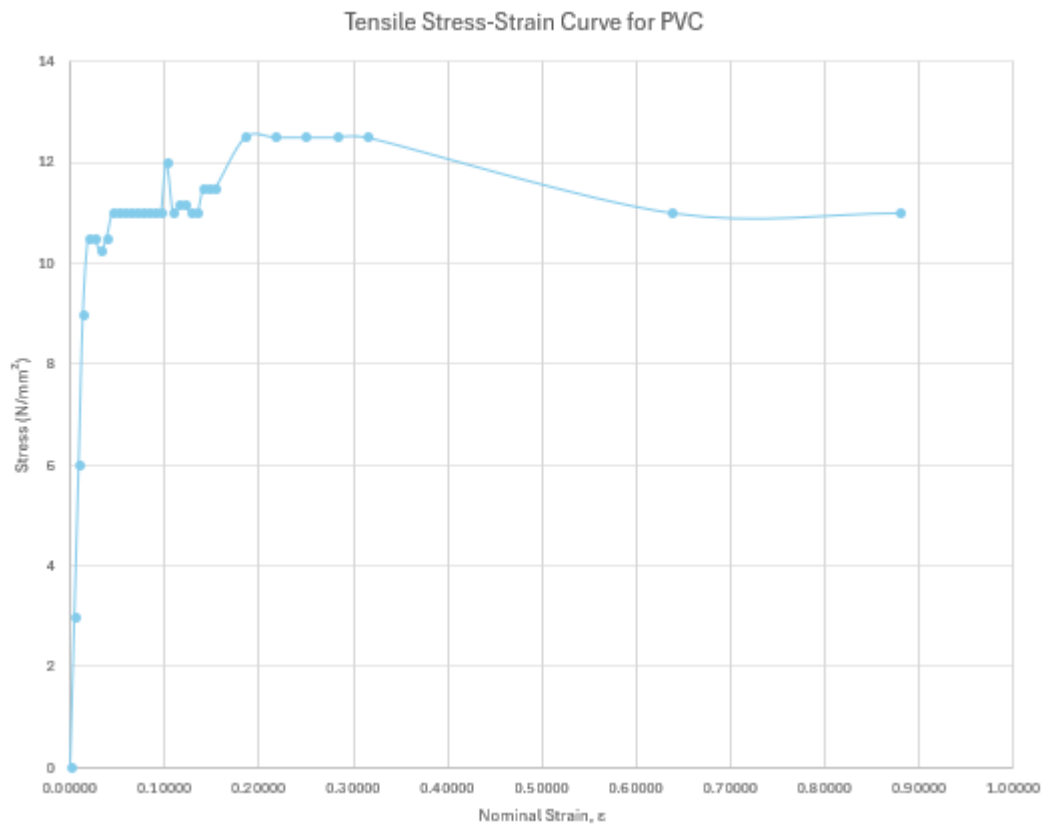


Figure 14: Stress-Strain curve for PVC

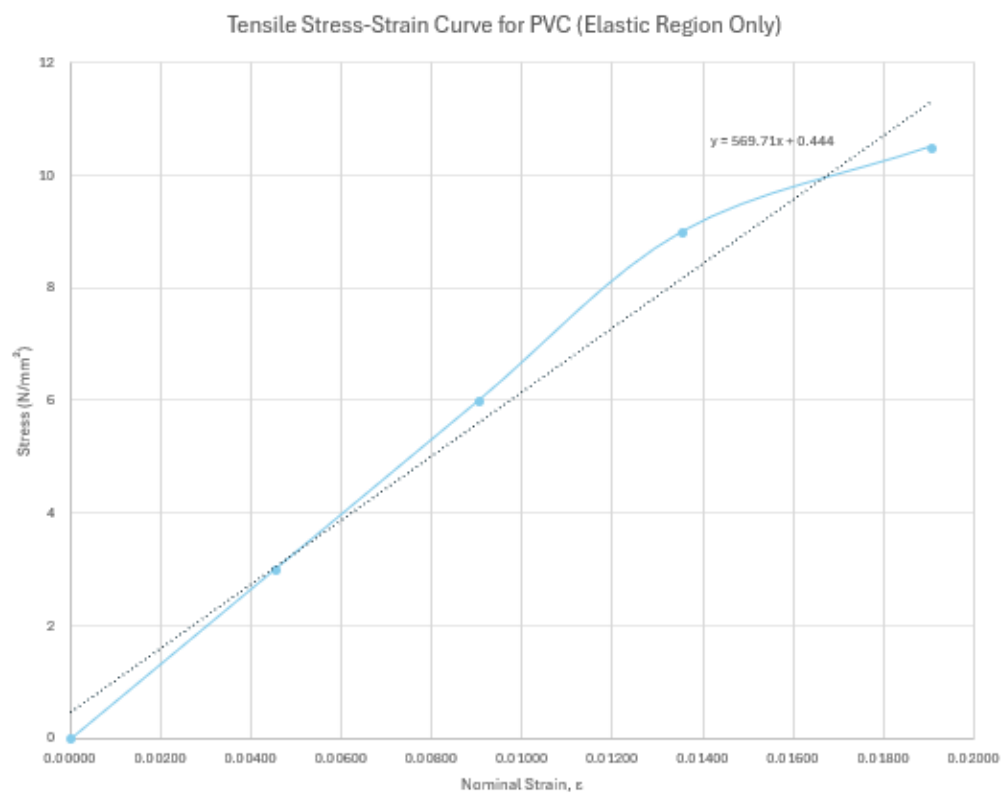


Figure 15: Elastic region Stress-Strain graph for PVC

Figures 14 and 15 show the stress-strain behaviour and the elastic region of the PVC specimen respectively. Using the same approach described for the metallic specimens, the yield stress, ultimate tensile strength and Young's modulus were calculated as 9 MPa, 13 MPa and 0.57 GPa respectively. Unlike the metallic specimens, PVC displayed a significantly lower stiffness and strength, as evidenced by the reduced gradient of the elastic region and lower maximum stress values.

Table 3: Summary of calculated mechanical properties for all specimens

Material	Yield Stress (MPa)	Ultimate Tensile Strength (MPa)	Experimental Young's Modulus (GPa)
Steel	205	335	1.22
Aluminium	89	130	1.02
Duralumin	202	275	22.25
PVC	9	13	0.57

5 Conclusion

Tensile testing was successfully carried out on steel, aluminium, duralumin and PVC specimens using the Tensile Tester Kit ES6. Stress-strain curves were produced for each material, allowing the yield stress, ultimate tensile strength and Young's modulus to be determined. Steel exhibited the highest ultimate tensile strength and yield stress of the materials tested, while PVC exhibited the lowest values. The highest experimental Young's modulus was obtained for duralumin rather than steel, which differs from published material properties and suggests limitations in the strain measurement method.

Table 4: Comparison of experimental and literature material properties

Material	Experimental Yield Stress (MPa)	Literature Yield Stress (MPa)	Experimental Young's Modulus (GPa)	Literature Young's Modulus (GPa)
Steel	205	≈235-275	1.22	≈210
Aluminium	89	≈80-130	1.02	≈70
Duralumin	202	≈300	22.25	≈76
PVC	9	≈58	0.57	≈3

The sources used for the literature values are (Eurocode Applied, 2024; Material Properties, n.d.; PTM Ltd, n.d.).

As shown in Table 4, the three metallic specimens produced yield stress values closer to the published values than the PVC specimen and demonstrated the expected differences in mechanical behaviour between the materials. The differences are likely attributable to limitations of the testing apparatus and measurement uncertainty. Overall, the experiment broadly followed expected trends in terms of yield stress and ultimate tensile strength of each material and demonstrated the tensile behaviour of each material.

However, the calculated Young's modulus values differed significantly from published data, indicating that the apparatus was more effective for demonstrating tensile behaviour than for accurately determining elastic stiffness.

6 Evaluation

During the experiment, all results were checked twice, and photos taken of each reading for later reference. Appropriate datum/zero points were set before each specimen was tested allowing for the most accurate readings possible by eye. The same intervals for turning the load nut were used with all four specimens to ensure a fair experiment and all specimens were lined up straight to eliminate bending stresses reducing the accuracy of the stress-strain results.

However, extension was calculated indirectly from the difference between load nut movement and dial indicator readings. Any inaccuracy in either measurement would affect the calculated strain values and therefore influence the gradient used to determine Young's modulus. The calculated Young's modulus values differed significantly from published values, particularly for steel and aluminium. This suggests that the apparatus was more suitable for demonstrating material behaviour than obtaining highly accurate stiffness measurements. Machine compliance, backlash within the mechanism and measurement resolution may have contributed to this discrepancy, as inaccuracies in strain measurement can significantly affect the determination of Young's modulus (Callister and Rethwisch, 2020).

7 Further Work and Improvements

Future experiments could utilise a calibrated extensometer and automated data acquisition system to improve strain measurement accuracy and the determination of Young's modulus (Instron, 2026; ZwickRoell, 2026). Additional testing could also investigate the effects of heat treatment and specimen geometry on tensile properties, as these factors are known to influence strength and ductility (NIST, 2015).

8 References

Callister, W.D. and Rethwisch, D.G. (2020) *Materials Science and Engineering: An Introduction*. 10th edn. Hoboken: John Wiley & Sons.

Ashby, M.F. and Jones, D.R.H. (2018) *Engineering Materials 1: An Introduction to Properties, Applications and Design*. 5th edn. Oxford: Butterworth-Heinemann.

Budynas, R.G. and Nisbett, J.K. (2020) *Shigley's Mechanical Engineering Design*. 11th edn. New York: McGraw-Hill Education.

TecQuipment Ltd. (2012) Engineering Science Worksheets: Tensile Tester Kit ES6 – Tensile Tests. Nottingham: TecQuipment Ltd.

Hibbeler, R.C. (2020) *Mechanics of Materials*. 11th edn. Harlow: Pearson Education.

Eurocode Applied (2024) *Steel design properties according to EN 1993-1-1 (Eurocode 3)*. Available at: <https://eurocodeapplied.com/design/en1993/steel-design-properties> (Accessed: 23 June 2026).

Material Properties (n.d.) *Aluminium – properties, applications, price and production*. Available at: <https://material-properties.org/aluminium-properties-applications-price-production/> (Accessed: 23 June 2026).

Material Properties (n.d.) *Duralumin – density, strength, hardness, melting point*. Available at: <https://material-properties.org/duralumin-density-strength-hardness-melting-point/> (Accessed: 23 June 2026).

PTM Ltd. (n.d.) *Rigid PVC: Technical Data Sheet*. Available at: <https://epdm.co.uk/wp-content/uploads/2024/06/Rigid-PVC-Data-Sheet-Copy.pdf> (Accessed: 23 June 2026).

Instron (2026) *Extensometers*. Available at: <https://www.instron.com/en/products/testing-accessories/extensometers/> (Accessed: 24 June 2026).

ZwickRoell (2026) *Extensometers: Strain measurement devices*. Available at: <https://www.zwickroell.com/accessories/extensometers/> (Accessed: 24 June 2026).

National Institute of Standards and Technology (2015) *Heat Treatment and Properties of Iron and Steel*. NBS Monograph 88. Available at: <https://nvlpubs.nist.gov/nistpubs/legacy/mono/nbsmonograph88.pdf> (Accessed: 24 June 2026).

9 Appendices

Appendix A – Raw Tensile Test Data

Steel:

A	B	C	D	E	F
Load nut movement (mm)	Dial indicator (mm)	Force (N)	Extension (mm)	Stress (MPa)	Nominal Strain
0	0	0	0	0	0.00000
0.2	0.165	16.5	0.035	8	0.00113
0.4	0.345	34.5	0.055	17	0.00177
0.6	0.53	53	0.07	27	0.00226
0.8	0.72	72	0.08	36	0.00258
1	0.95	95	0.05	48	0.00161
1.2	1.1	110	0.1	55	0.00323
1.4	1.2	120	0.2	60	0.00645
1.6	1.39	139	0.21	70	0.00677
1.8	1.58	158	0.22	79	0.00710
2	1.76	176	0.24	88	0.00774
2.2	1.95	195	0.25	98	0.00806
2.4	2.15	215	0.25	108	0.00806
2.6	2.33	233	0.27	117	0.00871
2.8	2.52	252	0.28	126	0.00903
3	2.69	269	0.31	135	0.01000
3.2	2.87	287	0.33	144	0.01065
3.4	3.05	305	0.35	153	0.01129
3.6	3.21	321	0.39	161	0.01258
3.8	3.34	334	0.46	167	0.01484
4	3.47	347	0.53	174	0.01710
4.2	3.59	359	0.61	180	0.01968
4.4	3.7	370	0.7	185	0.02258
4.6	3.85	385	0.75	193	0.02419
4.8	3.98	398	0.82	199	0.02645
5	4.09	409	0.91	205	0.02935
6	4.6	460	1.4	230	0.04516
7	5.01	501	1.99	251	0.06419
8	5.34	534	2.66	267	0.08581
9	5.49	549	3.51	275	0.11323
10	5.61	561	4.39	281	0.14161
13	6.7	670	6.3	335	0.20323
20		0	Snapped		
30		0			
40		0			
50		0			
60		0			

I	J	K	L	M	N
Area(mm ²)		Temp (°C)	24		
2		Measurement		OLD	NEW
				(mm)	
			Width	1	
			Height	2	
		Overall	Length	67	75
		Inside	Length	31	38

Aluminium:

A	B	C	D	E	F
Load nut movement (mm)	Dial indicator (mm)	Force (N)	Extension (mm)	Stress (MPa)	Nominal Strain
0	0	0	0	0	0.00000
0.2	0.175	17.5	0.025	9	0.00081
0.4	0.37	37	0.03	19	0.00097
0.6	0.56	56	0.04	28	0.00129
0.8	0.74	74	0.06	37	0.00194
1	0.935	93.5	0.065	47	0.00210
1.2	1.1	110	0.1	55	0.00323
1.4	1.295	129.5	0.105	65	0.00339
1.6	1.475	147.5	0.125	74	0.00403
1.8	1.64	164	0.16	82	0.00516
2	1.78	178	0.22	89	0.00710
2.2	1.9	190	0.3	95	0.00968
2.4	2	200	0.4	100	0.01290
2.6	2.09	209	0.51	105	0.01645
2.8	2.2	220	0.6	110	0.01935
3	2.28	228	0.72	114	0.02323
3.2	2.33	233	0.87	117	0.02806
3.4	2.4	240	1	120	0.03226
3.6	2.45	245	1.15	123	0.03710
3.8	2.49	249	1.31	125	0.04226
4	2.56	256	1.44	128	0.04645
4.2	2.56	256	1.64	128	0.05290
4.4	2.56	256	1.84	128	0.05935
4.6	2.575	257.5	2.025	129	0.06532
4.8	2.59	259	2.21	130	0.07129
5		0	Snapped		

Area(mm ²)	Temp (°C)	24		
2	Measurement		OLD	NEW
			(mm)	
		Width	1	
		Height	2	
	Overall	Length	67	71
	Inside	Length	31	34.5

Duralumin:

Dial indicator (mm)	Force (N)	Extension (mm)	Stress (MPa)	Nominal Strain
0	0	0	0	0.00000
0.005	0.5	0.195	0	0.00629
0.03	3	0.37	2	0.01194
0.03	3	0.57	2	0.01839
0.135	13.5	0.665	7	0.02145
0.33	33	0.67	17	0.02161
0.48	48	0.72	24	0.02323
0.65	65	0.75	33	0.02419
0.83	83	0.77	42	0.02484
1.03	103	0.77	52	0.02484
1.22	122	0.78	61	0.02516
1.41	141	0.79	71	0.02548
1.6	160	0.8	80	0.02581
1.78	178	0.82	89	0.02645
1.97	197	0.83	99	0.02677
2.165	216.5	0.835	108	0.02694
2.35	235	0.85	118	0.02742
2.54	254	0.86	127	0.02774
2.73	273	0.87	137	0.02806
2.92	292	0.88	146	0.02839
3.1	310	0.9	155	0.02903
3.29	329	0.91	165	0.02935
3.485	348.5	0.915	174	0.02952
3.67	367	0.93	184	0.03000
3.855	385.5	0.945	193	0.03048
4.045	404.5	0.955	202	0.03081
4.9	490	1.1	245	0.03548
5.29	529	1.71	265	0.05516
5.49	549	2.51	275	0.08097
	0	Snapped		

Area(mm ²)		Temp (°C)	24		
2		Measurement		OLD	NEW
				(mm)	
			Width	1	
			Height	2	
		Overall	Length	67	69.5
		Inside	Length	31	33

PVC:

A	B	C	D	E	F
Load nut movement (mm)	Dial indicator (mm)	Force (N)	Extension (mm)	Stress (MPa)	Nominal Strain
0	0	0	0	0	0.00000
0.2	0.06	6	0.14	3	0.00452
0.4	0.12	12	0.28	6	0.00903
0.6	0.18	18	0.42	9	0.01355
0.8	0.21	21	0.59	11	0.01903
1	0.21	21	0.79	11	0.02548
1.2	0.205	20.5	0.995	10	0.03210
1.4	0.21	21	1.19	11	0.03839
1.6	0.22	22	1.38	11	0.04452
1.8	0.22	22	1.58	11	0.05097
2	0.22	22	1.78	11	0.05742
2.2	0.22	22	1.98	11	0.06387
2.4	0.22	22	2.18	11	0.07032
2.6	0.22	22	2.38	11	0.07677
2.8	0.22	22	2.58	11	0.08323
3	0.22	22	2.78	11	0.08968
3.2	0.22	22	2.98	11	0.09613
3.4	0.24	24	3.16	12	0.10194
3.6	0.22	22	3.38	11	0.10903
3.8	0.223	22.3	3.577	11	0.11539
4	0.223	22.3	3.777	11	0.12184
4.2	0.22	22	3.98	11	0.12839
4.4	0.22	22	4.18	11	0.13484
4.6	0.23	23	4.37	12	0.14097
4.8	0.23	23	4.57	12	0.14742
5	0.23	23	4.77	12	0.15387
6	0.25	25	5.75	13	0.18548
7	0.25	25	6.75	13	0.21774
8	0.25	25	7.75	13	0.25000
9	0.25	25	8.75	13	0.28226
10	0.25	25	9.75	13	0.31452
20	0.22	22	19.78	11	0.63806
27.5	0.22	22	27.28	11	0.88000
30		0	Snapped		

Area(mm ²)		Temp (°C)	24		
2		Measurement		OLD	NEW
				(mm)	
			Width	1	
			Height	2	
		Overall	Length	67	91
		Inside	Length	31	55

Appendix B - Formulae Used for Spreadsheet Calculations

The following formulae are taken from the TecQuipment ES6 Tensile Tester laboratory manual (TecQuipment Ltd., 2012).

$$\text{Extension (mm)} = \text{Number of Turns of Force Control (mm)} - \text{Dial Indicator Reading (mm)}$$

$$\text{Force (N)} = \text{Dial Indicator reading (mm)} \times 100$$

$$\sigma = \frac{\text{Force}}{\text{Area acted on by the force}} \quad \sigma = \frac{F}{A}$$

$$\varepsilon = \frac{\text{Change in Length}}{\text{Original Length}} \quad \varepsilon = \frac{l}{L}$$

