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Tensile Test

Engineering Science 1 & Laboratory Skills

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Introduction

A tensile test is the characterisation of how materials behave when pulled. The test consists of measuring the load and elongation of the material, this allows main properties such as Young's modulus, yield and tensile strength to be calculated (Gdoutos and Konsta-Gdoutos, 2024).

Tensile testing is used in engineering to support engineering design. This is due to the strength of a material being a primary concern, ensuring that designs don't fail due to the materials chosen. Alongside strength, factors such as ductility, stress and plastic deformation can also be gathered from tensile testing, all of which can be used and considered during design (Davis, 2004).

The aim of the experiment was to compare the tensile properties of the different materials tested, and converting the data gathered into stress-strain data. The following materials were tested; steel, aluminium, duralumin, and PVC. The main properties of these materials which were trying to be found were the stress and nominal strain values, yield point, tensile strength, and Young's Modulus.

Experimental Procedure

The experiment was carried out using an ES6 Tensile Tester. This kit allows you to add increasing load to a specimen whilst measuring its elongation. Alongside this, calipers were used to take measurements of the width, thickness, and length of the specimens, later allowing calculations to understand the properties of the materials to be made.

Method:

Initially, readings of the specimens were taken using the calipers, including width, thickness and gauge length, as shown in Figure 1. This data was later used to calculate the cross-sectional area (width x thickness).



Figure 1. Measuring the thickness of the test sample.

Then, the specimen was securely fitted into the tester between the chucks and secured using the fittings provided. The safety guard was fitted to adhere to health and safety precautions. The dial indicator reading was set to zero (Figure 2) and load nut was turned to ensure there was tension between the specimen and the load nut.



Figure 2. Dial Indicator adjusted to read zero.

From there, the load nut was increased in steps of half a full rotation (Figure 3), dial indicator readings were recorded at each step. This carried on until the specimen broke (Figure 4), the safety guard could then be removed and the specimen unsecured and removed, then the final gauge length was measured by pushing the specimen back together and measuring its elongation (Figure 5).

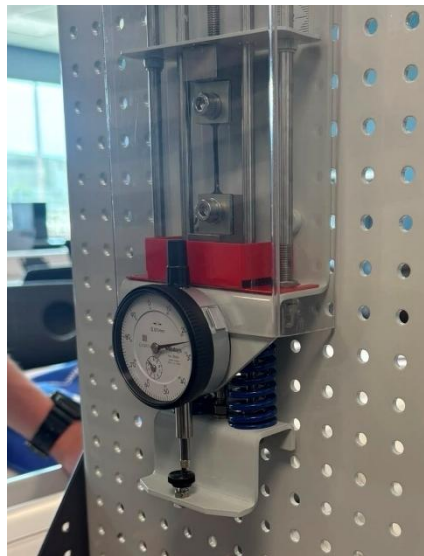


Figure 3. Load nut turned, starting to elongate the specimen



Figure 4. PVC specimen after snapping.



Figure 5. Measuring the final gauge length of aluminium specimen.

Results

The following results were gathered from the tensile testing of the steel, aluminium, duralumin and PVC specimens.

Material	Width (mm)	Thickness (mm)	Cross-sectional Area (mm ²)	Original Gauge Length (mm)	Final Gauge Length (mm)
Steel	2	1	2	31	35
Aluminium	2	1	2	31	34
Duralumin	2	1	2	31	33
PVC	2	1	2	31	39

These are the values gathered from each material with respect to their measurements.

Steel Specimen Table

Load Nut movement (mm)	Dial Indicator (mm)	Force (N)	Extension (mm)	Stress (MPa)	Nominal Strain
0	0	0	0	0	0.00000
0.2	0.1	10	0.1	5	0.00323
0.4	0.26	26	0.14	13	0.00452
0.6	0.46	46	0.14	23	0.00452
0.8	0.65	65	0.15	32.5	0.00484
1	0.84	84	0.16	42	0.00516
1.2	1.02	102	0.18	51	0.00581
1.4	1.21	121	0.19	60.5	0.00613
1.6	1.39	139	0.21	69.5	0.00677
1.8	1.59	159	0.21	79.5	0.00677
2	1.77	177	0.23	88.5	0.00742
2.2	1.91	191	0.29	95.5	0.00935
2.4	2.15	215	0.25	107.5	0.00806
2.6	2.33	233	0.27	116.5	0.00871
2.8	2.53	253	0.27	126.5	0.00871
3	2.72	272	0.28	136	0.00903
3.2	2.9	290	0.3	145	0.00968
3.4	3.08	308	0.32	154	0.01032
3.6	3.26	326	0.34	163	0.01097
3.8	3.44	344	0.36	172	0.01161
4	3.6	360	0.4	180	0.01290
4.2	3.73	373	0.47	186.5	0.01516
4.4	3.86	386	0.54	193	0.01742
4.6	4.12	412	0.48	206	0.01548
4.8	4.24	424	0.56	212	0.01806
5	4.37	437	0.63	218.5	0.02032
6	4.91	491	1.09	245.5	0.03516
7	5.36	536	1.64	268	0.05290
8	5.68	568	2.32	284	0.07484
9	5.89	589	3.11	294.5	0.10032
10	6.1	610	3.9	305	0.12581

Aluminium Specimen Table

Load Nut movement (mm)	Dial Indicator (mm)	Force (N)	Extension (mm)	Stress (MPa)	Nominal Strain
0	0	0	0	0	0.00000
0.2	0.2	20	0	10	0.00000
0.4	0.36	36	0.04	18	0.00129
0.6	0.54	54	0.06	27	0.00194
0.8	0.7	70	0.1	35	0.00323
1	0.87	87	0.13	43.5	0.00419
1.2	1.05	105	0.15	52.5	0.00484
1.4	1.22	122	0.18	61	0.00581
1.6	1.42	142	0.18	71	0.00581
1.8	1.56	156	0.24	78	0.00774
2	1.74	174	0.26	87	0.00839
2.2	1.91	191	0.29	95.5	0.00935
2.4	2.08	208	0.32	104	0.01032
2.6	2.26	226	0.34	113	0.01097
2.8	2.49	249	0.31	124.5	0.01000
3	2.61	261	0.39	130.5	0.01258
3.2	2.71	271	0.49	135.5	0.01581
3.4	2.8	280	0.6	140	0.01935
3.6	2.86	286	0.74	143	0.02387
3.8	2.96	296	0.84	148	0.02710
4	3.03	303	0.97	151.5	0.03129
4.2	3.09	309	1.11	154.5	0.03581
4.4	3.13	313	1.27	156.5	0.04097
4.6	3.18	318	1.42	159	0.04581
4.8	3.19	319	1.61	159.5	0.05194
5	3.21	321	1.79	160.5	0.05774

Duralumin Specimen Table

Load Nut movement (mm)	Dial Indicator (mm)	Force (N)	Extension (mm)	Stress (MPa)	Nominal Strain
0	0	0	0	0	0.00000
0.2	0.12	12	0.08	6	0.00258
0.4	0.26	26	0.14	13	0.00452
0.6	0.42	42	0.18	21	0.00581
0.8	0.59	59	0.21	29.5	0.00677
1	0.78	78	0.22	39	0.00710
1.2	0.96	96	0.24	48	0.00774
1.4	1.13	113	0.27	56.5	0.00871
1.6	1.31	131	0.29	65.5	0.00935
1.8	1.48	148	0.32	74	0.01032
2	1.67	167	0.33	83.5	0.01065
2.2	1.84	184	0.36	92	0.01161
2.4	2.15	215	0.25	107.5	0.00806
2.6	2.33	233	0.27	116.5	0.00871
2.8	2.51	251	0.29	125.5	0.00935
3	2.68	268	0.32	134	0.01032
3.2	2.86	286	0.34	143	0.01097
3.4	3.04	304	0.36	152	0.01161
3.6	3.22	322	0.38	161	0.01226
3.8	3.41	341	0.39	170.5	0.01258
4	3.59	359	0.41	179.5	0.01323
4.2	3.77	377	0.43	188.5	0.01387
4.4	3.95	395	0.45	197.5	0.01452
4.6	4.13	413	0.47	206.5	0.01516
4.8	4.31	431	0.49	215.5	0.01581
5	4.39	439	0.61	219.5	0.01968
6	5.5	550	0.5	275	0.01613
7	5.65	565	1.35	282.5	0.04355

PVC Specimen Table

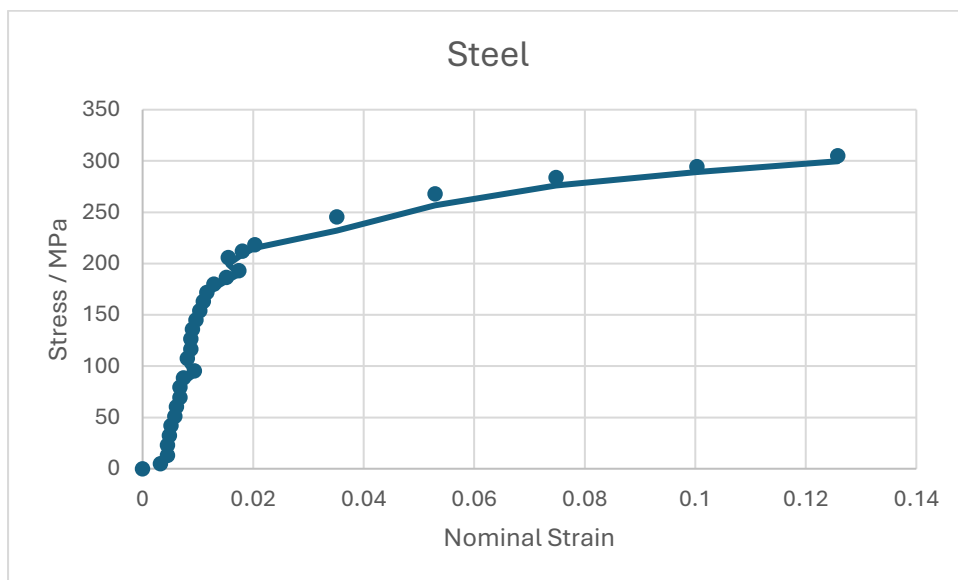
Load Nut movement (mm)	Dial Indicator (mm)	Force (N)	Extension (mm)	Stress (MPa)	Nominal Strain
0	0	0	0	0	0.00000
0.2	0.07	7	0.13	3.5	0.00419
0.4	0.16	16	0.24	8	0.00774
0.6	0.25	25	0.35	12.5	0.01129
0.8	0.33	33	0.47	16.5	0.01516
1	0.42	42	0.58	21	0.01871
1.2	0.5	50	0.7	25	0.02258
1.4	0.56	56	0.84	28	0.02710
1.6	0.57	57	1.03	28.5	0.03323
1.8	0.44	44	1.36	22	0.04387
2	0.4	40	1.6	20	0.05161
2.2	0.4	40	1.8	20	0.05806
2.4	0.4	40	2	20	0.06452
2.6	0.4	40	2.2	20	0.07097
2.8	0.41	41	2.39	20.5	0.07710
3	0.41	41	2.59	20.5	0.08355
3.2	0.41	41	2.79	20.5	0.09000
3.4	0.41	41	2.99	20.5	0.09645
3.6	0.41	41	3.19	20.5	0.10290
3.8	0.41	41	3.39	20.5	0.10935
4	0.41	41	3.59	20.5	0.11581
4.2	0.41	41	3.79	20.5	0.12226
4.4	0.41	41	3.99	20.5	0.12871
4.6	0.41	41	4.19	20.5	0.13516
4.8	0.41	41	4.39	20.5	0.14161
5	0.5	50	4.5	25	0.14516
6	0.44	44	5.56	22	0.17935
7	0.43	43	6.57	21.5	0.21194
8	0.4	40	7.6	20	0.24516

Analysis

Summary Table

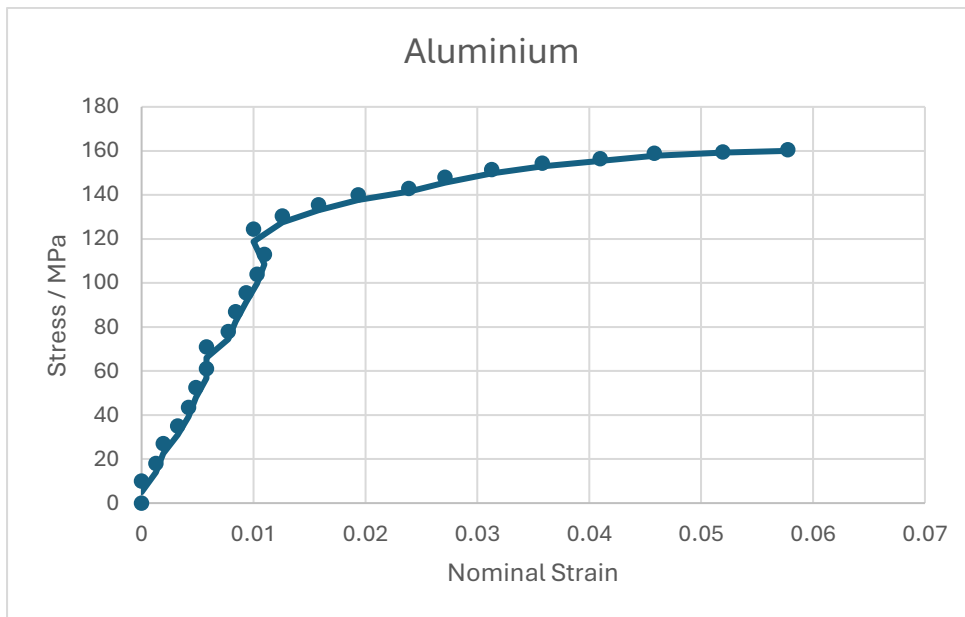
Material	Max Stress (MPa)	Yield Stress (MPa)	Final Extension (mm)	Final Nominal Strain	% Elongation
Steel	305	218	3.9	0.12581	12.9
Aluminium	160.5	113	1.79	0.05774	9.7
Duralumin	282.5	215	1.35	0.04355	6.5
PVC	28.5	28	7.6	0.64516129	25.8

Steel Graph



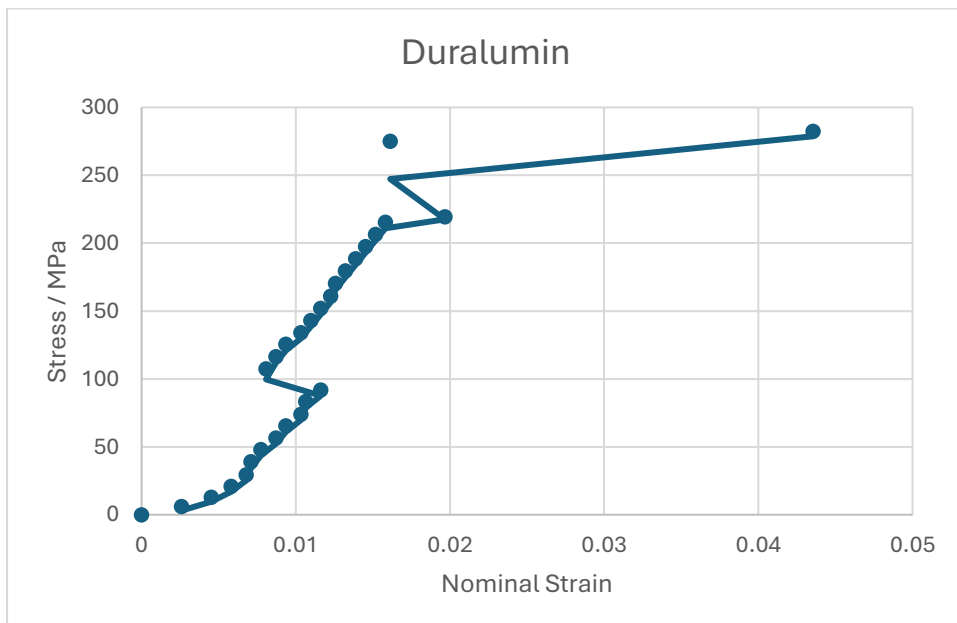
The steel graph starts with a clear indication of an elastic region, shown by the linear part of the graph at the start. This also shows stress rises quickly with small increase in strain. The line changes at around 220MPa, this is the elastic limit. From there, the material begins to yield and plastic deformation begins. The maximum stress is about 300MPa, and final nominal strain is around 0.125. This shows that steel has a high strength with some ductility before failure.

Aluminium Graph



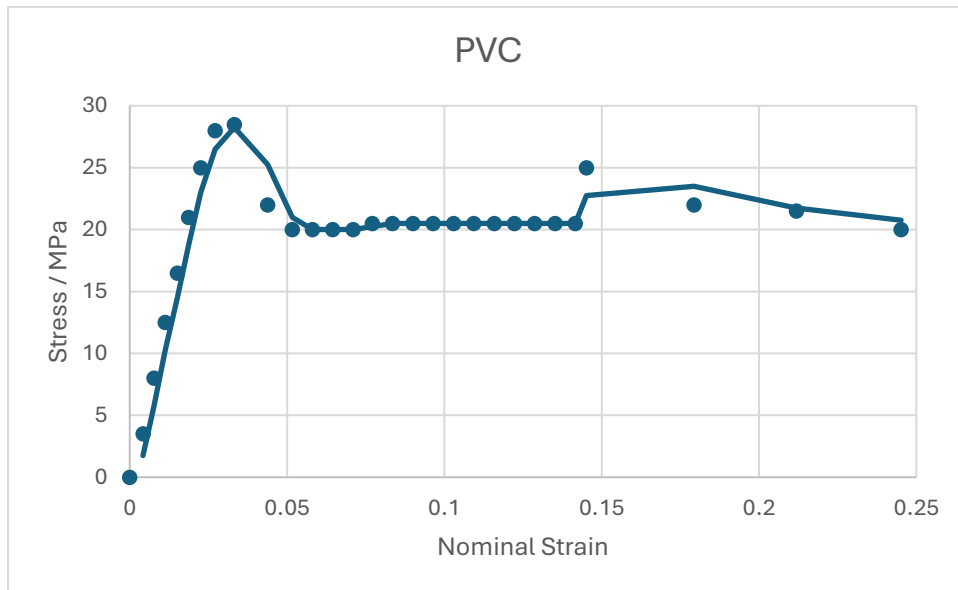
The aluminium graph starts with a mostly linear elastic region, with stress increasing quickly, with a small increase in nominal strain. The graph then begins to show the yield point and start of plastic deformation at around 120MPa. After this point, the stress rises more gradually until it reaches a maximum stress of approximately 160MPa. The final nominal strain is around 0.057. This shows aluminium has a lower tensile strength than steel but still showed some ductility before failure.

Duralumin Graph



The duralumin graph begins with a mostly linear elastic region, where stress increases rapidly with nominal strain. The graph starts to change shape at around 225MPa, suggesting that the yield region was reached and plastic deformation had begun. The maximum stress achieved was approximately 280MPa. The final nominal strain was around 0.045, showing that duralumin had a low ductility but high strength. Within the graph there also seem to be some anomalies in the data, likely caused by reading errors or equipment faults. This affects the shape of the graph drastically; however, it is still clear where the elastic region and plastic region lie on the graph.

PVC Graph



The PVC graph shows a completely different relationship between stress and strain as it behaves differently to the other metals tested. It began with a short elastic region where stress increases quickly with strain. The yield point is found early when stress reaches a maximum of approximately 28MPa. Stress then drops and remains constant at around 20MPa while strain increases. This shows that PVC has a much lower tensile strength than the metals tested, but much higher ductility shown by the continually increasing strain values. Final nominal strain was approximately 0.245, higher than any other materials tested.

Conclusion

Overall, the tensile test showed distinct differences between the four specimens. Steel had the highest maximum stress at approximately 305 MPa, followed by duralumin at 282.5 MPa, aluminium at 160.5 MPa and PVC at 28.5 MPa. This shows that the metallic materials had a much higher tensile strength than PVC. However, PVC showed the greatest ductility with the highest nominal strain value and percentage elongation. Steel and duralumin showed high strength, while aluminium had lower strength but still showed ductile behaviour. The results gathered from the testing broadly agree with the expected behaviour of the materials, as metals generally have higher tensile strength, while plastics such as PVC can deform to a greater extent before failure.

This is further proven when compared to researched material data. Steel typically has a tensile strength of 400 – 550 MPa, which is higher than the value obtained in this experiment but remains consistent with steel being the strongest material tested (ECONSTEEL, 2025). PVC has a low tensile strength of around 34-60 MPa, like the value obtained during the tensile test (Belshof, 2025). Further research shows that duralumin, an aluminium alloy, has a higher tensile strength than aluminium whilst remaining ductile like aluminium (Sreenivasa Rao et al., 2024). This was shown in the data gathered between the two materials, both of which showed similar traits. The yield stress values also followed the expected trend, with steel and duralumin yielding at higher stresses than aluminium and PVC, although the exact values differed from researched data because the yield points were estimated visually from the graphs. Differences found between the experimental and research values may be due to a range of factors which may have occurred during the testing.

Evaluation

Several factors will have affected the accuracy of the results gathered from the experiment. The dial indicator readings were taken manually by multiple people; this could have introduced small reading errors. The specimen dimensions were also measured using calipers, so small errors in width or thickness may have affected the resulting calculations, thus affecting the stress values found in the graph. The load nut was also turned manually, meaning the loading rate may not have been consistent throughout. This is particularly noticeable for PVC as the dial indicator reading changed constantly after the load was applied.

Another limitation was that the yield points were estimated from the stress-strain graphs, thus not being exact. The ES6 tester used also measures nominal strain, this means that movement from the tester may have contributed to the extension of the specimens, this could explain the small differences found between the experimental values and researched values.

Further Work

If further work was to be carried out, each test could be repeated several times and averaged to improve reliability. An improved tensile testing machine could also be used to apply the load more consistently and record the extension and force applied automatically. Finally, the tests may have been affected by environmental conditions such as temperature, thus affecting the results gathered. This may be improved using controlled conditions consistent across all materials.

Reference list

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