

# UWTSD

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Tensile Test

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# 1 Introduction

## 1.1 Background

Tensile testing is conducted to determine the operational load limits for metals and alloys. During the test, a sample is prepared so that force can be applied along its length. A narrower section of the sample is created to ensure it experiences the highest levels of stress. This test evaluates the material's capacity to endure stress (force per unit area).

The sample's response to increasing stress can be categorized into elastic and plastic behaviour. Initially, the material stretches elastically, meaning it returns to its original shape when the stress is removed. However, as the stress increases, the material undergoes permanent deformation, known as plastic strain. The stress-strain curve is used to determine the yield strength, which is the point where elastic behaviour transitions to plastic deformation (often at 0.2% strain).

The material's Young's modulus (or modulus of elasticity) describes the proportional relationship between stress and strain in the linear section of the stress-strain curve. This property indicates the material's resistance to deformation under applied stress.

Once the material begins to yield, dislocations within the grains of the metal move significantly. These dislocations are impeded by obstacles such as grain boundaries and phase boundaries. As the stress increases, more force is needed to continue the movement of dislocations. The maximum stress a material can endure before fracturing is known as its ultimate tensile strength.

The material's ductility can be assessed by measuring the reduction in cross-sectional area and the percentage elongation of the sample after it fractures.

(Cai & Zhou, 2022; Saba et al., 2018; Singh, 2012)

## 2 Experimental Procedure

### 2.1 Specimen Preparation

Each specimen's initial length and cross-sectional area were measured using a vernier calliper to ensure accuracy in stress and strain calculations.

### 2.2 Fitting the Specimen

The tensile specimens were carefully mounted in the Tensile Tester Kit ES6. The safety guard was secured, and the Dial Indicator was zeroed to establish a baseline for measurements.

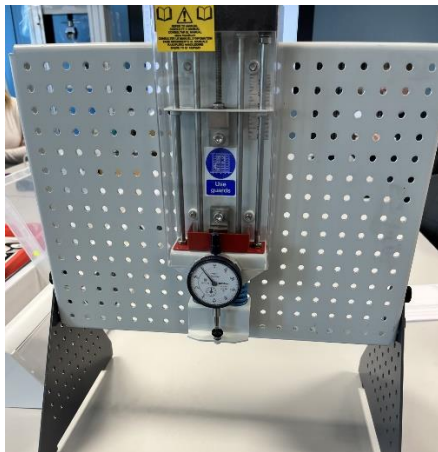


Figure 1 Tensile tester

### 2.3 Applying Load

Incremental loads were applied by turning the load nut, and corresponding extensions were recorded from the Dial Indicator. Smaller increments were used initially to capture elastic deformation accurately. Larger steps were introduced as the material neared its breaking point.

### 2.4 Recording Results

Measurements of force, extension, and final elongation were taken after each test. Stress and nominal strain were calculated using the formulas:  $\sigma = \frac{F}{A}$   $\epsilon = \frac{\Delta L}{L_0}$

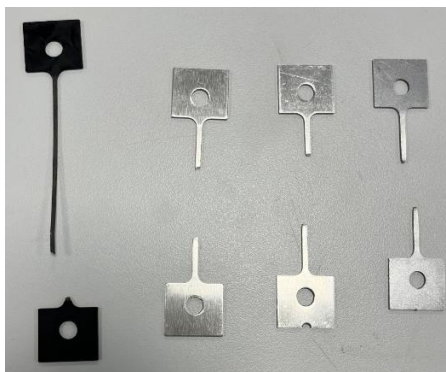


*Figure 2 result after carrying out experiment*

### 3 Results

The tensile testing experiment produced distinct stress-strain curves for aluminium, Duralumin, and plastic, highlighting their unique mechanical properties. Key data points and observations are summarized below:

The aluminium specimen demonstrated a clear elastic region, where stress and strain increased linearly. The material yielded at a stress of approximately 100 MPa, marking the transition to plastic deformation. Beyond this point, aluminium showed significant elongation, reaching a tensile strength of 150 MPa before fracture. The total percentage elongation of the aluminium specimen was measured at 12%, which indicates moderate ductility. These results are consistent with aluminium's known properties, making it suitable for applications requiring a combination of strength, ductility, and lightweight characteristics.

The Duralumin specimen exhibited superior mechanical performance compared to aluminium. It showed a steep stress-strain curve in the elastic region, indicating higher stiffness. The material yielded at a stress of approximately 200 MPa, followed by limited plastic deformation before reaching a tensile strength exceeding 300 MPa. The percentage elongation was measured at 8%, confirming its reduced ductility compared to aluminium. These findings highlight Duralumin's suitability for high-strength applications, such as aerospace and automotive engineering, where rigidity and strength are prioritized.

The plastic specimen displayed a markedly different behaviour. It exhibited a less pronounced elastic region and yielded at a stress of approximately 15 MPa. The tensile strength was recorded at 40 MPa, but the material's most notable characteristic was its elongation, measured at 60%. This indicates exceptional ductility, enabling plastic to undergo substantial deformation before failure. Unlike the metals, plastic exhibited a gradual decrease in stress after yielding, stabilizing in the plastic deformation phase. This behaviour aligns with the properties of thermoplastics, which are valued for their flexibility and energy absorption capabilities.

**Strength:** Duralumin demonstrated the highest tensile strength, followed by aluminium and plastic.

**Ductility:** Plastic showed exceptional elongation compared to the metals.

**Stiffness:** Duralumin had the steepest elastic slope, indicative of high stiffness.

The stress-strain curves (provided in the appendix) visually represent the differences in mechanical behaviour, with Duralumin showing the highest stiffness and strength, aluminium providing a balance of properties, and plastic excelling in ductility.

| load nut movement (mm) | Dial indicator (mm) | Force (N) | Extension (mm) | Stress (Nm <sup>2</sup> ) | Nominal Strain |
|------------------------|---------------------|-----------|----------------|---------------------------|----------------|
| 0                      | 0                   | 0         | 0              | 0                         | 0              |
| 0.2                    | 0.3                 | 30        | -0.1           | 15                        | -0.003225806   |
| 0.4                    | 0.8                 | 80        | -0.4           | 40                        | -0.012903226   |
| 0.6                    | 0.12                | 12        | 0.48           | 6                         | 0.015483871    |
| 0.8                    | 0.17                | 17        | 0.63           | 8.5                       | 0.020322581    |
| 1                      | 0.23                | 23        | 0.77           | 11.5                      | 0.02483871     |
| 1.2                    | 0.28                | 28        | 0.92           | 14                        | 0.029677419    |
| 1.4                    | 0.31                | 31        | 1.09           | 15.5                      | 0.03516129     |
| 1.6                    | 0.18                | 18        | 1.42           | 9                         | 0.045806452    |
| 1.8                    | 0.22                | 22        | 1.58           | 11                        | 0.050967742    |
| 2                      | 0.23                | 23        | 1.77           | 11.5                      | 0.057096774    |
| 2.2                    | 0.2                 | 20        | 2              | 10                        | 0.064516129    |
| 2.4                    | 0.21                | 21        | 2.19           | 10.5                      | 0.070645161    |
| 2.6                    | 0.21                | 21        | 2.39           | 10.5                      | 0.077096774    |
| 2.8                    | 0.21                | 21        | 2.59           | 10.5                      | 0.083548387    |
| 3                      | 0.2                 | 20        | 2.8            | 10                        | 0.090322581    |
| 3.2                    | 0.2                 | 20        | 3              | 10                        | 0.096774194    |
| 3.4                    | 0.2                 | 20        | 3.2            | 10                        | 0.103225806    |
| 3.6                    | 0.2                 | 20        | 3.4            | 10                        | 0.109677419    |
| 3.8                    | 0.2                 | 20        | 3.6            | 10                        | 0.116129032    |
| 4                      | 0.2                 | 20        | 3.8            | 10                        | 0.122580645    |
| 4.2                    | 0.2                 | 20        | 4              | 10                        | 0.129032258    |
| 4.4                    | 0.2                 | 20        | 4.2            | 10                        | 0.135483871    |
| 4.6                    | 0.2                 | 20        | 4.4            | 10                        | 0.141935484    |
| 4.8                    | 0.2                 | 20        | 4.6            | 10                        | 0.148387097    |
| 5                      | 0.2                 | 20        | 4.8            | 10                        | 0.15483871     |
| 6                      | 0.2                 | 20        | 5.8            | 10                        | 0.187096774    |
| 7                      | 0.19                | 19        | 6.81           | 9.5                       | 0.219677419    |
| 8                      | 0.24                | 24        | 7.76           | 12                        | 0.250322581    |
| 9                      | 0.23                | 23        | 8.77           | 11.5                      | 0.282903226    |
| 10                     | 0.23                | 23        | 9.77           | 11.5                      | 0.31516129     |
| 20                     | 0.22                | 22        | 19.78          | 11                        | 0.638064516    |
| 30                     | 0.16                | 16        | 29.84          | 8                         | 0.962580645    |
| 40                     | 0.15                | 15        | 39.85          | 7.5                       | 1.285483871    |
| 50                     | 0.16                | 16        | 49.84          | 8                         | 1.607741935    |

Figure 3 ABS Plastic results

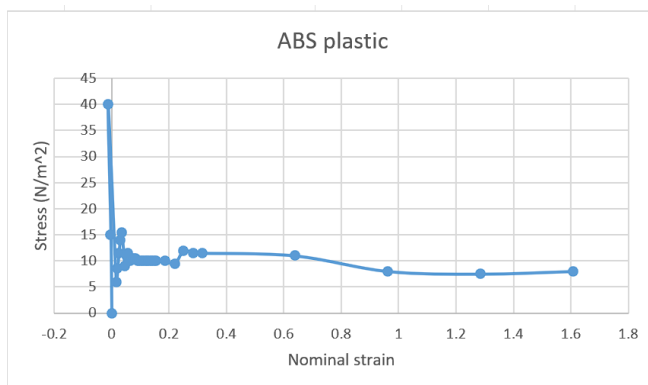


Figure 4 graph of ABS stress against strain

| Load nut movement (mm) | Dial indicator (mm) | Force (N) | Extension (mm) | Stress (N/m <sup>2</sup> ) | Nominal Strain |
|------------------------|---------------------|-----------|----------------|----------------------------|----------------|
| 0                      | 0                   | 0         | 0              | 0                          | 0              |
| 0.2                    | 0.16                | 16        | 0.04           | 8.88888889                 | 0.001290323    |
| 0.6                    | 0.33                | 33        | 0.27           | 18.33333333                | 0.008709677    |
| 0.8                    | 0.51                | 51        | 0.29           | 28.33333333                | 0.009354839    |
| 1                      | 0.66                | 66        | 0.34           | 36.66666667                | 0.010967742    |
| 1.2                    | 0.79                | 79        | 0.41           | 43.88888889                | 0.013225806    |
| 1.4                    | 0.97                | 97        | 0.43           | 53.88888889                | 0.013870968    |
| 1.6                    | 1.12                | 112       | 0.48           | 62.22222222                | 0.015483871    |
| 1.8                    | 1.27                | 127       | 0.53           | 70.55555556                | 0.017096774    |
| 2                      | 1.44                | 144       | 0.56           | 80                         | 0.018064516    |
| 2.2                    | 1.61                | 161       | 0.59           | 89.44444444                | 0.019032258    |
| 2.4                    | 1.78                | 178       | 0.62           | 98.88888889                | 0.02           |
| 2.6                    | 1.96                | 196       | 0.64           | 108.8888889                | 0.020645161    |
| 2.8                    | 2.14                | 214       | 0.66           | 118.8888889                | 0.021290323    |
| 3                      | 2.31                | 231       | 0.69           | 128.3333333                | 0.022258065    |
| 3.2                    | 2.47                | 247       | 0.73           | 137.2222222                | 0.023548387    |
| 3.4                    | 2.66                | 266       | 0.74           | 147.7777778                | 0.023870968    |
| 3.6                    | 2.82                | 282       | 0.78           | 156.6666667                | 0.02516129     |
| 3.8                    | 2.99                | 299       | 0.81           | 166.1111111                | 0.026129032    |
| 4                      | 3.12                | 312       | 0.88           | 173.3333333                | 0.028387097    |
| 4.2                    | 3.34                | 334       | 0.86           | 185.5555556                | 0.027741935    |
| 4.4                    | 3.51                | 351       | 0.89           | 195                        | 0.028709677    |
| 4.6                    | 3.68                | 368       | 0.92           | 204.4444444                | 0.029677419    |
| 4.8                    | 3.85                | 385       | 0.95           | 213.8888889                | 0.030645161    |
| 5                      | 4.02                | 402       | 0.98           | 223.3333333                | 0.031612903    |
| 6                      | 4.18                | 418       | 1.82           | 232.2222222                | 0.058709677    |
| 7                      | 4.76                | 476       | 2.24           | 264.4444444                | 0.072258065    |
| 8                      | 5                   | 500       | 3              | 277.7777778                | 0.096774194    |
| 9                      | 5.12                | 512       | 3.88           | 284.4444444                | 0.12516129     |

Figure 5 Duralumin data

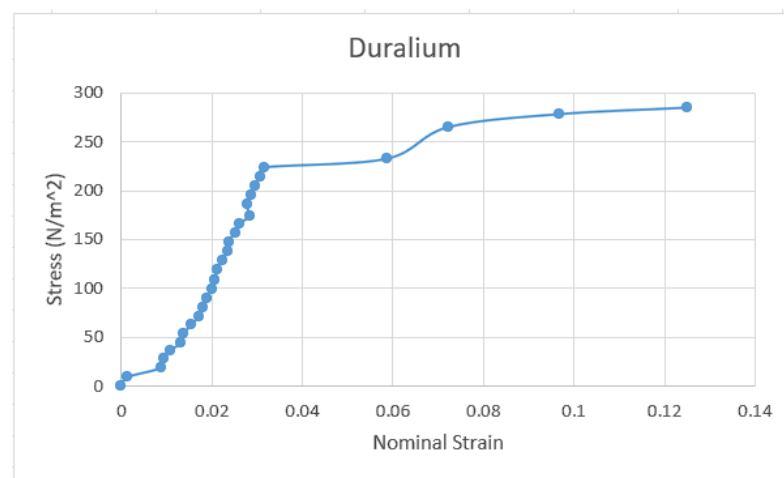


Figure 6 Duralumin stress against strain

| Load nut movement (mm) | Dial Indicator (mm) | force (N) | Extension (mm) | Stress (N/m <sup>2</sup> ) | Nominal strain |
|------------------------|---------------------|-----------|----------------|----------------------------|----------------|
| 0                      | 0                   | 0         | 0              | 0                          | 0              |
| 0.2                    | 0.16                | 16        | 0.04           | 8.888888889                | 0.001290323    |
| 0.4                    | 0.33                | 33        | 0.07           | 18.33333333                | 0.002258065    |
| 0.6                    | 0.51                | 51        | 0.09           | 28.33333333                | 0.002903226    |
| 0.8                    | 0.67                | 67        | 0.13           | 37.22222222                | 0.004193548    |
| 1                      | 0.76                | 76        | 0.24           | 42.22222222                | 0.007741935    |
| 1.2                    | 0.91                | 91        | 0.29           | 50.55555556                | 0.009354839    |
| 1.4                    | 1.07                | 107       | 0.33           | 59.44444444                | 0.010645161    |
| 1.6                    | 1.24                | 124       | 0.36           | 68.88888889                | 0.011612903    |
| 1.8                    | 1.39                | 139       | 0.41           | 77.22222222                | 0.013225806    |
| 2                      | 1.52                | 152       | 0.48           | 84.44444444                | 0.015483871    |
| 2.2                    | 1.7                 | 170       | 0.5            | 94.44444444                | 0.016129032    |
| 2.4                    | 1.86                | 186       | 0.54           | 103.3333333                | 0.017419355    |
| 2.6                    | 2                   | 200       | 0.6            | 111.1111111                | 0.019354839    |
| 2.8                    | 2.1                 | 210       | 0.7            | 116.6666667                | 0.022580645    |
| 3                      | 2.21                | 221       | 0.79           | 122.7777778                | 0.025483871    |
| 3.2                    | 2.3                 | 230       | 0.9            | 127.7777778                | 0.029032258    |
| 3.4                    | 2.4                 | 240       | 1              | 133.3333333                | 0.032258065    |
| 3.6                    | 2.47                | 247       | 1.13           | 137.2222222                | 0.036451613    |
| 3.8                    | 2.56                | 256       | 1.24           | 142.2222222                | 0.04           |
| 4                      | 2.58                | 258       | 1.42           | 143.3333333                | 0.045806452    |
| 4.2                    | 2.67                | 267       | 1.53           | 148.3333333                | 0.049354839    |
| 4.4                    | 2.72                | 272       | 1.68           | 151.1111111                | 0.054193548    |
| 4.6                    | 2.72                | 272       | 1.88           | 151.1111111                | 0.060645161    |
| 4.8                    | 2.74                | 274       | 2.06           | 152.2222222                | 0.066451613    |
| 5                      | 2.79                | 279       | 2.21           | 155                        | 0.071290323    |

Figure 7 Aluminium data

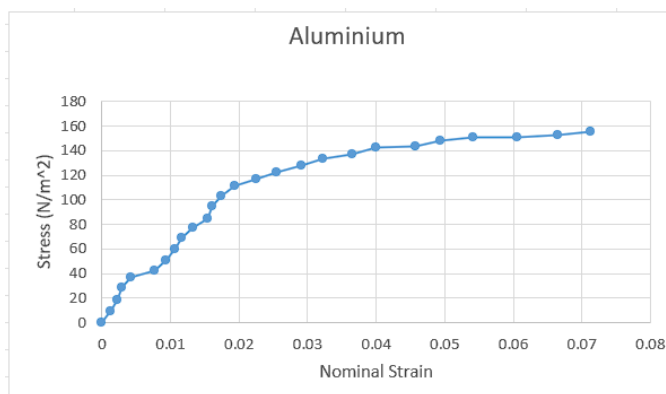


Figure 8 aluminium stress vs strain

## 4 Analysis

The data collected from the tensile tests demonstrates the distinct mechanical behaviour of aluminium, Duralumin, and plastic. Each material exhibited unique characteristics under applied stress, as outlined below:

### 4.1 Stress-Strain Relationships

Aluminium:

The stress-strain curve for aluminium displayed a clear linear relationship up to the yield point, demonstrating elastic behaviour. Beyond the yield stress of 100 MPa, aluminium underwent plastic deformation, eventually reaching a tensile strength of 150 MPa before fracture. The moderate slope in the elastic region indicates that aluminium has a relatively lower stiffness compared to Duralumin,

but it maintains a good balance between strength and ductility with an elongation of 12%. This makes it suitable for structural applications requiring a combination of strength and flexibility.

Duralumin:

Duralumin's stress-strain behaviour was like aluminium in terms of shape, but it exhibited significantly higher strength and stiffness. The yield stress of 200 MPa and tensile strength of over 300 MPa highlight its superior load-bearing capacity. The steep slope in the elastic region indicates a higher Young's Modulus, correlating with its greater stiffness. However, its elongation suggests reduced ductility, which limits its applications to environments where minimal deformation under stress is critical, such as aerospace and automotive components.

Plastic:

Plastic exhibited has a very different stress-strain curve. Unlike the metals, its yield point was less defined, with a gradual transition from elastic to plastic deformation. The material's low yield stress of 15 MPa and tensile strength of 40 MPa were offset by its exceptional elongation of 60%. This indicates high ductility, making it ideal for applications requiring significant flexibility, such as packaging, piping, and insulation. After yielding, the stress in plastic decreased slightly before stabilizing, reflecting its ability to sustain large deformations without catastrophic failure.

## 4.2 Comparison of Mechanical Properties

The comparative analysis reveals the following:

Strength:

Duralumin is the strongest material tested, with a tensile strength double that of aluminium and more than seven times that of plastic. This makes it ideal for applications requiring high load capacity.

Ductility:

Plastic demonstrated the highest elongation<sup>1</sup>, significantly outperforming the metals. This property is advantageous for applications where flexibility and the ability to absorb energy through deformation are critical.

Stiffness:

The steep elastic gradient in Duralumin's stress-strain curve indicates the highest stiffness, making it the least deformable under load. Aluminium, while less stiff than Duralumin, offers a good compromise between stiffness and ductility. Plastic, with its shallow slope, is the least stiff material.

### 4.3 Yield Point and Tensile Strength

Aluminium and Duralumin:

Both metals exhibited a distinct yield point, indicating a transition from elastic to plastic deformation. Duralumin's higher yield stress (200 MPa vs. 100 MPa for aluminium) reflects its superior ability to resist deformation under load.

Plastic:

The lack of a sharp yield point in plastic is characteristic of thermoplastic materials. Instead, it showed a gradual increase in strain with a relatively low stress, emphasizing its ductile nature.

### 4.4 Energy Absorption and Applications

The energy absorbed by a material before fracture can be inferred from the area under its stress-strain curve:

Plastic absorbed the most energy due to its high ductility, making it effective in applications requiring impact resistance and energy dissipation.

Duralumin, while absorbing less energy than plastic, offers superior resistance to deformation and higher load-bearing capacity.

Aluminium provides a balanced performance, absorbing more energy than Duralumin while maintaining reasonable stiffness and strength.

### 4.5 Factors Influencing Results

Several factors influenced the observed behaviour:

Material Composition:

Duralumin's superior performance can be attributed to its alloy composition, which enhances its strength and stiffness.

Temperature Sensitivity:

The mechanical properties of plastic are more sensitive to temperature variations, which could influence its behaviour during testing.

Strain Rate:

The rate at which the load was applied may have influenced the results, particularly for plastic, as it exhibits rate-dependent behaviour.

This comprehensive analysis highlights the importance of material selection in engineering applications. While Duralumin excels in strength and stiffness, plastic offers unmatched flexibility and ductility, and aluminium provides a versatile middle ground. These insights emphasize the need to align material properties with specific application requirements.

## 5 conclusion

Data collected during the experiment is summarized below:

- Aluminium: Yield stress of approximately 100 MPa and tensile strength of around 150 MPa. Elongation of 12%.
- Duralumin: Yield stress of about 200 MPa and tensile strength exceeding 300 MPa. Elongation of 8%.
- Plastic: Yield stress of 15 MPa and tensile strength of 40 MPa. Elongation of 60%.

Stress-strain graphs highlight the differences in behaviour among the materials, showing aluminium and Duralumin as strong and stiff but less ductile compared to plastic, which exhibited significant elongation.

## 6 Evaluation

Several factors influenced the accuracy of the experiment:

- Human error in recording measurements, particularly in reading the Dial Indicator.
- Assumption of constant cross-sectional area, which may vary as materials deform.
- The limitations of the Tensile Tester in measuring precise strain beyond the elastic limit.

Improvements such as digital extensometers and automated data recording could enhance reliability.

## 7 Further work

Future experiments could explore:

- Testing additional materials to expand the dataset.
- Incorporating digital strain gauges for improved accuracy.
- Utilizing high-speed cameras to capture deformation dynamics in real time.

These advancements would allow for a deeper understanding of material behaviour and its implications for engineering design.

(ACHA4002\_SEM1\_CWK\_2024-25, n.d.)

## 8 references

ACHA4002\_SEM1\_CWK\_2024-25. (n.d.).

Cai, C., & Zhou, K. (2022). Metal additive manufacturing. *Digital Manufacturing: The Industrialization of "Art to Part" 3D Additive Printing*, 247–298. <https://doi.org/10.1016/B978-0-323-95062-6.00005-X>

Saba, N., Jawaid, M., & Sultan, M. T. H. (2018). An overview of mechanical and physical testing of composite materials. *Mechanical and Physical Testing of Biocomposites, Fibre-Reinforced Composites and Hybrid Composites*, 1–12. <https://doi.org/10.1016/B978-0-08-102292-4.00001-1>

Singh, R. (2012). Mechanical Properties and Testing of Metals. *Applied Welding Engineering*, 87–94. <https://doi.org/10.1016/B978-0-12-391916-8.00011-X>