

University of Wales Trinity Saint David

Wales Institute of Science & Art



Tensile Test

Engineering science

(ACHA4002)

Suphakit Pratt

2203284

8/12/2024

Contents

1	Introduction.....	1
1.1	Aims	1
1.2	Background	1
1.3	Connection to motorsports	1
2	Experimental procedure	2
3	Results	3
3.1	Raw Data.....	3
4	Analysis.....	5
4.1	Equations	5
4.2	Stress vs Strain data	6
4.3	Steel	6
4.4	PVC.....	7
4.5	Aluminium	8
4.6	Duralumin	9
5	Conclusion	10
6	Evaluation	10
6.1	Further Work	10
7	Reference.....	11
7.1	Appendices	13

1 Introduction

1.1 Aims

The aim of this report is to understand the strength of materials and how they react to applied loads.

1.2 Background

What is Tensile Strength? Tensile strength is the maximum stress a material can withstand while being stretched or pulled before breaking. It represents the material ability to resist tension and is an important property in engineering.

1.3 Connection to motorsports

In motorsports, tensile strength plays a key role in the design and performance of vehicles. Racing environment subject's cars to extreme forces speed and stresses, requiring materials that are both strong and lightweight to maximise performance and safety.

Key areas:

1. Chassis and frame design

The chassis acts as the backbone of a race car, it must resist deformation while withstand dynamic loads from highspeed cornering, acceleration, and impact. High tensile strength materials like carbon Fiber composite, titanium and steel are commonly used for their straight to weight ratio.

2. Engine components

Engine components such as connecting rods, pistons, and crankshaft experience extreme tensile and compressive stress due to high rotational speed. Forged Steel or titanium in motorsports is often used because of their high tensile strength and durability to prevent catastrophic engine failure.

2 Experimental procedure

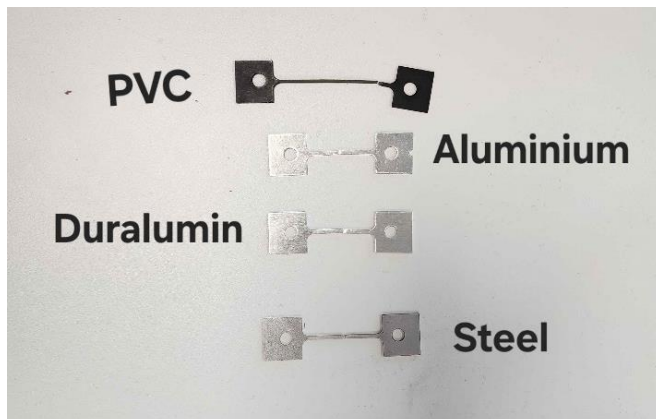


Figure 1 The 4 specimens Steel, Aluminium, Duralumin (high specification aluminium alloy) and Polyvinyl Chloride (PVC). after the Tensile Test (photo taken by student)

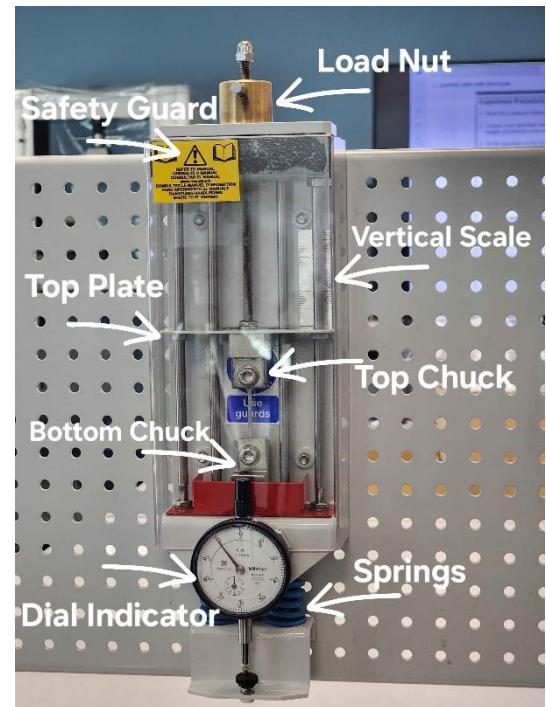


Figure 2 shows what the experiment should look like (photo taken by student)

1. Choose one of the specimen materials and use the Dial Caliper to measure the thickness and width at the gauge length and find its cross-sectional area. (Measure and record the original length, for reference).
2. Fit the specimen to the Tensile Tester and zero the dial indicator (fit the safety guard).
3. Slowly turn the load nut clockwise in 0.2 mm steps until 5mm then larger 1mm and 10 mm until specimen breaks.
4. To check the elongation, remove the specimen from the tester and push its broken together then measure its final length.
5. Convert the dial indicator reading (mm) into forces value (N) by multiplying the reading by one hundred.
6. To find extension, subtract the dial indicator reading from the load nut movement reading.
7. To find stress value, divide force with the cross-sectional area.
8. To find nominal strain value, divide extension with the original length.
9. For each specimen, In excel plot the stress value on the Y-axis and nominal strain value on the x-axis.
10. Note the yield point and tensile strength for each specimen.
11. For each specimen find the gradient of elastic region to compare the stiffness of the materials.

3 Results

3.1 Raw Data

Table 1 Raw Data for Steel

Load Nut Movement (mm)	Dial indicator (mm)
0	0
0.2	0.095
0.4	0.26
0.6	0.44
0.8	0.615
1	0.79
1.2	0.975
1.4	1.15
1.6	1.325
1.8	1.5
2	1.68
2.2	1.86
2.4	2.03
2.6	2.215
2.8	2.39
3	2.565
3.2	2.735
3.4	2.9
3.6	3.06
3.8	3.2
4	3.34
4.2	3.46
4.4	3.58
4.6	3.7
4.8	3.82
5	3.93
6	4.42
7	4.8
8	5.07
9	5.22
10	5.31
20	snap

Table 2 Raw Data for PVC

Load Nut Movement (mm)	Dial Indicator (mm)
0	0
0.2	0.06
0.4	0.12
0.6	0.18
0.8	0.22
1	0.23
1.2	0.2
1.4	0.15
1.6	0.12
1.8	0.12
2	0.12
2.2	0.12
2.4	0.12
2.6	0.13
2.8	0.125
3	0.125
3.2	0.12
3.4	0.12
3.6	0.13
3.8	0.13
4	0.13
4.2	0.13
4.4	0.14
4.6	0.13
4.8	0.13
5	0.13
6	0.13
7	0.13
8	0.13
9	0.13
10	0.11
20	0.115
30	snap

Original Gauge Length	30.8 mm
Final Gauge Length	38.8 mm
Width	1.9 mm
Thickness	0.9 mm

Original Gauge Length	31.2
Final Gauge Length	57.9
Width	1.9 mm
Thickness	1 mm

Table 3 Raw Data for Duralumin

Load Nut Movement (mm)	Dial Indicator (mm)
0	0
0.2	0.125
0.4	0.27
0.6	0.44
0.8	0.61
1	0.77
1.2	0.93
1.4	1.1
1.6	1.275
1.8	1.44
2	1.615
2.2	1.78
2.4	1.96
2.6	2.13
2.8	2.31
3	2.48
3.2	2.605
3.4	2.825
3.6	3
3.8	3.17
4	3.34
4.2	3.52
4.4	3.69
4.6	3.85
4.8	4.035
5	4.2
6	4.8
7	5
8	5.18
9	snap

Original Gauge Length	31 mm
Final Gauge Length	32.99 mm
Width	1.9 mm
Thickness	1 mm

Table 4 Raw Data for Aluminium

Load Nut Movement (mm)	Dial Indicator (mm)
0	0
0.2	0.15
0.4	0.33
0.6	0.51
0.8	0.69
1	0.875
1.2	1.06
1.4	1.245
1.6	1.43
1.8	1.61
2	1.78
2.2	1.952
2.4	2.1
2.6	2.2
2.8	2.33
3	2.43
3.2	2.5
3.4	2.59
3.6	2.65
3.8	2.7
4	2.77
4.2	2.8
4.4	2.83
4.6	2.83
4.8	2.87
5	2.86
6	snap

Original Gauge Length	31 mm
Final Gauge Length	33.3 mm
Width	2 mm
Thickness	1 mm

4 Analysis

From the raw data that was collected, use the data to work out the Force and Extension and then from there work out the Stress and Nominal strain value.

4.1 Equations

- Force (N) = Dial Indicator Reading (mm) x 100
- Extension (mm) = Load Nut Movement (number of turns) (mm) – Dial Indicator Reading (mm)
- Cross sectional area (m²) = $\frac{(\text{thickness (mm)} \times \text{width (mm)})}{1,000,000}$
- Stress (σ) (N/m²) = $\frac{\text{Force (N)}}{\text{Area (m}^2\text{)}}$
- Nominal Strain(ϵ) = $\frac{l}{L}$ (l = change in length or Extension) (L = original length)
- Young's modulus (Pa) = $\frac{\text{Stress } (\sigma)}{\text{Strain } (\epsilon)}$
- Percentage Elongation = $\frac{\text{Final length} - \text{Original length}}{\text{Original length}} \times 100$

4.2 Stress vs Strain data

4.3 Steel

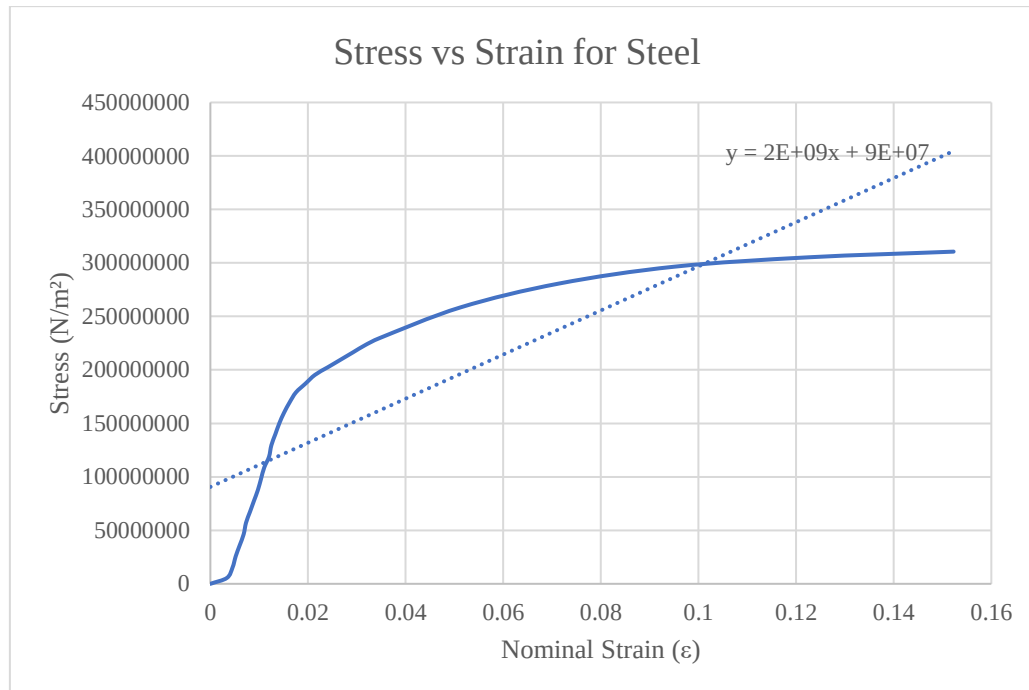


Figure 1 shows Stress and strain of steel

From figure 1, The elastic region is the initial, linear part of the stress strain curve. In this region stress is directly proportional to strain. The slope of the linear region Young's modulus determines the stiffness of the material. From the equation $y = 2E+09x + 9E+07$, the Young's modulus appears to be $E = 2 \times 10^9 \text{ Pa}$. The graph begins to deviate from the linearity at around $\epsilon = 0.02$ which would be the yield point. The corresponding stress here is the yield stress which is approximately $200,000,000 \text{ N/m}^2$, beyond this point the material undergoes plastic deformation and will not return to its original shape when the load is removed. The maximum tensile strength is around $3.0 \times 10^8 \text{ N/m}^2$, this is the highest stress the material can manage before the material fails (snaps).

4.4 PVC

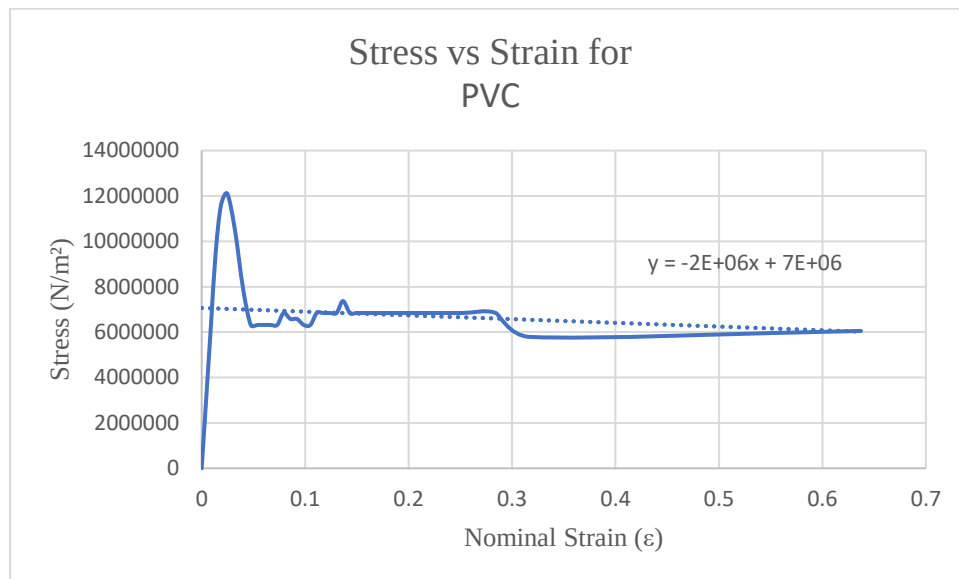


Figure 2 shows Stress and strain of PVC

From figure 2, the steep initial rise in stress indicates the elastic region, where PVC deforms elastically under stress. Stress and strain are proportional here, and the slope in the elastic regions gives the Young's modulus for PVC. From the graph, the negative trendline $y = -2E+06x + 7E+06$ indicates a decline in stress with increasing strain, however this is incorrect this is most likely due to an error when recording the data during the experiment or the material recovery meaning it can partially recover its shape. Yield point, the sharp peak at the start marks the yield point where the PVC transition from elastic to plastic deformation. This occurs at around 12,000,000 N/m² and a strain of around 0.02. beyond this point, PVC undergoes plastic deformation and does not return to its original shape. After the yield point the graph flattens. The PVC enters the plastic region where it stretches significantly under constant stress. This characteristic is normal for thermoplastics. The maximum tensile strength is around 12.0×10^7 N/m², this is the highest stress the material can manage before the material fails (snaps).

4.5 Aluminium

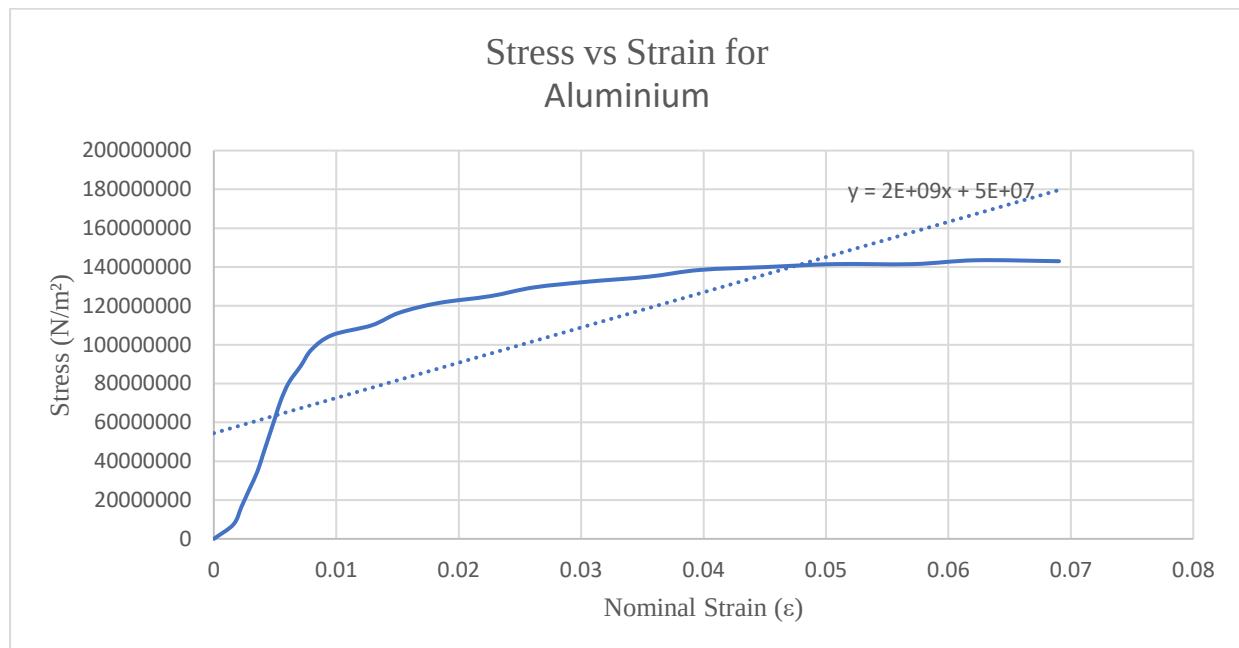


Figure 3 shows Stress and strain of Aluminium

From figure 3, the initial straight portion of the graph represents the elastic region, where stress and strain are proportional. The trendline equation $y = 2E+09x + 5E+07$ suggests that the Young's Modulus is $E = 2 \times 10^9 \text{ Pa}$. The slope is lower than steel which is expected as aluminium is less stiff than steel. The graph begins to deviate from the linearity at around $\epsilon = 0.01$ which indicates the yield point. At this point, the material transitions from elastic behaviour to plastic deformation. The stress at the yield point is around $1.4 \times 10^8 \text{ N/m}^2$. Beyond the yield point, the graph curves and levels off, showing the plastic region. In this region, aluminium undergoes preferment deformation. The maximum tensile strength is around $1.4 \times 10^8 \text{ N/m}^2$, this is the highest stress the material can manage before the material fails (snaps).

4.6 Duralumin

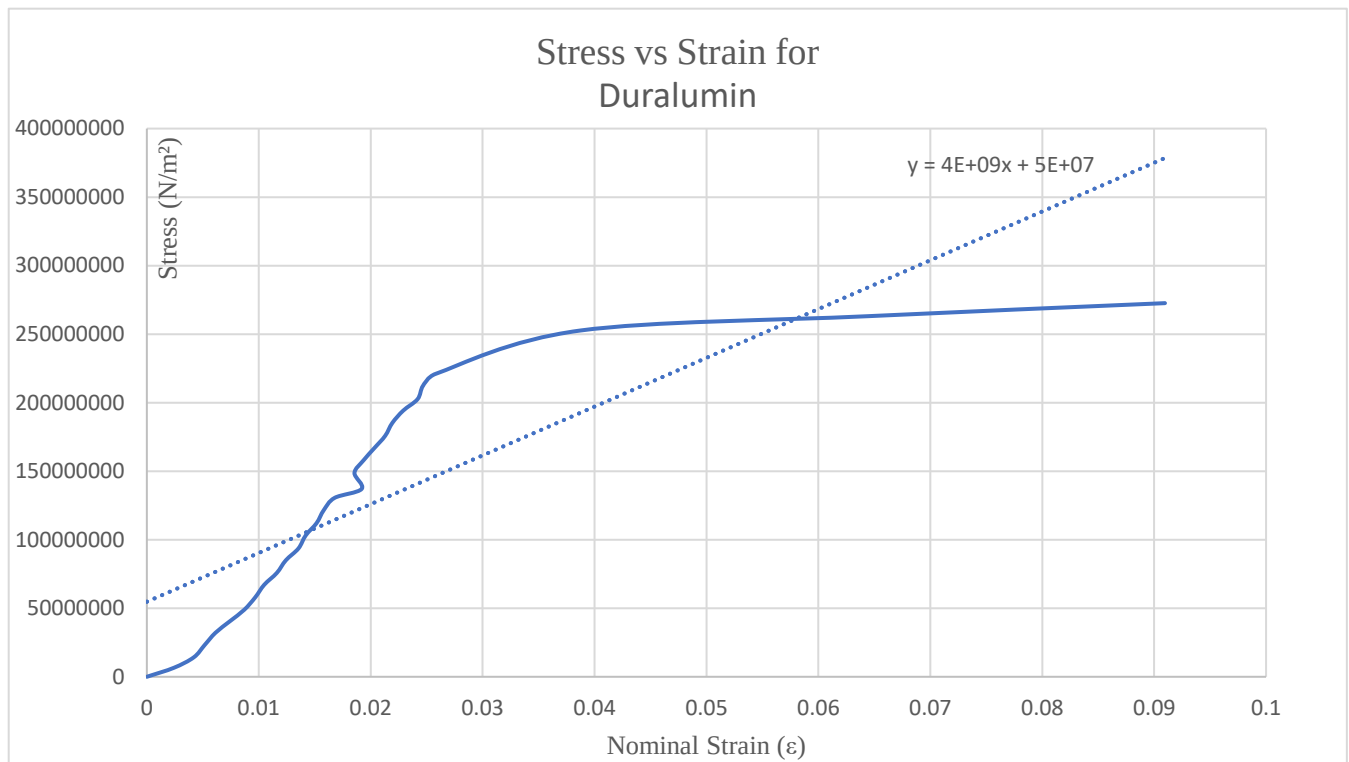


Figure 4 shows Stress and strain of Duralumin

From figure 4, [7] The initial straight portion of the graph represents the elastic behaviour of Duralumin. The trendline equation $y = 4E+09x + 5E+07$ indicates the slope of the elastic region. The Young's modulus is $E = 4 \times 10^9 \text{ Pa}$, this suggests that Duralumin is stiffer than pure Aluminium but less stiff than steel. The graph starts deviating from linearity at around $\epsilon = 0.015$. At this point, the duralumin transitions from elastic to plastic deformation. The yield stress is approximately $2.5 \times 10^8 \text{ N/m}^2$, higher than aluminium. Beyond the yield point the curve flattens, indicating the start of plastic deformation. The maximum tensile strength is around $2.7 \times 10^8 \text{ N/m}^2$, this is the highest stress the material can manage before the material fails (snaps).

5 Conclusion

In conclusion, the tensile test demonstrated essential mechanical properties. Such as stiffness, strength, and ductility, across multiple material including Steel, PVC, Aluminium, and Duralumin. The result demonstrated expected behaviours, such as high stiffness and strength of steel. However, challenges such as measurement inconsistent with PVC, highlight the importance of precise methodologies, such as maintaining a constant force applied on the Load Nut. The Experiment emphasises how important tensile testing is for engineering applications especially in fields like motorsports where material performance under stress is crucial.

6 Evaluation

The tensile testing kit provided valuable insight into the mechanical properties of materials such as Steel, PVC, Aluminium and Duralumin. While the results align with expected material characteristic, there are areas where the test could be improved to enhance accuracy and reliability. One notable issue encountered during the test involved the PVC specimen. As the material exhibits elastic recovery, the dial measurement constantly reversed as the material attempts to return to its original shape. To address the problem, a student was assigned to closely monitor the gauge.

6.1 Further Work

If given unlimited time and money to make the best version of this experiment. several improvements could improve its accuracy, reliability, and consistency.

Replacing the manual turning of the Load Nut with an automated system would provide more precise and consistent applied force. This automaton would eliminate human variability and error, ensuring a uniform loading rate, which is important for obtaining reliable data.

conducting the experiment in a climate-controlled chamber would allow for strict regulation of temperature and humidity. These environmental factors can impact the material behaviour. A controlled environment would ensure that results are reproducible and influenced by external factors. Also using a Digital Dial Indicator instead of an analogue one would improve the accuracy of the measurements. Digital indicators reduce the possibility of human error associated with reading the dial. This would enhance the accuracy and efficiency.

7 Reference

- The Editors of Encyclopaedia Britannica. 2024. *Tensile strength | Definition, Unit, & Facts*. Available at: <https://www.britannica.com/science/tensile-strength>.
- *Guide to Tensile Strength | OneMonroe*. [no date]. Available at: <https://monroeengineering.com/info-general-guide-tensile-strength.php>.
- AZoM. 2020. *Materials Used In Formula One (F1) Cars*. Available at: <https://www.azom.com/article.aspx?ArticleID=8194>.
- Admin. 2023. *From Concept To Track: Chassis Design Engineering In Formula 1*. Available at: <https://motorsportengineer.net/from-concept-to-track-chassis-design-engineering-in-formula-1/>.
- Writer, G.H.-. 2019. *How are composites used in motorsport?* Available at: <https://www.racecar-engineering.com/tech-explained/how-are-composites-used-in-motorsport/>.
- *What Goes Into Racing Engine Design? - Neil Brown Engineering*. [no date]. Available at: <https://nbe.co.uk/news-what-goes-into-racing-engine-design.html#:~:text=That%20is%20why%20all%20race,more%20durable%20and%20extremely%20light>.
- Team, G. 2023. *How Strong is Aluminum? How Does it Compare to Steel?* Available at: <https://www.gabrian.com/how-strong-is-aluminum/>.
- Hickey, K. 2023. *Elastic Modulus*. Available at: [https://ahssinsights.org/forming/mechanical-properties/elastic-modulus/#:~:text=The%20slope%20of%20the%20modulus,Cubic%20\(FCC\)%20atomic%20structure](https://ahssinsights.org/forming/mechanical-properties/elastic-modulus/#:~:text=The%20slope%20of%20the%20modulus,Cubic%20(FCC)%20atomic%20structure).

- AZoM. 2020a. *Aluminium: Specifications, Properties, Classifications and Classes*. Available at:
<https://www.azom.com/article.aspx?ArticleID=2863#:~:text=Mechanical%20Properties%20of%20Aluminium&text=It%20can%20also%20be%20cast,for%20some%20heat%2Dtreatable%20alloys>.
- *PVC Properties - Vinidex Pty Ltd*. 2024. Available at:
[https://www.vinidex.com.au/resources/technical-resources/material-properties/pvc-properties/#:~:text=PVC%2DU%20\(unplasticised\)%20is,is%20resistant%20to%20most%20chemicals](https://www.vinidex.com.au/resources/technical-resources/material-properties/pvc-properties/#:~:text=PVC%2DU%20(unplasticised)%20is,is%20resistant%20to%20most%20chemicals).
- AZoM. 2018. *Duralumin - Chemical Composition, Mechanical Properties and Common Applications*. Available at: <https://www.azom.com/article.aspx?ArticleID=8073>.

7.1 Appendices

Steel					
Load Nut Movement (mm)	Dial Indicator (mm)	Force (N)	Extension	Stress (N/m ²)	Nominal Strain (ε)
0	0	0	0	0	0
0.2	0.095	9.5	0.105	555555.556	0.003409091
0.4	0.26	26	0.14	15204678.36	0.004545455
0.6	0.44	44	0.16	25730994.15	0.005194805
0.8	0.615	61.5	0.185	35964912.28	0.006006494
1	0.79	79	0.21	46198830.41	0.006818182
1.2	0.975	97.5	0.225	57017543.86	0.007305195
1.4	1.15	115	0.25	67251461.99	0.008116883
1.6	1.325	132.5	0.275	77485380.12	0.008928571
1.8	1.5	150	0.3	87719298.25	0.00974026
2	1.68	168	0.32	98245614.04	0.01038961
2.2	1.86	186	0.34	108771929.8	0.011038961
2.4	2.03	203	0.37	118713450.3	0.012012987
2.6	2.215	221.5	0.385	129532163.7	0.0125
2.8	2.39	239	0.41	139766081.9	0.013311688
3	2.565	256.5	0.435	150000000	0.014123377
3.2	2.735	273.5	0.465	159941520.5	0.015097403
3.4	2.9	290	0.5	169590643.3	0.016233766
3.6	3.06	306	0.54	178947368.4	0.017532468
3.8	3.2	320	0.6	187134502.9	0.019480519
4	3.34	334	0.66	195321637.4	0.021428571
4.2	3.46	346	0.74	202339181.3	0.024025974
4.4	3.58	358	0.82	209356725.1	0.026623377
4.6	3.7	370	0.9	216374269	0.029220779
4.8	3.82	382	0.98	223391812.9	0.031818182
5	3.93	393	1.07	229824561.4	0.03474026
6	4.42	442	1.58	258479532.2	0.051298701
7	4.8	480	2.2	280701754.4	0.071428571
8	5.07	507	2.93	296491228.1	0.09512987
9	5.22	522	3.78	305263157.9	0.122727273
10	5.31	531	4.69	310526315.8	0.152272727
20	snap				

PVC					
Load Nut Movement (mm)	Dial Indicator (mm)	Force (N)	Extension	Stress (N/m ²)	Nominal Strain (ε)
0	0	0	0	0	0
0.2	0.06	6	0.14	3157894.737	0.004487179
0.4	0.12	12	0.28	6315789.474	0.008974359
0.6	0.18	18	0.42	9473684.211	0.013461538
0.8	0.22	22	0.58	11578947.37	0.018589744
1	0.23	23	0.77	12105263.16	0.024679487
1.2	0.2	20	1	10526315.79	0.032051282
1.4	0.15	15	1.25	7894736.842	0.040064103
1.6	0.12	12	1.48	6315789.474	0.047435897
1.8	0.12	12	1.68	6315789.474	0.053846154
2	0.12	12	1.88	6315789.474	0.06025641
2.2	0.12	12	2.08	6315789.474	0.066666667
2.4	0.12	12	2.28	6315789.474	0.073076923
2.6	0.13	13	2.47	6842105.263	0.079166667
2.8	0.125	12.5	2.675	6578947.368	0.085737179
3	0.125	12.5	2.875	6578947.368	0.092147436
3.2	0.12	12	3.08	6315789.474	0.098717949
3.4	0.12	12	3.28	6315789.474	0.105128205
3.6	0.13	13	3.47	6842105.263	0.111217949
3.8	0.13	13	3.67	6842105.263	0.117628205
4	0.13	13	3.87	6842105.263	0.124038462
4.2	0.13	13	4.07	6842105.263	0.130448718
4.4	0.14	14	4.26	7368421.053	0.136538462
4.6	0.13	13	4.47	6842105.263	0.143269231
4.8	0.13	13	4.67	6842105.263	0.149679487
5	0.13	13	4.87	6842105.263	0.156089744
6	0.13	13	5.87	6842105.263	0.188141026
7	0.13	13	6.87	6842105.263	0.220192308
8	0.13	13	7.87	6842105.263	0.25224359
9	0.13	13	8.87	6842105.263	0.284294872
10	0.11	11	9.89	5789473.684	0.316987179
20	0.115	11.5	19.885	6052631.579	0.637339744
30	snap				

Aluminium					
Load Nut Movement (mm)	Dial Indicator (mm)	Force (N)	Extension	Stress (N/m ²)	Nominal Strain (ε)
0	0	0	0	0	0
0.2	0.15	15	0.05	7500000	0.001612903
0.4	0.33	33	0.07	16500000	0.002258065
0.6	0.51	51	0.09	25500000	0.002903226
0.8	0.69	69	0.11	34500000	0.003548387
1	0.875	87.5	0.125	43750000	0.004032258
1.2	1.06	106	0.14	53000000	0.004516129
1.4	1.245	124.5	0.155	62250000	0.005
1.6	1.43	143	0.17	71500000	0.005483871
1.8	1.61	161	0.19	80500000	0.006129032
2	1.78	178	0.22	89000000	0.007096774
2.2	1.952	195.2	0.248	97600000	0.008
2.4	2.1	210	0.3	105000000	0.009677419
2.6	2.2	220	0.4	110000000	0.012903226
2.8	2.33	233	0.47	116500000	0.01516129
3	2.43	243	0.57	121500000	0.018387097
3.2	2.5	250	0.7	125000000	0.022580645
3.4	2.59	259	0.81	129500000	0.026129032
3.6	2.65	265	0.95	132500000	0.030645161
3.8	2.7	270	1.1	135000000	0.035483871
4	2.77	277	1.23	138500000	0.039677419
4.2	2.8	280	1.4	140000000	0.04516129
4.4	2.83	283	1.57	141500000	0.050645161
4.6	2.83	283	1.77	141500000	0.057096774
4.8	2.87	287	1.93	143500000	0.062258065
5	2.86	286	2.14	143000000	0.069032258
6	snap				

Duralumin					
Load Nut Movement (mm)	Dial Indicator (mm)	Force (N)	Extension	Stress (N/m ²)	Nominal Strain (ε)
0	0	0	0	0	0
0.2	0.125	12.5	0.075	6578947.368	0.002419355
0.4	0.27	27	0.13	14210526.32	0.004193548
0.6	0.44	44	0.16	23157894.74	0.00516129
0.8	0.61	61	0.19	32105263.16	0.006129032
1	0.77	77	0.23	40526315.79	0.007419355
1.2	0.93	93	0.27	48947368.42	0.008709677
1.4	1.1	110	0.3	57894736.84	0.009677419
1.6	1.275	127.5	0.325	67105263.16	0.010483871
1.8	1.44	144	0.36	75789473.68	0.011612903
2	1.615	161.5	0.385	85000000	0.012419355
2.2	1.78	178	0.42	93684210.53	0.013548387
2.4	1.96	196	0.44	103157894.7	0.014193548
2.6	2.13	213	0.47	112105263.2	0.01516129
2.8	2.31	231	0.49	121578947.4	0.015806452
3	2.48	248	0.52	130526315.8	0.016774194
3.2	2.605	260.5	0.595	137105263.2	0.019193548
3.4	2.825	282.5	0.575	148684210.5	0.018548387
3.6	3	300	0.6	157894736.8	0.019354839
3.8	3.17	317	0.63	166842105.3	0.020322581
4	3.34	334	0.66	175789473.7	0.021290323
4.2	3.52	352	0.68	185263157.9	0.021935484
4.4	3.69	369	0.71	194210526.3	0.022903226
4.6	3.85	385	0.75	202631578.9	0.024193548
4.8	4.035	403.5	0.765	212368421.1	0.024677419
5	4.2	420	0.8	221052631.6	0.025806452
6	4.8	480	1.2	252631578.9	0.038709677
7	5	500	2	263157894.7	0.064516129
8	5.18	518	2.82	272631578.9	0.090967742
9	snap				

