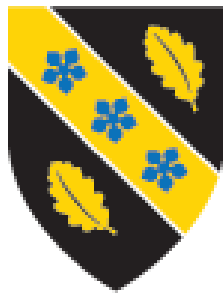


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Tensile Test

Engineering Science (ACHA4002 & ACMA4028)

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Introduction

This report investigates the tensile properties of Steel, Aluminium, Duralumin & PVC through experimental testing to determine their *Tensile stress*, *Yield stress* & *Young's modulus*. The materials were tested in controlled conditions and the Stress vs. Strain data was analysed to identify key properties. The results were compared with accepted values to evaluate and understand the accuracy at which the experiment was conducted at. Discrepancies involving the Young's modulus highlight potential errors involving the calculations and experimental procedure, highlighting areas for significant improvement.

Experimental Procedure

To carry out this procedure, each specimen was secured using two bolts onto the Tensile Testing apparatus as shown in Figure 1. The specimen being tested was then put under tension through a dial on a threaded bar called the 'load nut' which allowed for incremental movement of the plate attached to the specimen itself. To ensure the starting tension was not excessive, a DTI gauge at the lower end of the test rig was observed until the needle moved. This shows that tension has been applied to the specimen. Following this, the load nut was set to the closest mark (10 total), each one representing 0.1mm of movement on the specimen, the DTI was zeroed and the safety guard put in place, as shown in Figure 2.



Figure 1, Testing apparatus – specimen secured.



Figure 2, Testing apparatus – ready for testing.

With the test set up, the load nut was turned from 0mm to 5mm of travel in 0.2mm increments (2 marks) followed by 5mm to 10mm in 1mm increments (10 marks/1 full turn) and finally 10mm to 60mm in 10mm increments (10 full turns).

During the test, the reading on the DTI at each increment of movement had been recorded until the extension at which the specimen yielded. This process was then replicated for each material being tested.

Results (Raw data)

Figure 4, Steel – Raw data

Specimen Material: Steel	
Load Nut Movement (mm)	Dial Indicator (mm)
0.00	0.00
0.20	0.17
0.40	0.36
0.60	0.55
0.80	0.74
1.00	0.93
1.20	1.11
1.40	1.30
1.60	1.49
1.80	1.67
2.00	1.85
2.20	2.03
2.40	2.22
2.60	2.40
2.80	2.57
3.00	2.73
3.20	2.90
3.40	3.05
3.60	3.28
3.80	3.29
4.00	3.42
4.20	3.54
4.40	3.67
4.60	3.78
4.80	3.88
5.00	3.99
6.00	4.48
7.00	4.80
8.00	5.04
9.00	5.20
10.00	5.28

Original Length (mm): 31

Original Cross-sectional area (mm²): 1.818

New Length (mm): 39.1

Figure 3, Aluminium – Raw data

Specimen Material: Aluminium	
Load Nut Movement (mm)	Dial Indicator (mm)
0.00	0.00
0.20	0.07
0.40	0.24
0.60	0.42
0.80	0.61
1.00	0.79
1.20	0.96
1.40	1.15
1.60	1.32
1.80	1.50
2.00	1.66
2.20	1.78
2.40	1.89
2.60	2.02
2.80	2.13
3.00	2.27
3.20	2.33
3.40	2.44
3.60	2.49
3.80	2.59
4.00	2.62
4.20	2.71
4.40	2.74
4.60	2.76
4.80	2.79
5.00	2.82

Original Length (mm): 31

Original Cross-sectional area (mm²): 1.824

New Length (mm): 33.95

Figure 5, Duralumin – Raw data

Specimen Material: Duralumin

Load Nut Movement (mm)	Dial Indicator (mm)
0.00	0.00
0.20	0.13
0.40	0.29
0.60	0.46
0.80	0.64
1.00	0.81
1.20	0.98
1.40	1.16
1.60	1.34
1.80	1.52
2.00	1.69
2.20	1.87
2.40	2.05
2.60	2.24
2.80	2.41
3.00	2.59
3.20	2.77
3.40	2.94
3.60	3.12
3.80	3.30
4.00	3.48
4.20	3.65
4.40	3.83
4.60	4.01
4.80	4.18
5.00	4.35
6.00	5.02
7.00	5.37

Original Length (mm): 31

Original Cross-sectional area (mm²): 1.8914

New Length (mm): 33.5

Figure 6, PVC - Raw data

Specimen Material: PVC

Load Nut Movement (mm)	Dial Indicator (mm)
0.00	0.00
0.20	0.05
0.40	0.11
0.60	0.16
0.80	0.19
1.00	0.21
1.20	0.06
1.40	0.09
1.60	0.10
1.80	0.09
2.00	0.09
2.20	0.09
2.40	0.09
2.60	0.09
2.80	0.09
3.00	0.10
3.20	0.10
3.40	0.10
3.60	0.10
3.80	0.09
4.00	0.09
4.20	0.09
4.40	0.10
4.60	0.09
4.80	0.08
5.00	0.09
6.00	0.09
7.00	0.08
8.00	0.03
9.00	0.05
10.00	0.08
20.00	0.04
30.00	0.05
40.00	0.05

Original Length (mm): 31.2

Original Cross-sectional area (mm²): 1.9602

New Length (mm): 69.51

Analysis

Figure 7, Steel – Processed data

Load Nut Mov. (mm)	Dial Indicator (mm)	Force (N)	Extension (mm)	Stress σ (N/m ²)	Strain ϵ
0.00	0.00	0.00	0.00	0	0.00
0.20	0.17	17	0.03	9350935.094	0.000968
0.40	0.36	36	0.04	19801980.2	0.00129
0.60	0.55	55	0.05	30253025.3	0.001613
0.80	0.74	74	0.06	40704070.41	0.001935
1.00	0.93	93	0.07	51155115.51	0.002258
1.20	1.11	111	0.09	61056105.61	0.002903
1.40	1.30	130	0.1	71507150.72	0.003226
1.60	1.49	149	0.11	81958195.82	0.003548
1.80	1.67	167	0.13	91859185.92	0.004194
2.00	1.85	185	0.15	101760176	0.004839
2.20	2.03	203	0.17	111661166.1	0.005484
2.40	2.22	222	0.18	122112211.2	0.005806
2.60	2.40	240	0.2	132013201.3	0.006452
2.80	2.57	257	0.23	141364136.4	0.007419
3.00	2.73	273	0.27	150165016.5	0.00871
3.20	2.90	290	0.3	159515951.6	0.009677
3.40	3.05	305	0.35	167766776.7	0.01129
3.60	3.28	328	0.32	180418041.8	0.010323
3.80	3.29	329	0.51	180968096.8	0.016452
4.00	3.42	342	0.58	188118811.9	0.01871
4.20	3.54	354	0.66	194719471.9	0.02129
4.40	3.67	367	0.73	201870187	0.023548
4.60	3.78	378	0.82	207920792.1	0.026452
4.80	3.88	388	0.92	213421342.1	0.029677
5.00	3.99	399	1.01	219471947.2	0.032581
6.00	4.48	448	1.52	246424642.5	0.049032
7.00	4.80	480	2.2	264026402.6	0.070968
8.00	5.04	504	2.96	277227722.8	0.095484
9.00	5.20	520	3.8	286028602.9	0.122581
10.00	5.28	528	4.72	290429042.9	0.152258

Figure 9, Stress vs. Strain of Steel

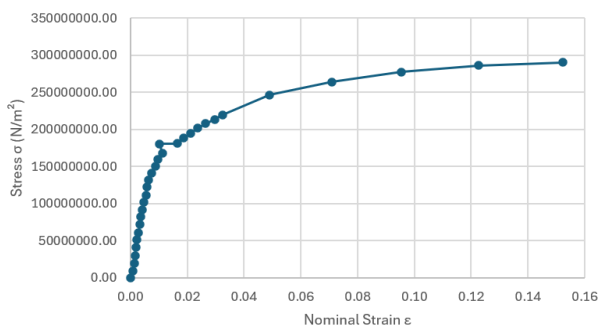


Figure 8, Stress vs. Strain of Steel - Elastic region

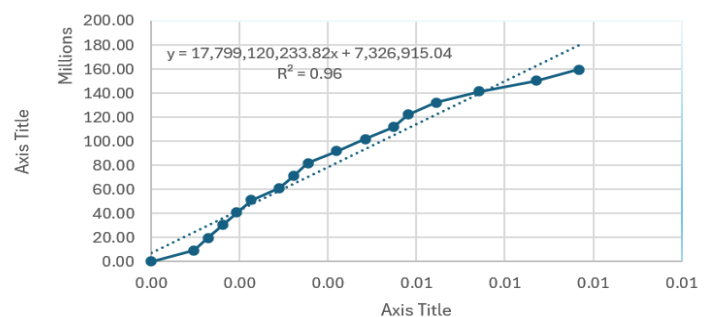


Figure 7 shows the processed data for the specimen. This includes Force measured in Newtons, Extension in relation to the Load Nut movement in mm, Stress measured in N/m^2 and Nominal Strain.

Figure 8 shows the graphing of the data, displaying both the elastic and plastic stages of the specimen. This also displays the yield point, which is where the materials stress vs strain deviated from a linear path and began to deform permanently. The last recorded point of data is the point at which the specimen failed and snapped.

Figure 9 is an isolated graph of the elastic stage, therefore yield point also, of the specimen which allows the calculation of gradient which is equal to the Young's modulus of the material. This graph also shows the R^2 value which represents how linear the line of best fit is in relation to the data points, 1.00 being perfectly linear.

Figure 10, Aluminium - Processed data

Load Nut Mov. (mm)	Dial Indicator (mm)	Force (N)	Extension (mm)	Stress σ (N/m^2)	Strain ϵ
0.00	0.00	0.00	0.00	0	0.00
0.20	0.07	7	0.13	3837719.298	0.00419
0.40	0.24	24	0.16	13157894.74	0.00516
0.60	0.42	42	0.18	23026315.79	0.00581
0.80	0.61	61	0.19	33442982.46	0.00613
1.00	0.79	79	0.21	43311403.51	0.00677
1.20	0.96	96	0.24	52631578.95	0.00774
1.40	1.15	115	0.25	63048245.61	0.00806
1.60	1.32	132	0.28	72368421.05	0.00903
1.80	1.50	150	0.3	82236842.11	0.00968
2.00	1.66	166	0.34	91008771.93	0.01097
2.20	1.78	178	0.42	97587719.3	0.01355
2.40	1.89	189	0.51	103618421.1	0.01645
2.60	2.02	202	0.58	110745614	0.01871
2.80	2.13	213	0.67	116776315.8	0.02161
3.00	2.27	227	0.73	124451754.4	0.02355
3.20	2.33	233	0.87	127741228.1	0.02806
3.40	2.44	244	0.96	133771929.8	0.03097
3.60	2.49	249	1.11	136513157.9	0.03581
3.80	2.59	259	1.21	141995614	0.03903
4.00	2.62	262	1.38	143640350.9	0.04452
4.20	2.71	271	1.49	148574561.4	0.04806
4.40	2.74	274	1.66	150219298.2	0.05355
4.60	2.76	276	1.84	151315789.5	0.05935
4.80	2.79	279	2.01	152960526.3	0.06484
5.00	2.82	282	2.18	154605263.2	0.07032

Figure 11, Stress vs. Strain of Aluminium

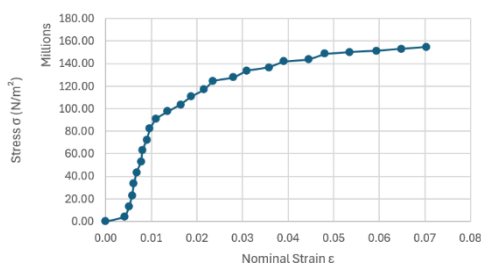


Figure 12, Stress vs. Strain of Aluminium - Elastic region

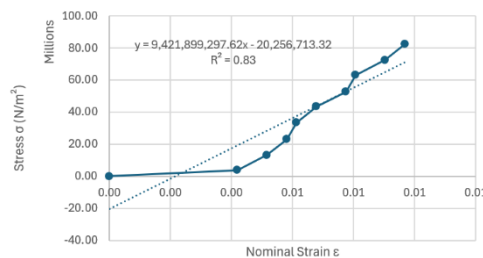


Figure 13, Stress vs. Strain of Aluminium - Elastic region (0,0 removed)

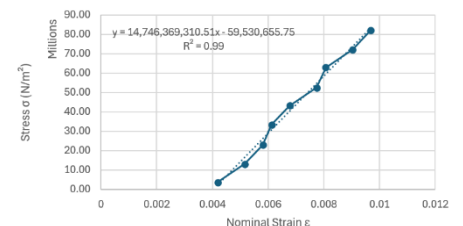


Figure 13 displays the elastic region of Aluminium with the (0,0) data point removed. This is to improve the line of best fit, therefore improving the accuracy of the Young's Modulus. This is well shown as the R^2 value from Figure 12 equals 0.83 whereas Figure 13 shows 0.99, meaning that the line of best fit displayed in Figure 13 is nearly perfectly linear.

Figure 14, Duralumin – Processed data

Load Nut Mov. (mm)	Dial Indicator (mm)	Force (N)	Extension (mm)	Stress σ (N/m ²)	Strain ϵ
0.00	0.00	0	0.00	0	0
0.20	0.13	13	0.07	6873215.607	0.002258
0.40	0.29	29	0.11	15332557.89	0.003548
0.60	0.46	46	0.14	24320609.07	0.004516
0.80	0.64	64	0.16	33837369.14	0.005161
1.00	0.81	81	0.19	42825420.32	0.006129
1.20	0.98	98	0.22	51813471.5	0.007097
1.40	1.16	116	0.24	61330231.57	0.007742
1.60	1.34	134	0.26	70846991.65	0.008387
1.80	1.52	152	0.28	80363751.72	0.009032
2.00	1.69	169	0.31	89351802.9	0.01
2.20	1.87	187	0.33	98868562.97	0.010645
2.40	2.05	205	0.35	108385323	0.01129
2.60	2.24	224	0.36	118430792	0.011613
2.80	2.41	241	0.39	127418843.2	0.012581
3.00	2.59	259	0.41	136935603.3	0.013226
3.20	2.77	277	0.43	146452363.3	0.013871
3.40	2.94	294	0.46	155440414.5	0.014839
3.60	3.12	312	0.48	164957174.6	0.015484
3.80	3.30	330	0.50	174473934.7	0.016129
4.00	3.48	348	0.52	183990694.7	0.016774
4.20	3.65	365	0.55	192978745.9	0.017742
4.40	3.83	383	0.57	202495506	0.018387
4.60	4.01	401	0.59	212012266	0.019032
4.80	4.18	418	0.62	221000317.2	0.02
5.00	4.35	435	0.65	229988368.4	0.020968
6.00	5.02	502	0.98	265411864.2	0.031613
7.00	5.37	537	1.63	283916675.5	0.052581

Figure 15, Stress vs. Strain of Duralumin

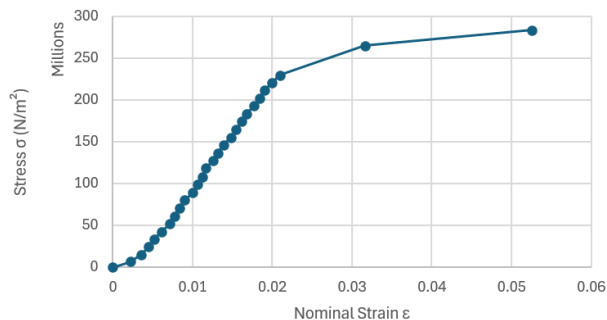


Figure 16, Stress vs. Strain of Duralumin - Elastic region

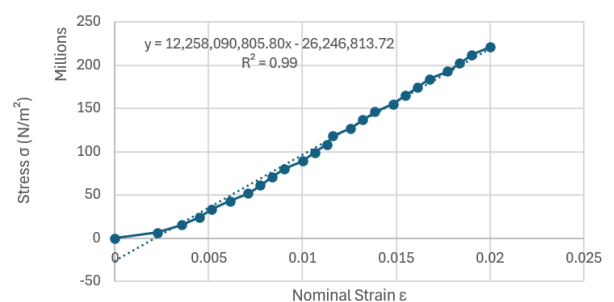


Figure 17, PVC – Processed data

Load Nut Mov. (mm)	Dial Indicator (mm)	Force (N)	Extension (mm)	Stress σ (N/m ²)	Strain ϵ
0.00	0.00	0.00	0.00	0	0
0.20	0.05	5.00	0.15	2550760.127	0.004808
0.40	0.11	11.00	0.29	5611672.278	0.009295
0.60	0.16	16.00	0.44	8162432.405	0.014103
0.80	0.19	19.00	0.61	9692888.481	0.019551
1.00	0.21	21.00	0.79	10713192.53	0.025321
1.20	0.06	6.00	1.14	3060912.152	0.036538
1.40	0.09	9.00	1.31	4591368.228	0.041987
1.60	0.10	10.00	1.50	5101520.253	0.048077
1.80	0.09	9.00	1.71	4591368.228	0.054808
2.00	0.09	9.00	1.91	4591368.228	0.061218
2.20	0.09	9.00	2.11	4591368.228	0.067628
2.40	0.09	9.00	2.31	4591368.228	0.074038
2.60	0.09	9.00	2.51	4591368.228	0.080449
2.80	0.09	9.00	2.71	4591368.228	0.086859
3.00	0.10	10.00	2.90	5101520.253	0.092949
3.20	0.10	10.00	3.10	5101520.253	0.099359
3.40	0.10	10.00	3.30	5101520.253	0.105769
3.60	0.10	10.00	3.50	5101520.253	0.112179
3.80	0.09	9.00	3.71	4591368.228	0.11891
4.00	0.09	9.00	3.91	4591368.228	0.125321
4.20	0.09	9.00	4.11	4591368.228	0.131731
4.40	0.10	10.00	4.30	5101520.253	0.137821
4.60	0.09	9.00	4.51	4591368.228	0.144551
4.80	0.08	8.00	4.72	4081216.202	0.151282
5.00	0.09	9.00	4.91	4591368.228	0.157372
6.00	0.09	9.00	5.91	4591368.228	0.189423
7.00	0.08	8.00	6.92	4081216.202	0.221795
8.00	0.03	3.00	7.97	1530456.076	0.255449
9.00	0.05	5.00	8.95	2550760.127	0.286859
10.00	0.08	8.00	9.92	4081216.202	0.317949
20.00	0.04	4.00	19.96	2040608.101	0.639744
30.00	0.05	5.00	29.95	2550760.127	0.959936
40.00	0.05	5.00	39.95	2550760.127	1.280449

Figure 19, Stress vs. Strain of PVC

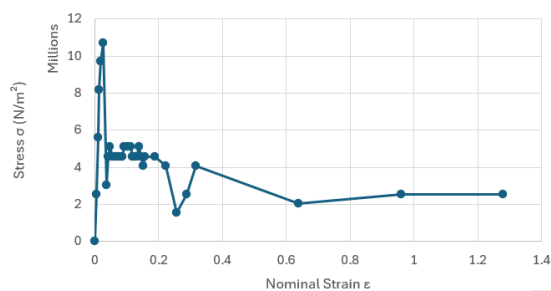
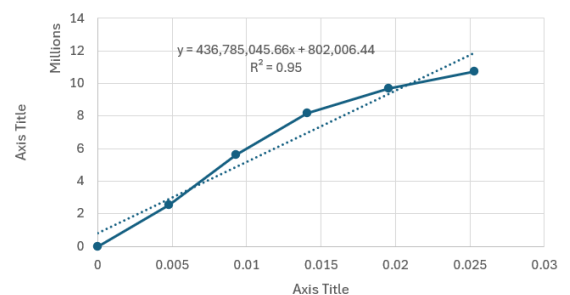


Figure 18, Stress vs. Strain of PVC - Elastic region



Conclusion

Steel

Using external sources, the common Tensile stress & Yield stress steel vary between 300-500MPa (300-500million N/m²) Tensile stress and 200-300MPa (200-300million N/m²) Yield stress. (Callister, 2007) Compared to the results from the experiment which were approximately 295,000,000N/m² and 250,000,000N/m² respectively. These values are reasonably comparable, outlining a positive result from the test. The common values found through research for the Young's modulus of steel were between 157-217GPa (157-217billion N/m²) (Gandhi, 2012) whereas the calculated value from the investigation carried out was approximately 17.9billion N/m². This value is not comparable to that gathered from research. This could be for multiple reasons, one of which being measurement errors of materials impurities.

Aluminium

Through research on the topic, the values understood for aluminium are accepted to be 80-240MPa (80-240million N/m²) Tensile stress and 30-200MPa (30-200million N/m²) Yield stress, depending on the alloy of aluminium. (Sobotka & Salfironk, 2020). When comparing these values to those calculated, approximately 155,000,000N/m² and 82,000,000N/m², the results appear to be very reasonable and align with the ranges found through research. The Young's Modulus calculated from the test for aluminium was 14.7billion N/m² which relates very poorly to the taken values of 65-70GPa (65-70billion N/m²) which suggests there is potential flaws throughout the test or perhaps during calculation. As these values do not align, but the Tensile stress & Yield stress do, it is probable that the cause of this issue will have been made through the processing of data and/or the calculating of the Young's modulus.

Duralumin

A common range for duralumin when looking at stress are between 450-480MPa (450-480million N/m²) Tensile and 300-345MPa (300-345million N/m²) Yield. (Manoj, 2024) In comparison to the calculated values from the data collected, these ranges are reasonable and align well with the collected data as follows: Tensile stress of 284,000,000N/m² and Yield stress of 230,000,000N/m². Research suggests that this comparison is reasonable for Duralumin, more specifically the '2024 alloy'. (Material-properties.org, 2024). The data after processing resulted in a Young's modulus value of 12.24billion N/m². This is deemed not reasonable once again as the accepted values range from 69-71GPa (69-71billion N/m²). Following previous materials, this is likely due to an error during calculations as the stress values are within widely accepted ranges.

PVC

The Tensile and Yield stress for PVC is much more difficult to measure as the elastic region is much smaller than the other materials used in this experiment. The values found through research are: Tensile stress 40-55MPa (40-55million N/m²) & Yield stress 40-50MPa (40-50million N/m²) (Fischer, 2012). Comparatively, the calculated values from the experiment were approximately 10,700,000 N/m² for both Tensile and Yield stress. These values seem to align rather poorly, suggesting that issues were present. This issue could be due to reading error, material imperfections or errors during specimen measurement. An acceptable range for the Young's modulus of PVC is 2.1-2.7GPa (2.1-2.7billion N/m²) (Cardarelli, 2018) which, as seen in the other materials, differs greatly from the recorded results; 437,000,000N/m².

Deviation in Young's Modulus

For all four of the materials tested, the Young's modulus values are not comparable to values found throughout the research done on this topic. This could be for several reasons, with the most likely being errors made while calculating. Other possible causes to this consist of human error while carrying out the experiment, incorrect specimen measurements and possibly faulty equipment. However it is more than likely that the error is present in the calculation for Young's modulus, this is because for all four specimen both the Tensile stress and Yield stress values are well within acceptable limits meaning that it is very unlikely that any major errors will have been present to offset the Young's modulus data so dramatically.

Evaluation

To reduce the chance of error during the experiment, there were many precautions taken place. One of which was making sure that the specimen was under tension before any measured turns of the load nut took place. This was to ensure that first turn(s) were accurate and not false readings; as if there was no tension prior to the turns, the DTI readings would not have been accurate.

Another procedure that was implemented to reduce the chance or error was measuring the cross-sectional area on all four specimen, even while provisional measurements were provided. This was done to ensure that the values used when calculating were correct and not causing false end values. If the true cross-sectional area was much smaller than the estimated values given, the results would be much smaller and vice versa.

Additionally, an effective method of measuring the fracture point of the specimen is by capturing the test thorough a high framerate recording device. This will allow the experiment to be replayed and reviewed for a much more accurate understanding for under which tension the specimen fractured.

Further Work

Provided no restrictions on time and resources, this experiment could be much more accurate. A large way that accuracy was being lost was the speed at which the DTI had to be recorded by the human eye. For this to be replaced with a video device recording said DTI and/or a digital DTI gauge would improve the accuracy drastically, particularly on the test using the PVC specimen. Another flaw in the method used was the speed at which the load nut was being turned. As this was done manually, the rate at which the force was being applied, especially for the longer 10.0mm turns, was not very repeatable and smooth which could cause inaccurate readings when looking at yield points or fractures. This could be solved using a motor to apply the load nut as this would ensure a constant and adjustable rate.

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