SCHOOL OF ENGINEERING
TAYLOR'S UNIVERSITY

ENG60503
PROPERTIES AND APPLICATIONS OF MATERIALS

Tensile Test Experiment
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Table of Content

Date of Experiment:	
Report due date:	
Report submission date:	
Checked by:	
Item/marks	
Format/10	
Abstract and Introduction/10	
Figures and Diagrams/15	
Materials and Method/10	
Results Discussions/45	
References/10	
Total	

Abstract

The objective of this experiment is to obtain and study the stress-strain curve and the tensile strength of various materials. A universal testing machine is used in this experiment along with specimens made from copper, brass, steel and aluminium that are made specifically for the testing machine. Initial length of the specimens were recorded and the specimens were then placed into the universal testing machine for tensile test. The data obtained from the experiment was recorded by the software for the universal testing machine. The specimen was placed under tensile stress until the specimen breaks. The elongation and forces applied to the specimen were recorded by the software while the diameter of the specimen at the breaking point was recorded. Based on the data received, steel has the highest yield strength followed by brass , copper and aluminium having the lowest yield strength. This is due to the difference between the ductility of metals. It is observed that higher yield strength metals have lower necking effects.

1.0 Introduction

Tensile tests [1] are the fundamental experiment carried out in material science and engineering fields. This test subjects a specimen to a controlled tension until failure of the material is met. Tensile testing is used to predict the characteristic of the material under normal and extreme forces. It is also used as a proof of concept during development of products. Tensile testing measures the ultimate tensile strength, breaking strength, maximum elongation and reduction in area. We are able to determine the Young's modulus, yield strength and strain-handling characteristics of the material under testing.

Young's modulus [2] is the relation of stress and strain. It is used to describe the elastic properties of the material under tension or compression loads. The equation for Young's Modulus equates to tensile stress divided by the extension stress of the specimen:

$$\text{Young modulus, } E = \frac{stress}{strain}$$

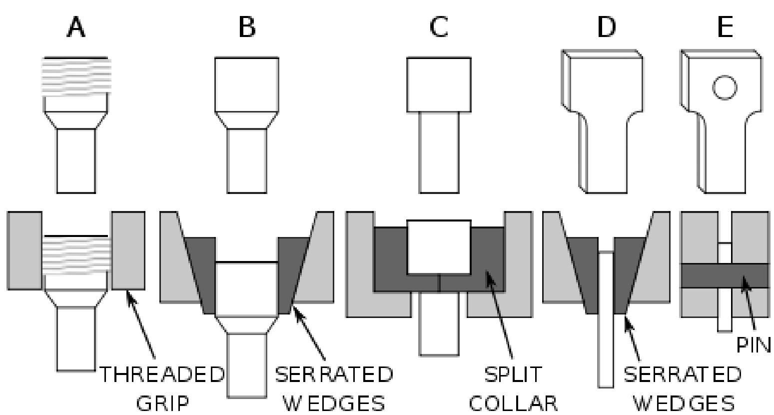
Where stress of the specimen can be calculated using the equation

$$\text{Stress, } \sigma = \frac{Force\ applied\ to\ specimen}{Cross\ Sectional\ Area\ of\ specimen}$$

While the strain of the specimen can be calculated using the equation

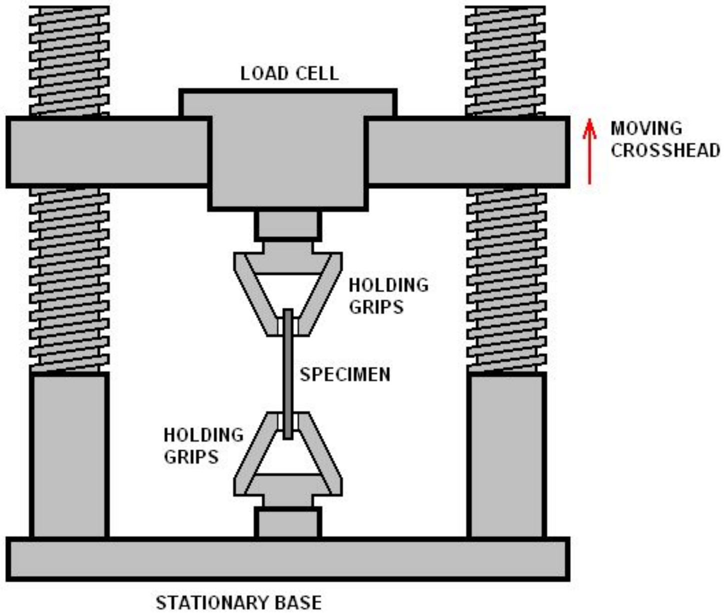
$$\text{Strain,} \varepsilon = \frac{Extension\ of\ the\ Specimen}{Initial\ Length\ of\ the\ Specimen}$$

The specimens used in tensile testing have been produced and prepared according to the type of machine used. Specimens usually have a standardized sample cross-section and have two shoulders to be held by the tensile testing machine and a gage section [3].



[4] Picture showing various styles of Tensile Specimens

Specimens are commonly tested inside a universal testing machine. The universal testing machine is able to accurately measure the force applied and the elongation of the specimen accurately using various electronic sensors connected throughout the testing machine. The data is then shown to the user via software.



[5] Diagram showing the Mechanics of a Universal Testing Machine

2.0 Experimental Design

2.1 Apparatus

Figure 1 : Instron Universal Testing Machine

Figure 2 : Digital Vernier Caliper and 4 testing samples (Copper, Brass, Steel, Aluminium) used in experiment

2.2 Objectives

The main objective of the tensile strength experiment is to obtain and study the stress-strain curve and the tensile strength for the testing samples which are copper, brass, steel, and aluminium.

2.3 Experimental Procedures

1) The vernier caliper was used to measure the initial length and diameter of the sample.
2) The mounting points on the Instron Universal Testing Machine were adjusted accordingly.
3) The sample was securely mounted to the mounting point of the machine.
4) The machine was started and force was gradually applied to the sample.
5) The breakage length and diameter of the sample was measured using the vernier caliper and recorded.
6) Step 1 to 5 were repeated for the other 3 samples.
7) The results and graph were obtain and analyzed to determine the maximum load before breakage and it is later used to determine the Young's modulus of the sample.

2.4 Experimental Methods

All initial diameter and length 4 testing samples (Copper, Brass, Aluminium, Steel) were measured and recorded. One sample was then placed on the mounting point of the Instron Universal testing machine and was adjusted accordingly until the testing sample secure on the mounting point. The samples were not overly tighten to avoid any stress applied before the experiment begin which will provide inaccurate results. The machine was then started and force was gradually applied to the sample. The samples were closely observed to assure if any necking happen during the period where force was applied. The sample eventually broke and the machine stopped. The same steps were repeated to all testing samples and all the related results and graph were recorded and analyzed to calculate and plot the strain and stress of the materials.

3.0 Experimental Results and Discussion

3.1 Tabulation of Data

Materials	Initial Length (mm)	Initial Diameter (mm)	Final Length (mm)	Final Diameter (mm)
Copper	40.15	6.00	46.76	2.37
Steel	40.07	6.00	43.26	4.76
Brass	40.09	6.00	46.47	5.04
Aluminium	40.10	6.00	45.67	4.58

Table 3.1.1 Initial and Final dimension of material

Specimen label	Load at Tensile strength (N)	Extension at Tensile strength (mm)	Load at Break (Standard) (N)	Extension at Break (Standard) (mm)
Steel	20901.96348	7.8478	15753.95312	10.38679
Brass	14271.43155	11.84483	13426.10742	12.94494
Aluminium	8695.41182	9.69567	6850.09521	11.54046
Copper	9390.43225	7.10779	326.75815	15.68200

Table 3.1.2 Result taken from Instron

Copper			
Extension (mm)	**Force (N)**	**Stress (MPa)**	**Strain**
0	3.03422	0.107	0
0.5	318.13815	11.254	0.012
1	318.25	11.258	0.025
1.5	318.180	11.255	0.037
2	318.177	11.255	0.050
2.5	318.241	11.257	0.062
3	318.964	11.288	0.075
3.5	334.946	11.848	0.087
4	334.895	11.846	0.100
4.5	334.942	11.848	0.112
5	334.777	11.842	0.125
5.5	334.842	11.844	0.137
6	335.687	11.874	0.150
6.5	1806.634	63.906	0.162
7	9383.987	331.942	0.174
7.11	9390.509	332.172	0.177
7.5	9275.092	328.090	0.187
8	9181.157	324.757	0.199

Table 3.1.3 Stress-strain result for copper

Aluminium			
Extension (mm)	**Force (N)**	**Stress (MPa)**	**Strain**
0	0.374	0.013	0
1	4.114	0.146	0.025
2	4.071	0.144	0.050
3	4.426	0.157	0.075
4	20.362	0.720	0.100
5	20.458	0.724	0.125
6	21.109	0.747	0.150
7	7977.832	282.201	0.175
8	8375.883	296.282	0.200
9	8621.575	304.973	0.224
9.69	8695.600	307.591	0.242
10	8687.561	307.307	0.249
11	7975.065	282.103	0.275
11.54	4153.920	146.937	0.288

Table 3.1.4 Stress-strain result for Aluminium

Brass			
Extension (mm)	**Force (N)**	**Stress (MPa)**	**Strain**
0	0.621	0.022	0
1	96.940	3.429	0.025
2	97.104	3.435	0.050
3	98.539	3.450	0.075
4	113.504	4.015	0.100
5	113.608	4.019	0.125
6	114.229	4.041	0.150
7	10899.069	385.557	0.175
8	13098.287	463.328	0.200
9	13721.979	485.390	0.225
10	14067.980	497.630	0.250
11	14270.500	504.793	0.274
11.8	14271.388	504.824	0.295
12	14256.945	504.314	0.300
12.95	7891.662	279.153	0.323

Table 3.1.5 Stress-strain result for brass

Steel			
Extension (mm)	**Force (N)**	**Stress (MPa)**	**Strain**
0	1.098	0.039	0
1	2442.926	86.414	0.025
2	2442.727	86.407	0.050
3	2443.289	86.427	0.075
4	2459.359	86.995	0.100
5	2459.202	86.990	0.125
6	2459.719	87.008	0.150
7	14886.339	526.577	0.175
7.84	20902.240	739.379	0.196
8	20898.223	739.237	0.200
9	19863.664	702.641	0.225
10	17251.533	610.242	0.250
10.39	9518.704	366.707	0.259

Table 3.1.6 Stress-strain result for steel

Calculation Sample

Area of copper = πr^2

= π x (6 x 6)mm

28.27mm ^{2}

Stress of copper at 1 mm extension = Force / Area

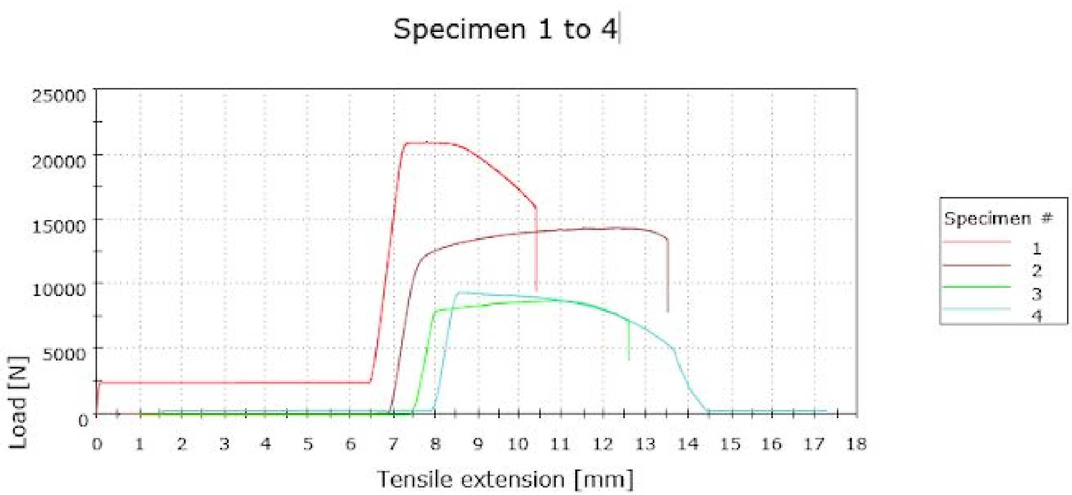
= 318.25 / 28.27

= 11.258 MPa

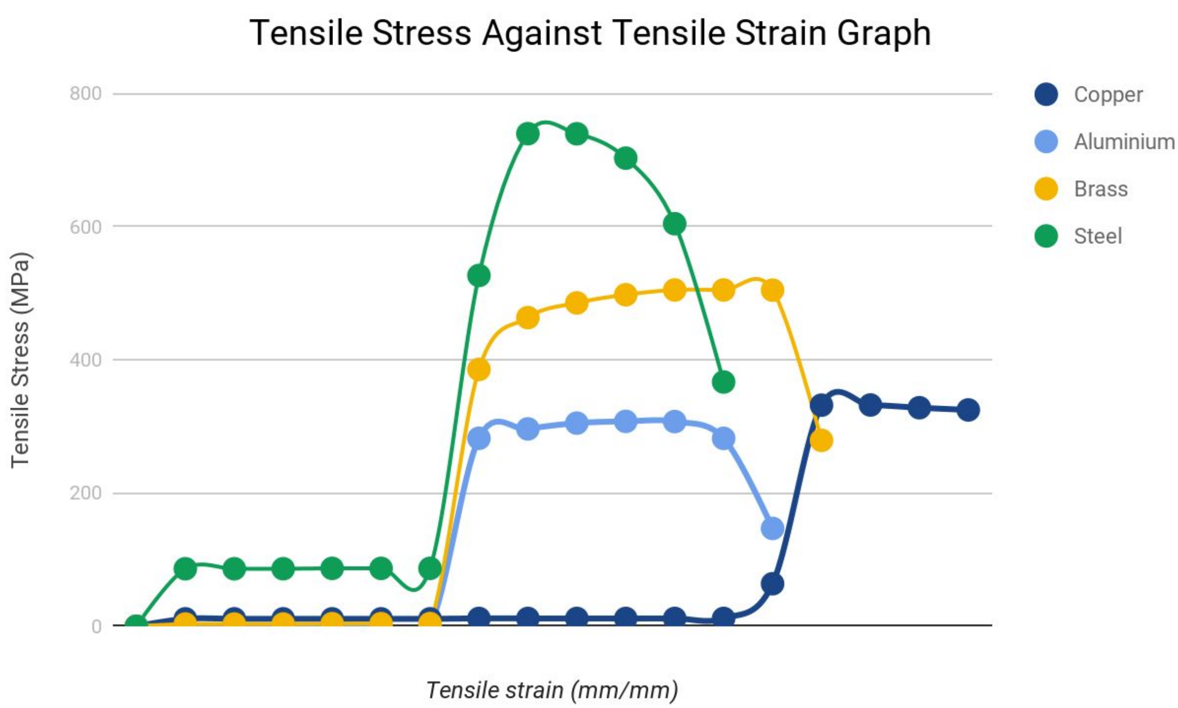
Strain of copper at 1 mm extension = Extension / Initial length

= 1 / 40.15
=0.0249

3.2 Graphs



Graph 1. Load against tensile extension



Material	Yield Strength(MPa)
Copper	332.172
Steel	739.379
Brass	504.824
Aluminium	307.591

Table 3.1.7 Yield strength of material

Material	Young's Modulus (MPa)
Copper	13336.16
Steel	17582.76
Brass	15260.64
Aluminium	11258.16

Table 3.1.8 Young's Modulus of material

Material	Fracture strength (MPa)
Copper	177.07
Steel	593.19
Brass	486.69
Aluminium	265.59

Table 3.1.9 Fracture strength of material

Material	% Elongation	% Reduction in area
Copper	14.13	60.5
Steel	7.37	20.6
Brass	13.7	16
Aluminium	12.2	23.7

Table 3.1.10 Percentage of Elongation and Reduction in area of material

3.2 Discussion

According to table Table 3.1.7, steel has the highest yield strength which is 739.379 MPa among the four samples, continued by brass which is 504.824 MPa and copper which is 332.172 Mpa while Aluminium has the lowest yield strength which is 307.591 MPa.

Next, based on the table 3.1.8, the modulus of elasticity which also known as Young's modulus is displayed based on the stress-strain graph, the formula for Young's modulus is:

$$\text{Young modulus, } E = \frac{stress}{strain}$$

$$\text{Stress, } \sigma = \frac{Force}{Area}$$

$$\text{Strain, } \varepsilon = \frac{Extension}{original\ length}$$

Young's modulus is defined as the tendency of a material to resist elastic deformation. A higher Young's modulus which gives a high stiffness of material that will make the material more brittle and hence the sample will deform easily when load is applied on it. Besides, when the material is ductile which means it is more flexible and stretchable will elongate when the force is applied. Based on table 3.1.8, aluminium has the lowest young's modulus while steel has the highest young's modulus. Error occured will be explained in the error analysis, due to copper has the longest final length which means it is more flexible and elongate more when force is exerted.

Fracture strength is defined as the stress that is applied when the material fractures or breaks when force applied on it. The stress equation from the above can be used to calculate the fracture strength for each examples. Based on table 3.1.9, it can be clearly seen that copper has the lowest fracture strength which is 177.07 MPa due to its ductile nature. The area under the stress strain graph is the energy absorbed by the materials before it fractures is called tensile strength. Therefore in this experiment steel has the highest tensile strength which is 593.19 MPa compared to the other three samples due to higher magnitude of stress that can be hold before fracture occurs.

In order to measure the ductility of the samples, there are two equations that is needed to be introduced.

$$\%\text{Elongation} = \frac{l_f - l_o}{l_o} \text{x}100$$

$$\%\ \text{Reduction in area} = \frac{A_o - A_f}{A_o}\ \text{x}\ 100$$

The characteristic for a ductile material based on the equation that is introduced from the above should have a high percentage for both elongation and reduction in area. In contrast, for a more brittle material, the percentage for both elongation and reduction in area should be lower due to less occurrence of stretching and necking inside the material and hence a less deformation is take place. On table 3.1.10, we can conclude that copper has a percentage of 14.13% for the percentage of elongation and 60.5% for the percentage of reduction in area which show that copper is the most ductile among the 4 samples. The nature for steel should be brittle due to lowest percentage for elongation and reduction in area according from the data on the above.

4.0 Error Analysis

Based on the tables and the graphs that is plotted from the above, it can be clearly seen that, the experimental results has a similar trend compare to the theoretical results. Steel is the most brittle while copper is the ductile among the four samples which are steel, aluminum and brass.

During this experiment, several errors that have been made which gives an inaccurate results. First of all, a table of percentage of elongation and reduction area is recorded by using the initial length, final length and diameter of the four samples with help of vernier calliper (figure ?). Human error occurs when we take down the readings. The reading taken down might be slightly more or less than the original reading due to parallax error. Besides, error also occurs when we placed the four samples into the Instron Universal Testing Machine 5969. The sample should we placed precisely and equally spaced between the upper and lower gripper hence the accuracy will be improved. Last but not least, after we placed the samples onto the gripper (Figure 4), the crosshead is lowered down until it reach the surface of the samples, but during this experiment, lowering the crosshead too much will give an extra force on the sample which therefore affects the accuracy if the results.

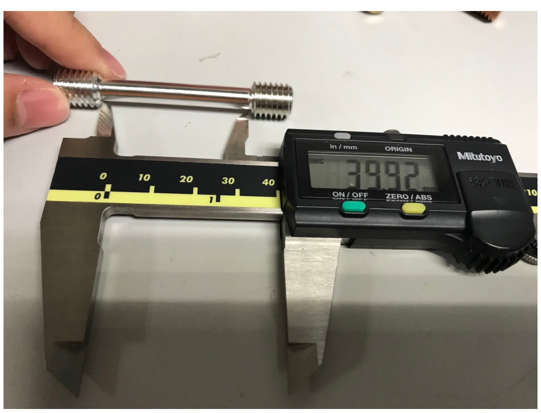


Figure 3: Digital Caliper.

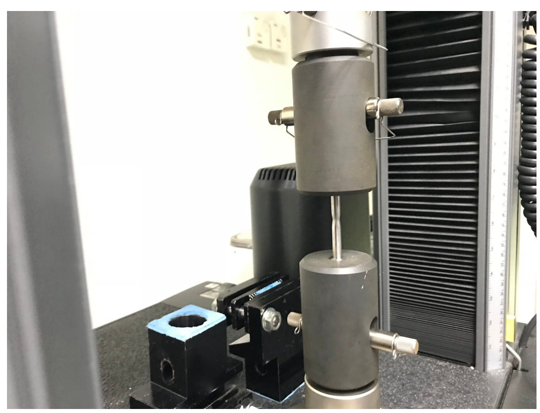


Figure 4: The specimen holder.

5.0 Conclusion

From the results of the experiment, a trend can be seen that shows that steel has the highest yield strength of 739 MPa, while brass is second with a yield strength of 504 MPa, copper is third with a yield strength of 332 MPa, and aluminium has the lowest yield strength of 308 MPa. From the graphs, all specimens show a similar trend before breaking, where all the specimens elongate after a certain amount of load, then proceeds to necking, and after the critical load, the specimens break into two. From the graphs, it can also be deduced that copper has the highest ductility while steel is lowest as copper elongated the most and steel elongated the least before breaking point.

The experiment could have been improved by reducing and minimizing the amount of human error. One method is to place the specimens carefully between the upper and lower grippers and also make sure that the temperature condition of the room is constant to prevent expansion of the specimen. By understanding the tensile strength and ductility of different materials, engineers are able to determine the breaking point and the suitability of materials to specific uses.

6.0 References

[1]H. Czichos, T. Saito and L. Smith, *Springer Handbook of Materials Measurement Methods*. Berlin: Springer, 2007.

[2]C. Truesdell, *The rational mechanics of flexible or elastic bodies, 1638-1788*. Turici: Orell Füssli, 1960.

[3]J. Davis, *Tensile testing*. Materials Park, Ohio: ASM International, 2004.

[4]Wizard191, *A schematic of various shoulder styles for tensile specimens. Keys A through C are for round specimens, while keys D and E are for flat specimens.*. 2010.

[5]Engineering Archives, *Diagram Showing the Mechanics of a Universal Testing Machine*. 2008.