

APPENDIX GA36a

LEVEL 4 ASSESSMENT SPECIFICATION

Student name:	TOM FERGUSON	Student ID number:	TF196540
Programme:	HNC Mechanical Engineering		
Module:	Materials		
Module code:	SGDM4003	Contribution to Overall Module Assessment (%):	50%
Lecturer:	Chris Davies	Internal Verifier:	Robert Rees
Assignment Title:	Assignment 1 Tensile Test to Destruction.	Word count (or equivalent):	2000
Submission deadline:	21/11/19	Return date of provisional marks & written feedback:	
Submission method:	All written assessments, where practical and possible, must be submitted via Turnitin unless otherwise instructed by the Lecturer. (Please DO NOT put this assessment specification into Turnitin or it will match many similarities with other students' submissions.) Alternative submission method (if applicable): Late submission of the assessment will result in a late penalty mark. Penalties for late submission: Up to one week late, maximum mark of 40%. Over one week late, 0%. Only the Extenuating Circumstances Panel may approve a change to submission dates.		
Academic honesty / referencing:	Academic honesty is required. In the main body of your submission you must give credit to authors on whose research and ideas your work is based. Append to your submission a reference list that indicates the books, articles, etc. that you have used, cited or quoted in order to complete this assessment.		

Module Learning Outcomes (from module syllabus)

1. Demonstrate a detailed knowledge and understanding of the structure, properties, processing and subsequently the use of engineering materials;
2. Use standard materials testing apparatus and derive the mechanical properties of materials and analyse and understand the cause of materials failures.

STUDENT FEEDBACK FORM

This section details the extent to which the assessment criteria are demonstrated by you, which in turn determines your mark. The marks available for each category of skill are shown. Lecturers will use the space provided to comment on the achievement of the task(s), including those areas in which you have performed well and areas that would benefit from development/improvement.

Generic Assessment Criteria	Marks available	Marks awarded
1. Engagement with Literature Skills	20	
Engagement with appropriate literature is evident and you have included relevant points. Sometimes you did not fully explore a topic (for example alloying and heat treatment).	13	
2. Knowledge and Understanding Skills	30	
Good knowledge and understanding demonstrated throughout. Some issues not explained (like the linkage between Carbon Content in steel or heat-treatment and their impact on properties).	20	
3. Cognitive and Intellectual Skills	20	
Good use of data and correct calculations made. I liked the manner in which you compared the results of each material. Good observations made.	15	
4. Practical Application Skills	15	
Some good points made but I would have liked some specific examples of the test in used	10	
5. Transferable Skills for Life and Professional Practice	15	
Well written and presented. Well structured although some minor issues noted.	10	

Assessment Mark (Assessment marks are subject to ratification at the Exam Board. These comments and marks are to give feedback on module work and are for guidance only until they are confirmed.)

Late Submission Penalties (tick if appropriate)

Up to 1 week late (40% Max)

Over 1 week late (0%)

%

68%



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TENSILE TEST TO

DESTRUCTION

SGDM4003



Tom Ferguson - TF196540

Mechanical Engineering HNC – Year 2

Summary

This assignment has been conducted as a lab test analysis into the characteristics of different metal samples. The main task was to test five samples using a destructive method called tensile testing. Doing this the author relates the effect of a uniaxial tensile load (force) on the elongation (change in length) of the test samples.

The ^{five} four different test piece metals are; 70/30 Brass, 70/30 Annealed Brass, Annealed Copper, 0.1% Normalised Carbon Steel and 0.4% Carbon Steel. The test pieces or specimens are the other component parts of this lab experiment. These pieces are all standard dimensions, 25mm in length, cross sectional area (C.S.A) of 20mm² and all have enlarged shoulders for the machine to grip.

Upon reviewing the graphs above the carbon steel tests show a well-defined discontinuous yield point. However, this is not evident in the annealed brass and annealed copper samples. To find out the yield point on these samples, an engineer would use the proof stress. The reason for the carbon steel samples exhibiting what is known as a discontinuous yielding is to do with the fact that this graph does not measure true stress and the formation of Cottrell atmospheres around dislocations in the lattice.

The main differences between the two carbon steel, copper and brass test results are discussed and concluded that chemical compositions have a massive influence on the mechanical and physical properties.

This tensile test was considered as successful in identifying the test sample's properties but there are some shortfalls in the fairness of this test, as BS EN ISO 6892 was not completely followed.

Good summary provided although some specific results and conclusions were needed.

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Good structure.

1.0. Introduction

This assignment will be conducted as a lab test analysis into the characteristics of different metal samples. The main task is to test five samples using a destructive method called tensile testing. This involves using a Hounsfield Tensile Tester or Tensometer (figure 1). The tests in this assignment should be carried out to BS EN ISO 6892-1:2016 (appendix 1) for accurate and fair results.

The aim of this assignment is to gather data from all the tensile tests in a force applied vs extension graph, from these sets of data the author can work out a number of different properties from the test materials. The set of test results is then discussed and concluded.

2.0. Objective

The experiment's objective is to measure the mechanical properties of the test pieces. Doing this the author relates the impact of a uniaxial tensile load (force) on the extension (change in length) of the test pieces. Using this data, compiled by measuring the force required to elongate a test material to failure, a designer or engineer can make decisions on which material is the best suited for an application.

3.0. Background

Tensile testing is a method of establishing how a certain material reacts when a force is applied trying to pull it apart. This type of material testing is one of the most popular and basic methods that can be carried out mechanically on a material.

As shown in figure 1, the results of how much force is required to pull apart a test specimen are plotted into one of these stress-strain graphs, the graphs in this report are classed as engineering stress/strain graphs which is different to true stress/strain. A typical tensile test will produce a similar graph as shown in figure 1. From these graphs a number of properties can be identified.

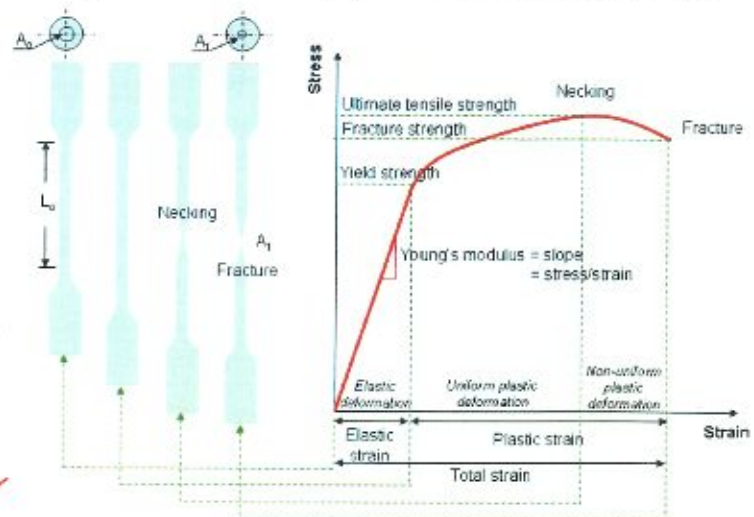


Figure 1 - Stress-Strain Relationship under Uniaxial Tensile Loading (Harish, 2019)

The tensile test is important for industrial quality assurance, especially for the materials use in hazardous environments and materials used for components which undergo large stresses. By performing a tensile test the engineer can verify the certain material property values that are required.

As stated in Tensile Testing by W.F. Hosford, *"The tensile test can only determine one set of properties of a material at a specific temperature, a specific strain rate and the anisotropy"* (Hosford, 1992). Meaning there are a number of factors that have an effect on the shape of the stress-strain curve which an engineer must take into account.

Some key figures/data that would be observed and considered in discussions around the tensile test are as follows;

Original Gauge Length – Length of the test material before any force is applied.

Final Gauge Length – Length of the test material after fracture/destruction.

Ultimate Tensile Strength (UTS) – The maximum force the test material can withstand once the yield point has been crossed. After this point the material would start to show signs of necking.

Lower Yield Force – This is the force applied to a material to begin to permanently deform its shape. This is also called the elastic limit.

Yield Strength – This is a sign of the maximum stress that can be applied to a material without causing irreversible deformation.

Fracture – When the test material has failed, just after the maximum elongation and the applied force is most likely zero.

% Elongation at fracture – Percentage of elongation at fracture is equal to the difference between the final gauge length and the original gauge length divided by the original gauge length times 100%

% Reduction in area at fracture – When necking has occurred there is also a reduction in cross-sectional area. This is calculated by the difference between the original cross-sectional area and the area at time of fracture, divided by the original area times 100%. This can be an expression of how ductile a material is.

4.0. Equipment & materials

There are two components to consider for this lab experiment, the main piece of equipment used for this tensile test is the Hounsfield H20K-W Tensile Tester (figure 1). There are a range of different types of tensile testers, this one is a horizontal style with a digital reader that shows the force applied in Newtons and the resulting elongation of the test piece in Millimeters.



Figure 3 – Hounsfield Tensile Tester/Tensometer

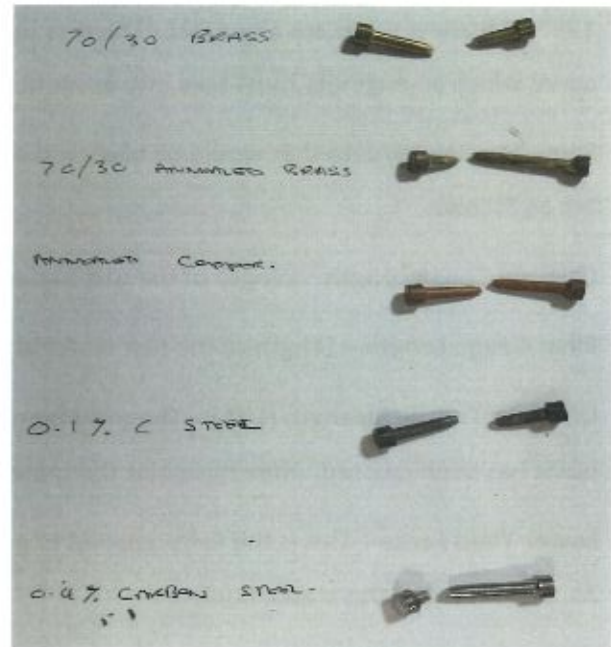


Figure 2 – Test pieces/specimens

The test pieces or specimens are the other component parts of this lab experiment. These pieces are all standard dimensions, 25mm in length, cross sectional area (C.S.A) of 20mm² and all have enlarged shoulders for the machine to grip.

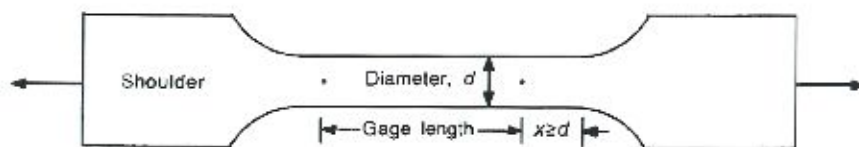


Figure 4 - Typical tensile specimen (ASM International, 2004)

4.1. Background information on test piece materials used

The four different test piece metals are; 70/30 Brass, 70/30 Annealed Brass, Annealed Copper, 0.1% Normalised Carbon Steel and 0.4% Carbon Steel.

4.1.1. 70/30 Brass & Annealed Brass



Figure 5 - Crystal structure of Cu-Zn brass (Bhadeshia & Honeycombe, 2017)

70/30 Brass known as cartridge brass, this alloy is 70% copper and 30% zinc and is characterized by properties of high strength and ductility. At room temperature 70/30 Brass is a single-phase substitutional solid solution of zinc in the FCC (face centered cubic) copper structure (figure 4, this picture shows a BCC but Brass is FCC). Annealing brass by heating and cooling suddenly makes the material even more ductile.

4.1.2. Annealed Copper

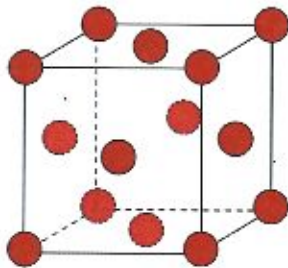


Figure 6 - Crystal structure of Copper (Whiting, 2016)

Copper has a FCC structure that gives high ductility. Annealing copper requires a high temperature as copper melts at 1357Kelvin and annealing generally occurs at more than half the melting point. The typical temperature is 400C. As Thomas Stoebe states, "Annealing causes the structure to create and grow new grains that are free of strain. (Stoebe, 2007)" Which gives the material a softer and even more ductile property.

4.1.3. Carbon steel

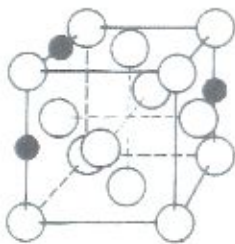


Figure 7 - Crystal structure of Carbon steel (Rewan Engineering, 2009)

Carbon steel has an ~~B~~CC structure that gives a low ductility or in other words brittle and high strength properties. Depending on the amount of carbon content the range of properties can be vast. As Terence Bell states; "steel is composed of iron and carbon, although it is the amount of carbon, as well as the level of impurities and additional alloying elements that determine the properties of each steel grade."

5.0. Method

The method of the tensile test is as follows;

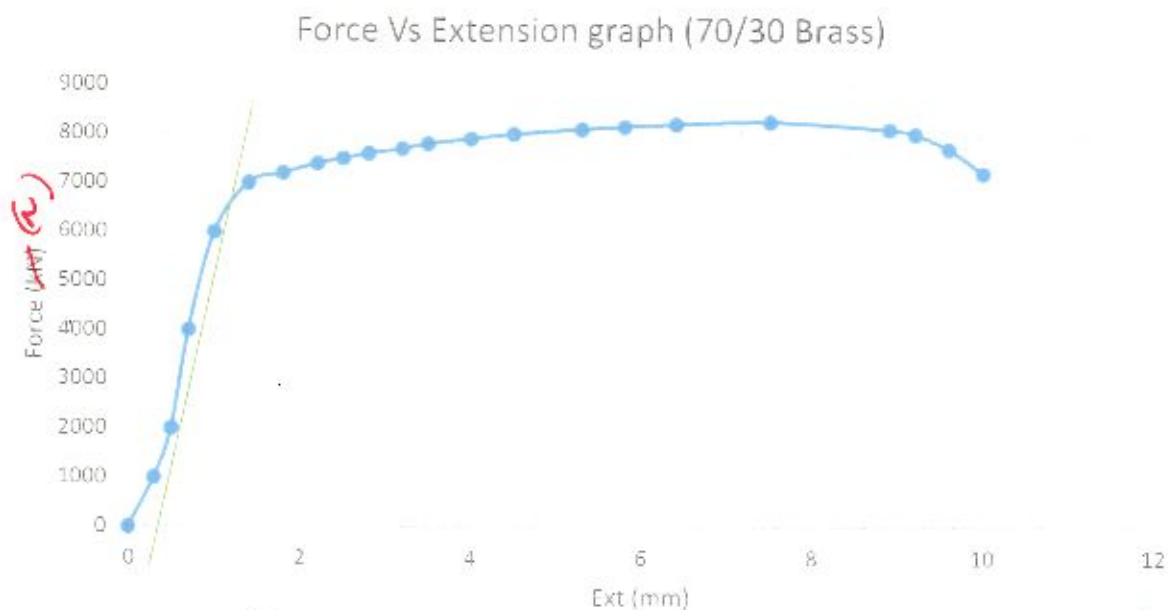
Firstly the test piece is loaded into the tensile testing machine according to the manual and calibrate the tensile tester to make sure it is zeroed. A steady load is then put onto the test piece via the Tensometer. Continuous readings are read out by the equipment operator and recorded by another person into an excel spreadsheet.

The test piece load force and extension values are observed until the piece passes through the elastic limit, into the plastic zone and up until the test piece fails. The cross sectional area at failure is also recorded and inputted into the excel spreadsheet. Overall length is measured to indicate total extension at failure point.

The test piece is then removed from the Tensometer and laid out on a piece of paper for further inspection. This test is repeated for each test piece material.

6.0. Results

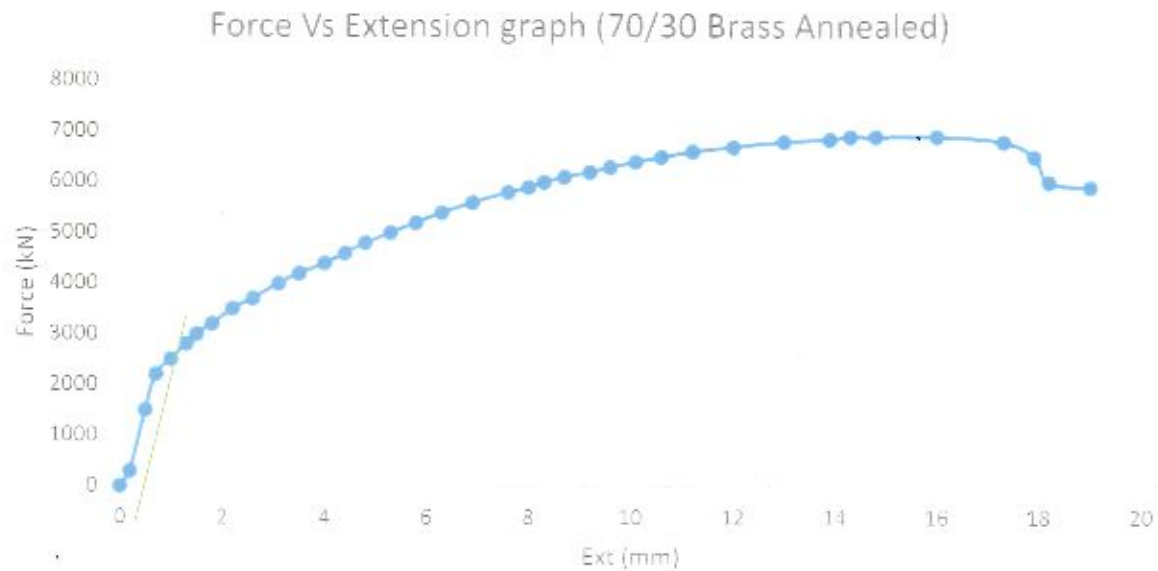
The results from the tensile tests conducted in the classroom have been plotted into stress verses strain graphs:



Graph 1 - 70/30 Brass force/ext graph

Yield or flow stress:				
Elastic Limit (Proof Stress) (N)	=	6900	=	345 MN/m ²
Original C.S.A. (mm ²)		20		
Tensile Strength:				
Max Force (N)	=	8250	=	413 MN/m ²
Original C.S.A. (mm ²)		20		
Elongation % at Fracture:				
Extension at Fracture (mm)	x 100%			
Original gauge length (mm)			=	41.9%

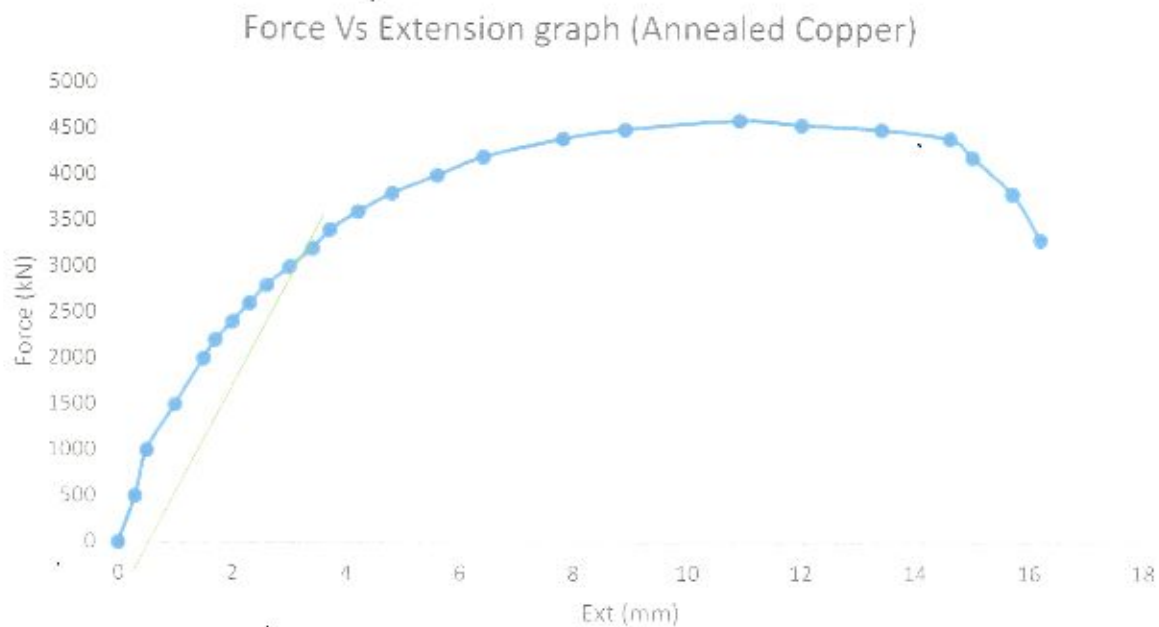
Table 1 - 70/30 Brass test values



Graph 2 - 70/30 Brass Annealed force/ext graph

Yield or flow stress:				
Elastic Limit (Proof Stress) (N)	=	2600	=	130 MN/m ²
Original C.S.A. (mm ²)		20		
Tensile Strength:				
Max Force (N)	=	6900	=	345 MN/m ²
Original C.S.A. (mm ²)		20		
Elongation % at Fracture:				
Extension at Fracture (mm)	x100%	19	=	76.0%
Original gauge length (mm)		25		

Table 2 - 70/30 Brass test values

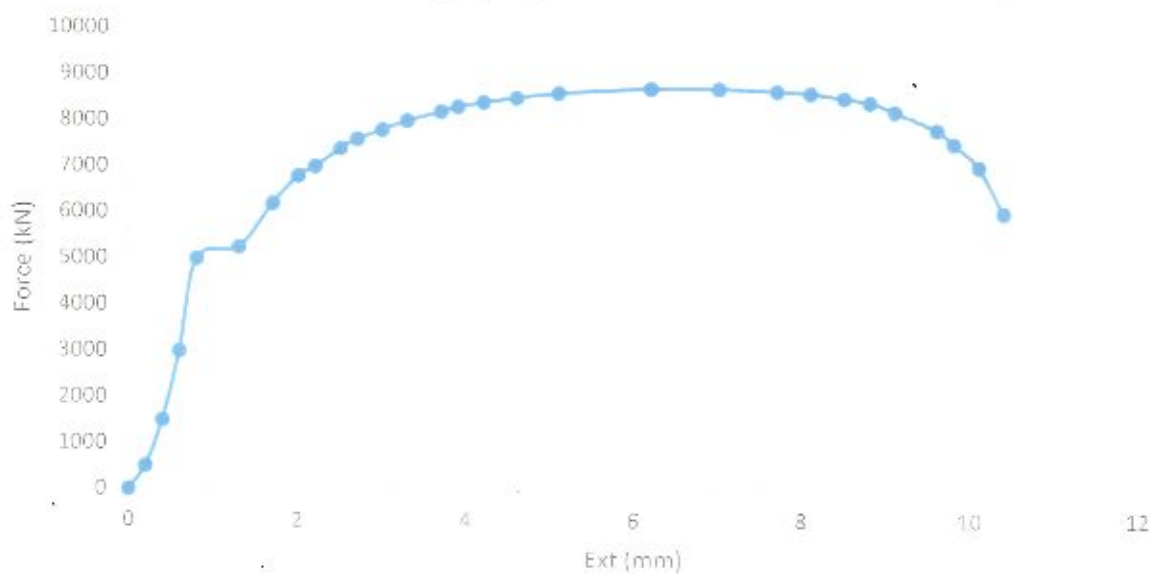


Graph 3 - Annealed Copper force/ext graph

Yield or flow stress:					
Elastic Limit (Proof Stress) (N)	=	2800	=	140	MN/m ²
Original C.S.A. (mm ²)		20			
Tensile Strength:					
Max Force (N)		4600			
Original C.S.A. (mm ²)	=	20	=	230	MN/m ²
Elongation % at Fracture:					
Extension at Fracture (mm)	x 100%				
Original gauge length (mm)			=	16.5	=
				25	66.0%

Table 3 - Annealed Copper test values

Force Vs Extension graph (0.1% Carbon Steel Normalised)

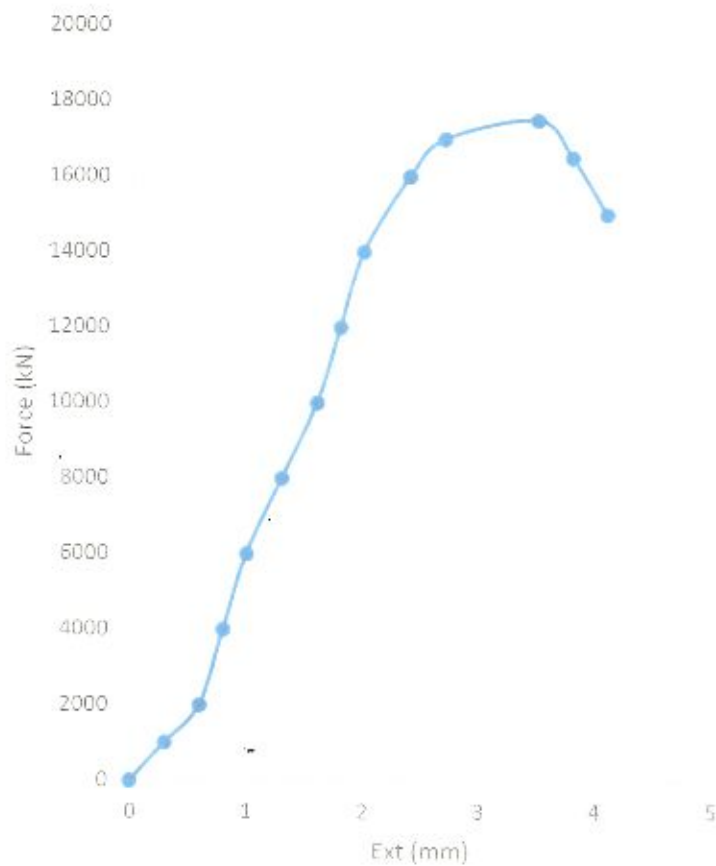


Graph 4 - 0.1% Carbon Steel Normalised force/ext graph

Yield or flow stress:				
Elastic Limit (Proof Stress) (N)	=	5000	=	250 MN/m ²
Original C.S.A. (mm ²)		20		
Tensile Strength:				
Max Force (N)		8700		
Original C.S.A. (mm ²)	=	20	=	435 MN/m ²
Elongation % at Fracture:				
Extension at Fracture (mm)		10.6		
Original gauge length (mm)	x100%	=	25	= 42.4%

Table 4 - 0.1% Carbon Steel Normalised test values

Force Vs Extension graph (0.4% Carbon Steel)



Graph 5 - 0.4% Carbon Steel force/ext graph

Yield or flow stress:				
Elastic Limit (Proof Stress) (N)	=	$\frac{16700}{20}$	=	835 MN/m ²
Original C.S.A. (mm ²)				
Tensile Strength:				
Max Force (N)	=	$\frac{17500}{20}$	=	875 MN/m ²
Original C.S.A. (mm ²)				
Elongation % at Fracture:				
Extension at Fracture (mm)	x100%	=	$\frac{4.3}{25}$	= 17.2%
Original gauge length (mm)				

Table 5 - 0.4% Carbon Steel test values

7.0. Analysis of results

7.1. Carbon steel results

Upon reviewing the graphs above the carbon steel tests show a well-defined discontinuous yield point. This is less so with the 0.4% carbon content but still visible. However, this is not evident in the annealed brass and annealed copper samples. To find out the yield point on these samples, an engineer would use the proof stress.

The proof stress is an approximation of the yield point for materials that do not have a well-defined yield point. Comparing the 0.1% carbon steel graph with the two brass and copper graphs, there is a discontinuation as the material travels past the elastic limit and into the plastic zone but on the latter graphs it cannot be distinguished where the elastic limit is visually. To find this approximation a tangent line is drawn 0.2% to the right of where the graph starts. Where this tangent intersects, this value defines the proof stress of the material.

The reason for the carbon steel samples exhibiting what is known as a discontinuous yielding is to do with the presence of the carbon interstitial atoms and the fact that this graph does not measure true stress. As shown on figure 4, "Carbon atoms, with a radius of 0.071 nm, fit nicely in the open spaces between the larger (0.124 nm) iron atoms." (Advanced Technological Education, 2019). These

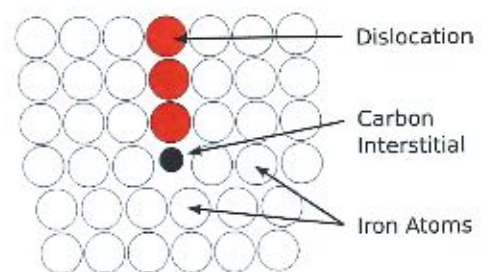


Figure 8 - Carbon steel atoms

interstitial atoms create point defects in the lattice structure because the size of the interstitial impurities is larger than the interstitial space between the iron atoms. Also the yield point phenomenon occurs because of the formation of *Cottrell atmospheres* around dislocations. This causes a local compressive strain in the lattice. As stated by (Bhadeshia & Honeycombe, 2017) "consequently dislocations can be locked in position by strings of carbon atoms along the dislocations, thus substantially raising the stress which would be necessary to cause dislocation movement".

The main differences between the two carbon steel test samples are shown on the result graphs and are as follows: The 0.4% carbon steel sample has more than double the UTS of the 0.1% carbon steel sample. Thus making it stronger, but what the 0.4% sample has gained in strength it has lost a lot of its ductility in the process. This is evidence that the more carbon added to iron, the more brittle it becomes.

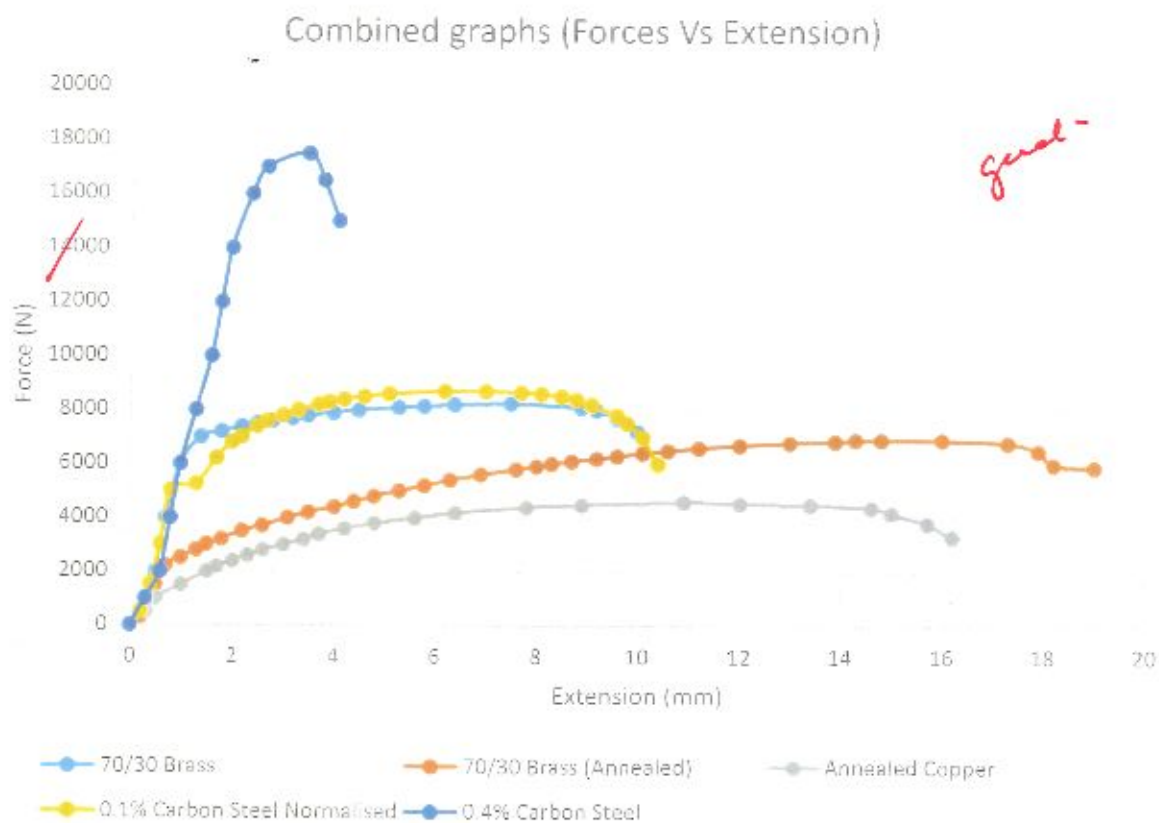
7.2. Brass & copper results

The two brass and copper result graphs are very similar as they are all relatively ductile and low strength. Graph 6 shows that the annealed 70/30 brass is the most ductile, meaning that it can be stretched the longest before fracturing. This type of property is useful in decorative purposes due to its resistance to weathering.

The annealed copper is the second most ductile according to this graph but it has the lowest UTS meaning it cannot withstand much stress before failing. Copper is also naturally resistant to weathering which makes it ideal for use in plumbing materials for low pressure applications. Also copper is a very good conductor of both heat and electricity which makes it useful for us in electrical appliances.

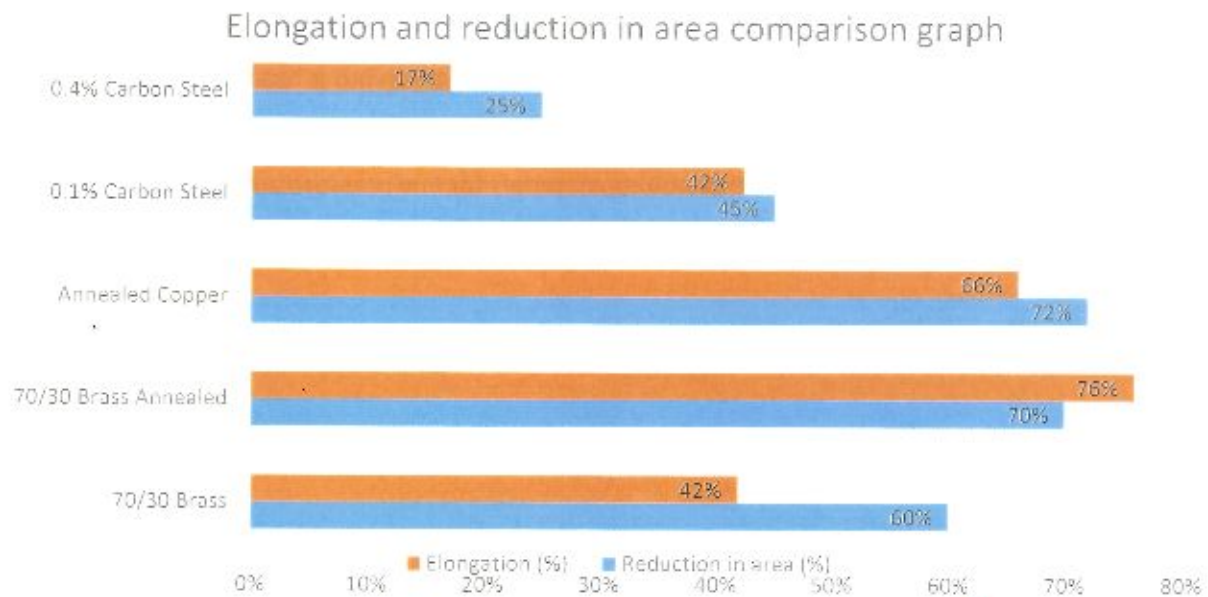
7.3. Comparing Material Properties

The below graph shows all of the materials stress/strain graphs plotted into one graph for comparison.



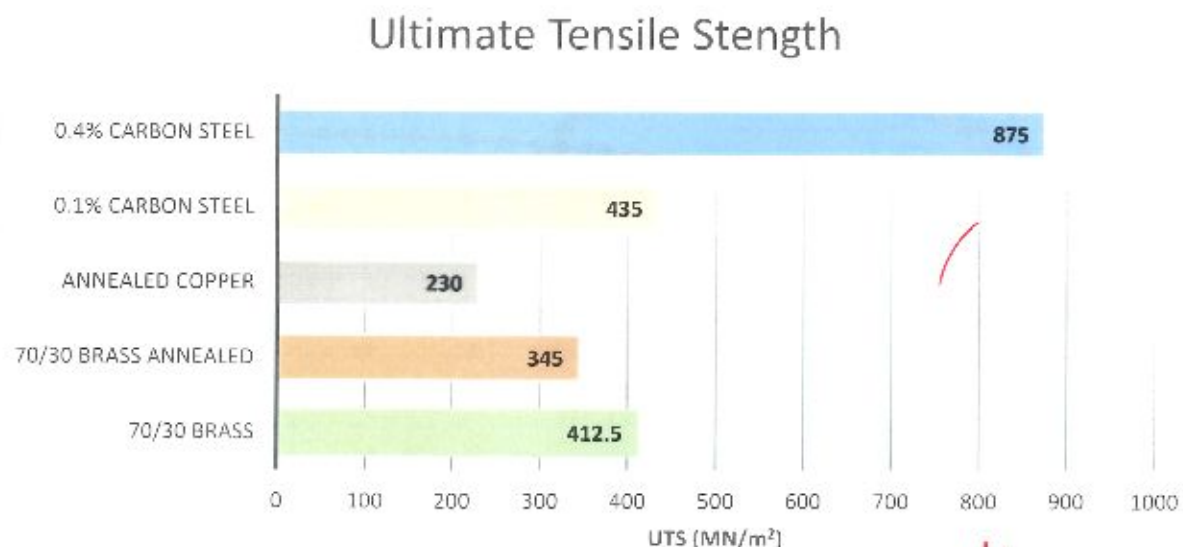
Graph 6 - Combined force/ext graph

Graph 6 shows that 0.4% carbon steel is the least ductile but has the highest UTS. These properties would be great for components that are in high stress situations, for example stud bolts on pipe flanges for high pressure processes. But this would not be used for a component that requires ductility like wire.



Graph 7 - Elongation & reduction in area comparison graph

The graph above is showing the elongation % alongside the reduction in area %. This is another piece of evidence to show the ductility of the metal samples.



Graph 8 - UTS comparison graph

The graph above shows the UTS of each sample, this shows which sample metal can take the most force. From this an engineer can give a factor of safety, usually 3 so divide the UTS by 3 to get its working stress limit.

8.0. Conclusion

It is safe to say the chemical compositions have influence on the mechanical and physical properties. From the test results and background research the author can come to a conclusion that pure metals have few uses due to the lack of properties that are required in industries. Alloys offer better properties due to the inclusion of foreign atoms in the crystalline structures. Plastic deformation of metals typically refines the microstructure and increases the strength, in the carbon steel sample this is evident but in the brass samples this statement is quite the opposite. The annealed brass has a lower UTS but it is more ductile.

This tensile test would be considered as successful in identifying the test sample's properties but there are some shortfalls in the fairness of this test. As BS EN ISO 6892 (British Standards Institution, 2016) was not completely followed, there are some variations of the test results in comparison to others that have been researched (appendix 1). To have fairer results, the test should have been done on more than one sample per metal. This should iron out any samples that have defects/impurities that they shouldn't already have.

The graphs used in this report are calculated in engineering stress/strains which calculates the stresses in relation to the original cross-sectional area. This could be seen as un-true results as the true stress/strains are not calculated. This can be done with taking the actual real-time cross-sectional area into consideration.

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11.0. Appendices

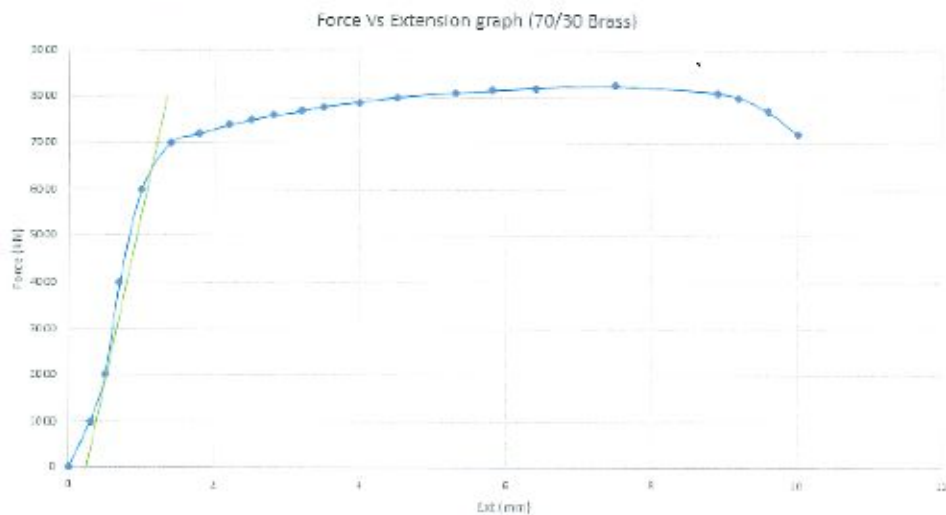
Appendix 1 – Properties of Generic Materials

Table 1.6 Properties of the Generic Metals

Metal	Density (Mg m^{-3})	Young's Modulus (GN m^{-2})	Yield Strength (MN m^{-2})	Tensile Strength (MN m^{-2})	Ductility	Fracture Toughness ($\text{MN m}^{-3/2}$)	Melting Temperature (K)	Specific Heat ($\text{J kg}^{-1}\text{K}^{-1}$)	Thermal Conductivity ($\text{W m}^{-1}\text{K}^{-1}$)	Thermal Expansion Coefficient (MK^{-1})
Iron	7.9	211	50	200	0.3	80	1809	456	75	12
Mild steel	7.9	210	220	430	0.21	140	1785	432	60	12
High-carbon steel	7.8	210	350–1600	650–2000	0.1–0.2	20–80	1570	460	40	12
Low-alloy steels	7.8	203	280–1000	420–2000	0.1–0.2	50–170	1750	460	40	12
High-alloy steels	7.3	215	170–1800	460–1700	0.1–0.5	50–170	1680	500	12–30	10–18
Cast irons	7.4	152	50–400	10–800	0–0.18	6–20	1403			
Copper	8.9	130	75	220	0.5–0.9	>100	1356	385	397	17
Brasses	8.4	105	200	350	0.5	30–100	1190		121	20
Bronzes	8.4	120	200	350	0.5	30–100	1120		85	19
Nickel	8.9	214	50	300	0.4	>100	1728	460	88	13
Monels	8.9	185	340	650	0.5	>100	1500	420	22	14
Superalloys	7.9	214	500	1300	0.2	>100	1550	450	11	12
Aluminum	2.7	71	25–125	75–135	0.1–0.5	45	933	917	240	24
1000 Series	2.7	71	28–65	75–180	0.1–0.45	45	915			24
2000 Series	2.8	71	200–500	300–800	0.1–0.25	10–50	860		180	24
5000 Series	2.7	71	40–300	120–430	0.1–0.35	20–40	880		130	22
7000 Series	2.8	71	350–600	500–870	0.1–0.17	20–70	880		150	24
Casting alloys	2.7	71	55–350	130–400	0.01–0.15	5–30	860		140	20
Titanium	4.5	120	170	240	0.25		1940	530	22	9
Ti–6 Al4V	4.4	115	800–900	900–1000	0.1–0.2	50–80	1920	510	6	8
Zinc	7.1	105		120	0.4		893	390	120	31
Lead–tin solder	9.4	40					456			
Diecasting alloy	6.7	105		280–330	0.07–0.15		550	420	110	27

Appendix 2 – 70/30 Brass Excel records

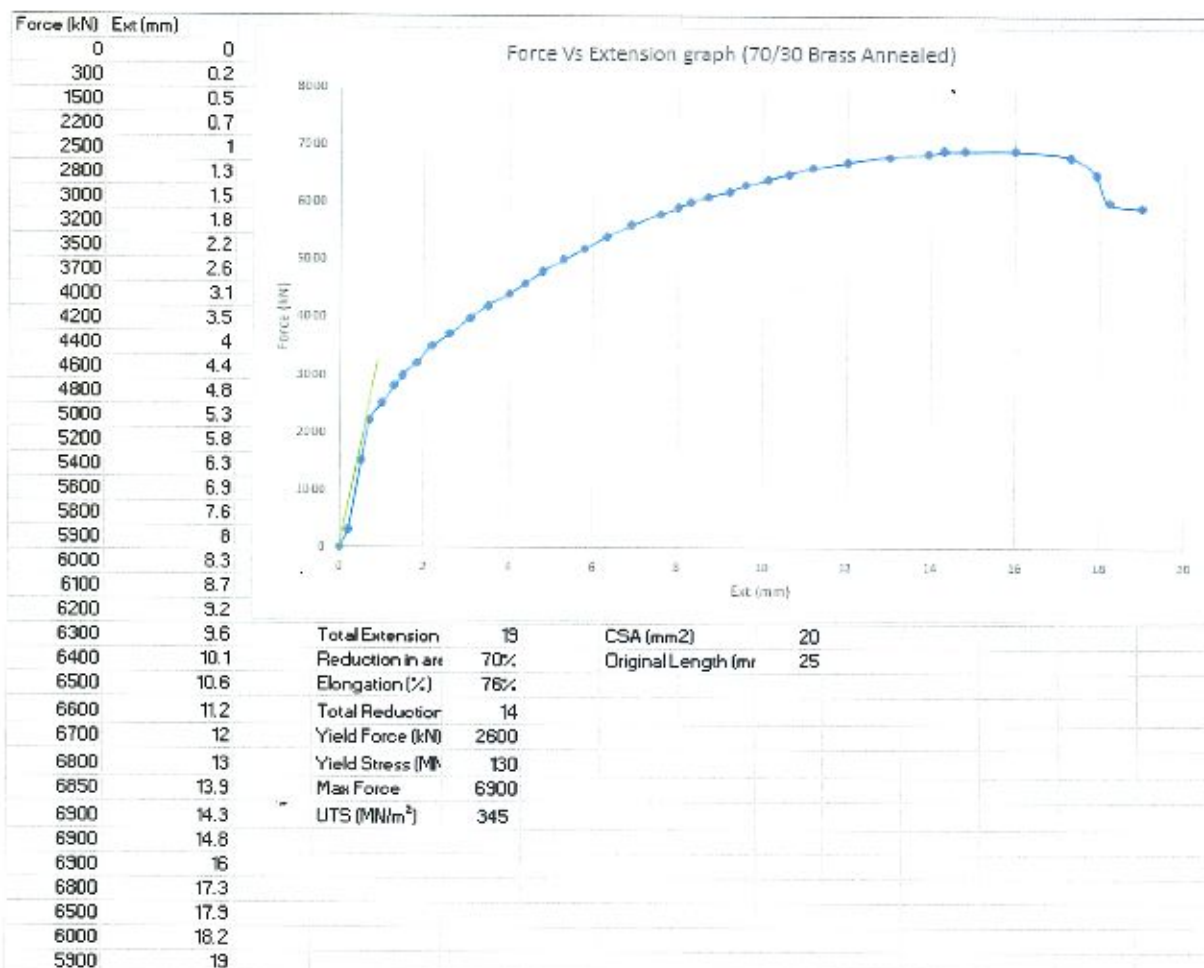
Force (kN)	Ext (mm)
0	0
1000	0.3
2000	0.5
4000	0.7
6000	1
7000	1.4
7200	1.8
7400	2.2
7500	2.5
7600	2.8
7700	3.2
7800	3.5
7900	4
8000	4.5
8100	5.3
8150	5.8
8200	6.4
8250	7.5
8100	8.5
8000	9.2
7700	9.6
7200	10



Total Extension (mm)	10.47	CSA (mm ²)	20
Reduction in area (%)	60%	Original Length (mm)	25
Elongation (%)	42%		
Total Reduction in Area (mm ²)	12		
Yield Force (kN)	6900		
Yield Stress (MN/m ²)	345		
Max Force (kN)	8250		
UTS (MN/m ²)	413		

Yield or flow stress:				
Elastic Limit	=	6900	=	345 MN/m ²
Original C.S.A.	=	20		
Tensile Strength:				
maximum Force	=	8250	=	413 MN/m ²
Original c.s.a	=	20		
Elongation % at Fracture:				
Extension at Fracture	×100%	10.47	=	41.9%
Original gauge length		25		

Appendix 3 – 70/30 Brass Annealed Excel records

**Yield or flow stress:**

$$\frac{\text{Elastic Limit}}{\text{Original C.S.A.}} = \frac{2600}{20} = 130 \text{ MN/m}^2$$

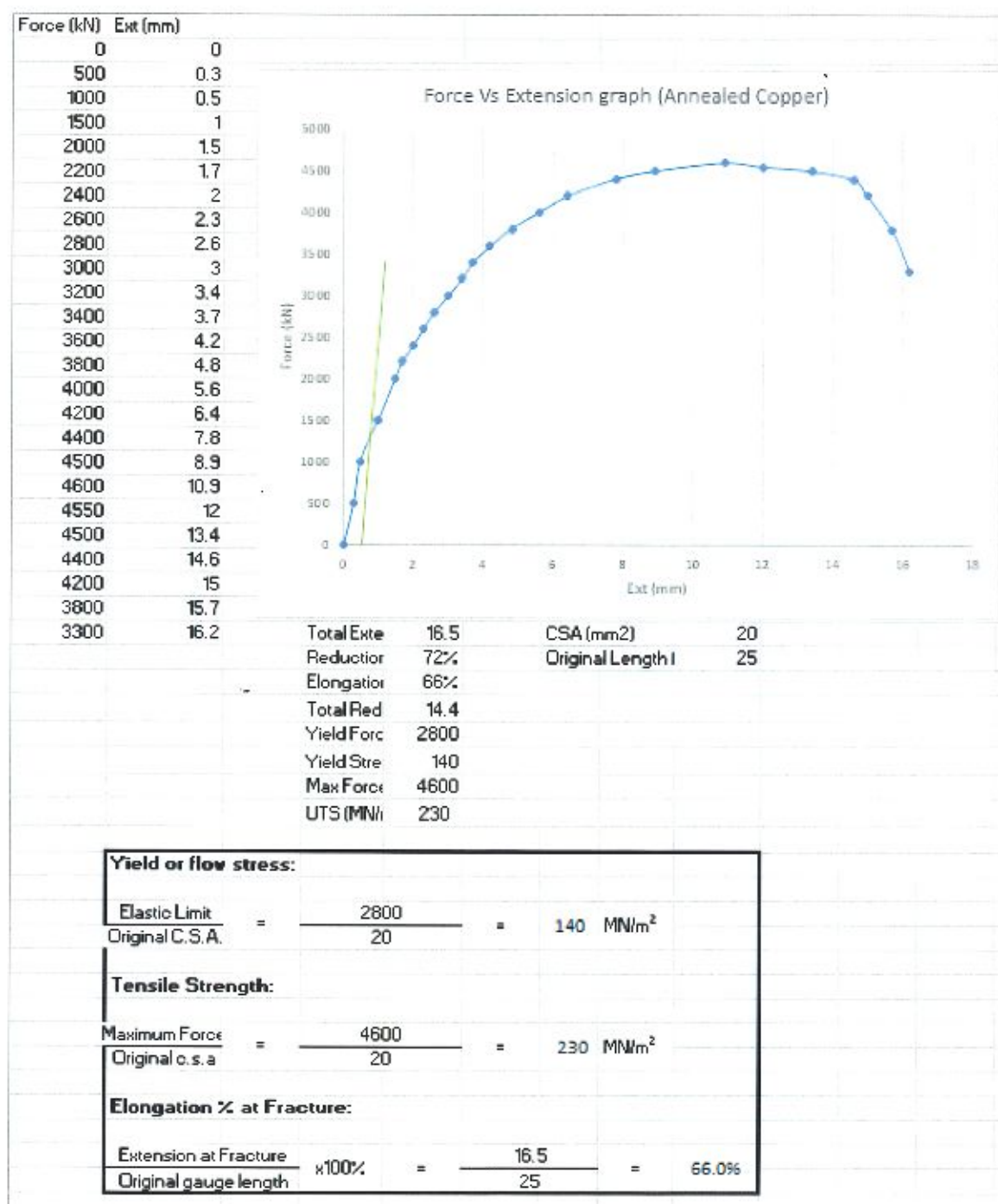
Tensile Strength:

$$\frac{\text{maximum Force}}{\text{Original c.s.a.}} = \frac{6900}{20} = 345 \text{ MN/m}^2$$

Elongation % at Fracture

$$\frac{\text{Extension at Fracture}}{\text{Original gauge length}} \times 100\% = \frac{19}{25} = 76.0\%$$

Appendix 4 – Annealed Copper Excel records

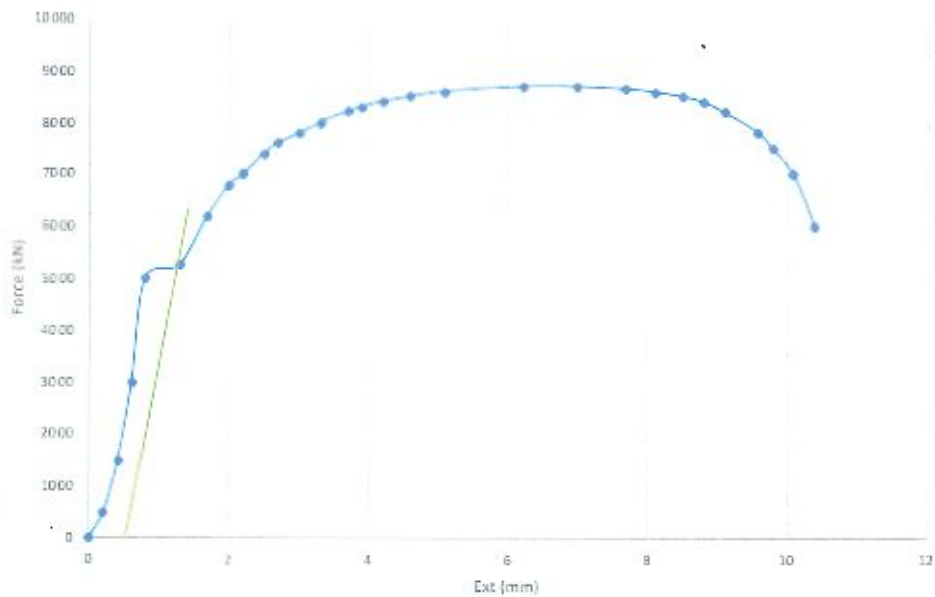


Appendix 5 – 0.1% Normalised Carbon Steel Excel records

Force (kN) Ext (mm)

0	0
500	0.2
1500	0.4
3000	0.6
5000	0.8
5250	1.3
6200	1.7
6800	2
7000	2.2
7400	2.5
7600	2.7
7800	3
8000	3.3
8200	3.7
8300	3.9
8400	4.2
8500	4.6
8600	5.1
8700	6.2
8700	7
8650	7.7
8600	8.1
8500	8.5
8400	8.8
8200	9.1
7800	9.6
7500	9.8
7000	10.1
6000	10.4

Force Vs Extension graph (0.1% Carbon Steel Normalised)



Total Extensi	10.6	CSA (mm2)	20
Reduction in	45%	Original Length	25
Elongation (%)	42%		
Total Reduct	9		
Yield Force (	5000		
Yield Stress (	250		
Max Force	8700		
UTS (MN/m ²)	435		

Yield or flow stress:

$$\frac{\text{Elastic Limit}}{\text{Original C.S.A.}} = \frac{5000}{20} = 250 \text{ MN/m}^2$$

Tensile Strength:

$$\frac{\text{Maximum Force}}{\text{Original c.s.a.}} = \frac{8700}{20} = 435 \text{ MN/m}^2$$

Elongation % at Fracture:

$$\frac{\text{Extension at Fracture}}{\text{Original gauge length}} \times 100\% = \frac{10.6}{25} = 42.4\%$$

Appendix 6 – 0.4% Carbon Steel Excel records

