UCI Samueli School of Engineering | Department of Mechanical and Aerospace Engineering

Full Engineering Laboratory Report

MAE XXX Course Name

Lab 3 Materials Tension Test

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Adviser/s:

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XXX

Date of Experiment:

Submission Date:

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Nomenclature List

SYMBOL	DEFINITION
A	Area over which force (F) acts ($inch^2$)
E	Elastic modulus (ksi)
F	Force (lbs)
l_0	Initial length (inch)
l_f	Final length (inch)
σ	Engineering stress (pound per square inch (psi))
ε	Strain
σ_y	Yield strength (psi)
σ_u	Ultimate strength (psi)

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1. Abstract

The motivation of conducting uniaxial tension test is to determine mechanical properties of a material while it is loaded to the point of failure. Both the elastic and inelastic properties can be determined by analyzing a stress-strain diagram. The objective is to experimentally measure yield strength, ultimate tensile strength, modulus of elasticity, ductility of each sample. These properties are determined via using a stress-strain diagram. In this experiment, a tension type load was simulated where button head round bar samples of A36 steel and cast Iron were fixed in such a way that that the sample could be pulled from both the top and bottom. Prior to the breaking portion of the experiment diameters of both metal samples as well as the gage lengths were recorded. The gage length is the predetermined length of the sample under examination prior to the experiment, this measurement would allow us to easily examine the elongation of the sample prior to failure. The load experienced by the sample up until the point of failure was recorded in an excel sheet. Sample's final length and diameter as well as the final load were also recorded to draw an appropriate conclusion for samples. These values essentially helped us develop a strain stress diagram so we could see and overall visual of the path to failure for each type of sample. From the present experiment, A36 steel experienced high deformation prior to failure, while on the other hand, cast Iron Steel experienced only a small deformation. A36 steel stretched its length 41.2%, supporting a load of 10116 pounds before fracturing. The cast iron did not deform any measurable amount and held only 9409 pounds. The fracture of the steel occurred only after stretching and necking, a visible process. The point of fracture demonstrated a perfect cup and cone fracture surface. The iron, however, simply cracked. When reassembled, the specimen looks identical to before the test. From these results, it can be seen that A36 is a ductile material, and cast iron is a brittle one.

2. Introduction

Tensile testing is one of the most fundamental tests for engineering. It provides valuable information about a material and its associated properties. These properties can be used for design and analysis of engineering structures, and for developing new materials that better suit a specified use.

The tensile testing laboratory was conducted using a Universal Testing Machine (UTS). Load was applied uniaxially along the long axis of a specimen as Figure 2.1 [1]. Two different materials were tested, including A-36 steel and cast iron. The samples were cylindrical in cross section, with a reduced gage section like “dog-bone” geometry as Figure 2.2. The reduced gage section ensured that the highest stresses occurred within the gage, and not near the grips of the load frame, preventing strain and fracture of the specimen near or in the grips. The samples were already machined to the proper dimensions required for the test, according to ASTM standards. One samples of each material was tested, and the data gathered into an Excel spreadsheet. A computer was setup to take data at intervals, recording the load and stretch length at each interval. From this data, all the above listed properties can be calculated, and the behavior of the material can be seen graphically. The following pages outline this information. The purpose of the tension test is to determine the strength and inelastic properties of A36 steel and cast iron, and to observe the deformation and fracture behavior of these materials under extreme, slow tensile load.

The strength of a material can be measured as the maximum tensile load it can hold before fracture. A material that is more ductile can hold more before fracture due to the property of elasticity. The ductile material will stretch much like a spring, even past the point of recovery to withstand the load. A brittle load may not behave similarly. It may be more likely to simply crack rather than deform. The impact of this study will have, is deepening the understanding of mechanical properties of different materials. It also impacts the understanding of different types of fracture modes, which will demonstrate necessary proofs for materials selection and materials applications of future study.

The rest of the report will include 5 sections. The theoretical presentation section will discuss the theory behind the results and necessary equations for the analysis in this experiment. The background and previous work section will discuss test data of other researchers. Experimental procedure section will describe detailed procedure for this experiment. Results section will display the results of the experiment and present the plots and graphs of data. Conclusion section will summarize the experiment and important results.

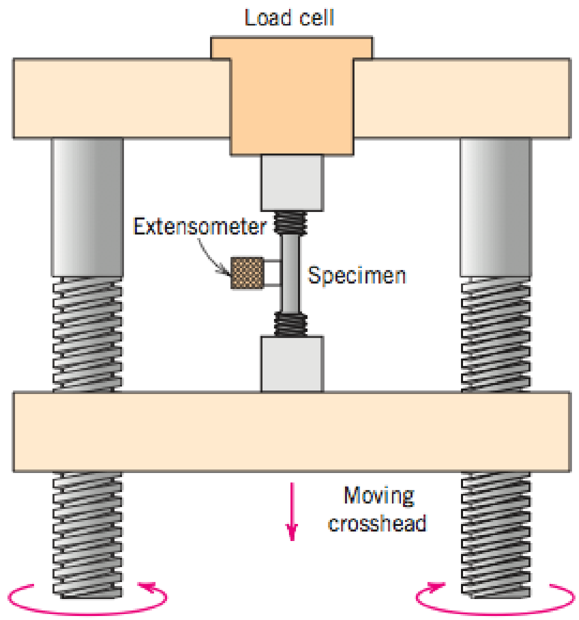

Figure 2.1 Loading configuration of a uniaxial tensile test [1]

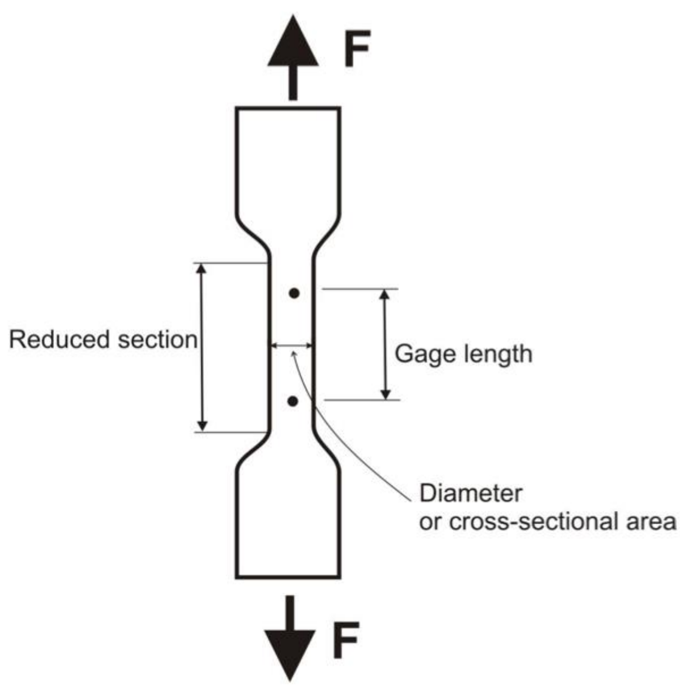

Figure 2.2 "Dog-bone" sample geometry used for tensile test

3. Background and previous work

ASTM A36 is a structural quality mild carbon steel. It's strength, formability, and excellent welding properties make it suitable for a large variety of applications, including welding, fabricating, and bending. Cast iron is produced by smelting iron-carbon alloys that have a carbon content greater than 2%. Although both steel and cast iron contain traces of carbon and appear similar, there are significant differences between the two metals. Steel contains less than 2% carbon, which enables the final product to solidify in a single microcrystalline structure. The higher carbon content of cast iron means that it solidifies as a heterogeneous alloy, and therefore has more than one microcrystalline structure present in the material. Table 3.1 outlines mechanical properties of A36 steel and cast iron [2-4]. (Note: at least 3 different papers of references are expected to be used in this section)

Table 3.1 Mechanical properties of A36 steel and cast iron

Properties	A36 steel	Cast iron
Yield stress	210-300MPa	98-290MPa
Elastic modulus	190GPa	60-180GPa
Poisson's ratio	0.26	0.29
Elongation at break	≥20%	9.6%
Ultimate tensile stress	400-550MPa	160-450MPa

4. Theoretical presentation

Materials will deform when forces are applied. The magnitude of the deformation for a constant force depends on the geometry of materials. Likewise, the magnitude of the force required to cause a given deformation, depends on the geometry of the material. For these reasons, engineering stress is given by Equation 4.1, while engineering strain is given by Equation 4.2 [5].

$$\sigma = \frac{F}{A} \qquad \text{(Equation 4.1)}$$

$$\varepsilon = \frac{L - L_0}{L_0} \qquad \text{(Equation 4.2)}$$

The relationship between the stress and strain is geometry independent. It is given by a simplified form of Hooke's Law [5]. Hooke's Law (Equation 4.3) predicts a linear relationship between the strain and the stress and describes the elastic response of a material. In materials where Hook's Law describes the stress-strain relationship, the elastic response is the dominant deformation mechanism. However, many materials exhibit nonlinear behavior at higher levels of stress. This nonlinear behavior occurs when plasticity becomes the dominant deformation mechanism. The transition from an elastic response to a plastic response occurs at a critical point known as the yield point (σ_y). Since a plastic response is characterized by permanent deformation, the yield point is an important characteristic to know. In practice, the yield point is the stress where the stress-strain behavior transforms from a linear relationship to a non-linear relationship. The most commonly used method to experimentally determine the yield point is the 0.2% offset method [6]. In this method, a line is drawn from the point (σ =0, ε =0.2%) parallel to the linear region of the stress-strain graph. The slope of this line is equal to the elastic modulus. The yield point is then determined as the intersection of this line with the experimental data.

$$\sigma = E\varepsilon \qquad \text{(Equation 4.3)}$$

In materials that exhibit a large plastic response, the deformation tends to localize. Continued deformation occurs only in this local region and is known as necking [1]. Necking begins at a critical point known as the ultimate stress (σ_{ult}). Materials failure occurs soon after necking begins.

5. Experimental procedure

The specimens we tested were in a button head round bar shape and those are A36 Steel and cast Iron. Initial diameter (D_0) of two samples were measured to get the initial cross-sectional area (A_0) and then a two-inch spot for the gage length was determined to view elongation deformation. Gage length was measured by using a micrometer measuring the distance between two tick marks previously inflicted on the bar. Following the measurements, load cell and the extensometer were calibrated so the proportionality constant and the calibration constant could be determined. Preceding the calibration, test for A36 steel specimen was ready. The bar in the cell was loaded and we ran the test mechanism until failure. A second test for the cast iron sample was done as repeating the same process. After the testing was complete, the new length between the two reference points (final gage length) and the diameter of the specimen after the failure were measured. The two different materials were tested the same way. The data of load versus elongation were collected in excel file.

Table 5.1 Equipment for present experiment

Experiment Equipment	Description
Universal Testing Machine	Major machine for tensile test. Common components include: Load frame, load cell, cross head, output device etc.
Extensometer	Device used to measure changes in the length of a sample
Calipers	Device used to measure the distance between two opposite sides of an object

5.1 Calculating the Engineering Stress and Strain

To calculate the engineering stress and strain, we used extensometers up until necking, which measured the strain induced on the sample. The diameter of the gage on the sample was measured using calipers, and from there the area was calculated using Equation 5.1.1. The engineering stress is a function of the force applied and the original cross-sectional area of the gage of the sample. Using Equation 5.1.2, the engineering stress was calculated. P denotes the tensile force applied to the specimen [5].

$$A_0=\pi(\frac{D_0}{2})^2 \qquad \text{(Equation 5.1.1)}$$

$$\sigma = \frac{P}{A_0} \qquad \text{(Equation 5.1.2)}$$

5.2 Determining the Modulus of Elasticity and the Yield Stress

The modulus of elasticity and the yield stress was calculated for all samples. To find the modulus of elasticity, a small portion of the stress-strain curve was plotted to only include the linear region around zero strain. The slope of the graph at this point is the modulus of elasticity for that material. Excel was used to plot this portion of the stress-strain curve, and a trend line was added to best fit the data. Using the modulus of elasticity, the yield stress was also found. A line was plotted with the modulus of elasticity as the slope, but it was offset 0.2% of strain. The value of the stress where the two lines cross is the corresponding yield stress. This method is the standard 0.2% offset method used to find the yield stress.

5.3 Determining the Percent Reduction in Area, and Percent Elongation

The percent reduction in area and the percent elongation provide useful information about the ductility of the material. A more ductile material typically has a higher percent elongation up until fracture, and the reduction in area is greater as the material necks down before fracture. A brittle material will not elongate much past the yield strain, and the percent reduction of area is lower than for a ductile material. Equation 5.3.1 is used to calculate the percent reduction in area. is the area at fracture, and is the area of the cross section before testing, both taken from caliper measurements before and after each test. Elongation of length can be determined by Equation 5.3.2.

$$\mathrm{RA} = 100\% \left(\frac{\mathrm{A_0} - \mathrm{A_f}}{\mathrm{A_0}}\right) \qquad \text{(Equation 5.3.1)}$$

$$\text{Elongation of length} = 100\% \left(\frac{L_f - L_0}{L_0}\right) \qquad \text{(Equation 5.3.2)}$$

5.4 Determining the True Stress and the True Strain

The engineering stress and strain does not account for the reduction in area as the sample is pulled apart, nor does it account for strains besides the axial direction. The true stress and true strain show the actual stress and strain encountered during the tensile test. The true stress can be calculated at any point using Equation 5.4.1, but since the instantaneous area was not known for this test, other methods had to be incorporated. σ_T denotes the true stress. The tensile force is denoted by P, and the instantaneous area is shown by A [5].

$$\sigma_\mathrm{T} = \frac{\mathrm{P}}{\mathrm{A}} \qquad \text{(Equation 5.4.1)}$$

For strains below two times the yield strain, the true stress is well approximated by the engineering stress, shown by Equation 5.4.2. Between two times the yield strain and necking (the strain at the ultimate tensile stress), the true stress is approximated by Equation 5.4.3. σ is the engineering stress, and ε is the engineering strain. The true strain was calculated using Equation 5.4.4 [5].

$$\sigma_\mathrm{T} = \sigma \qquad \text{(Equation 5.4.2)}$$

$$\sigma_T = \sigma(1 + \varepsilon) \qquad \text{(Equation 5.4.3)}$$

$$\varepsilon_T = \ln(1 + \varepsilon) \qquad \text{(Equation 5.4.4)}$$

6. Results

Initial and final diameter values, gauge lengths and area values for A36 steel and cast iron are listed in Table 6.1.

Table 6.1 Initial and final geometries of test samples

Initial Values	Diameter D_0 (in)	Gauge length l_0 (in)	Cross-sectional area A_0 (in^2)
A36 Steel	0.505	1.990	0.2006
Cast iron	0.504	1.990	0.1996
Final Values	Diameter D_f (in)	Gauge length l_f (in)	Cross-sectional area A_f (in^2)
A36 Steel	0.296	2.809	0.0689
Cast iron	0.5039	2.005	0.1995

Load cells and extensometer displacements were recorded during the tests. All raw data were exhibited in Appendix. Stress of samples can be calculated by Equation 5.1.2. After calculation, the stress and strain curve of A36 steel is shown in Figure 6.1. Stress and strain curve of cast iron is shown in Figure 6.2.

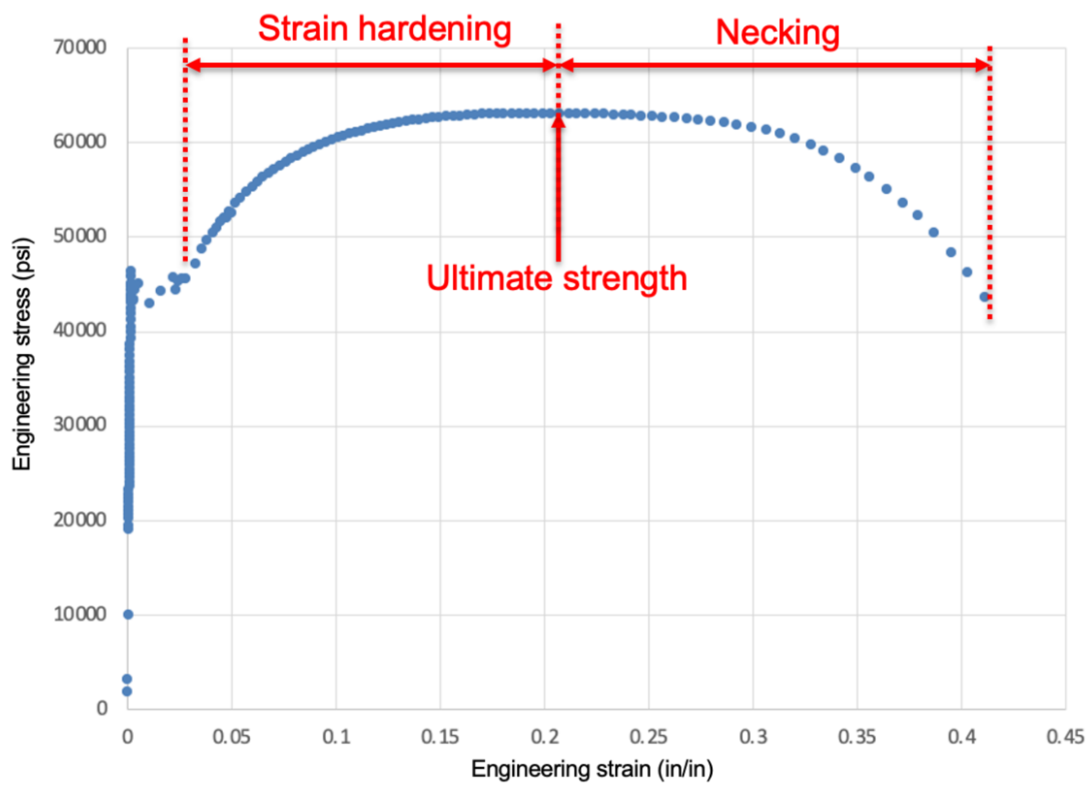

Figure 6.1 Engineering stress-strain curve for A36 steel

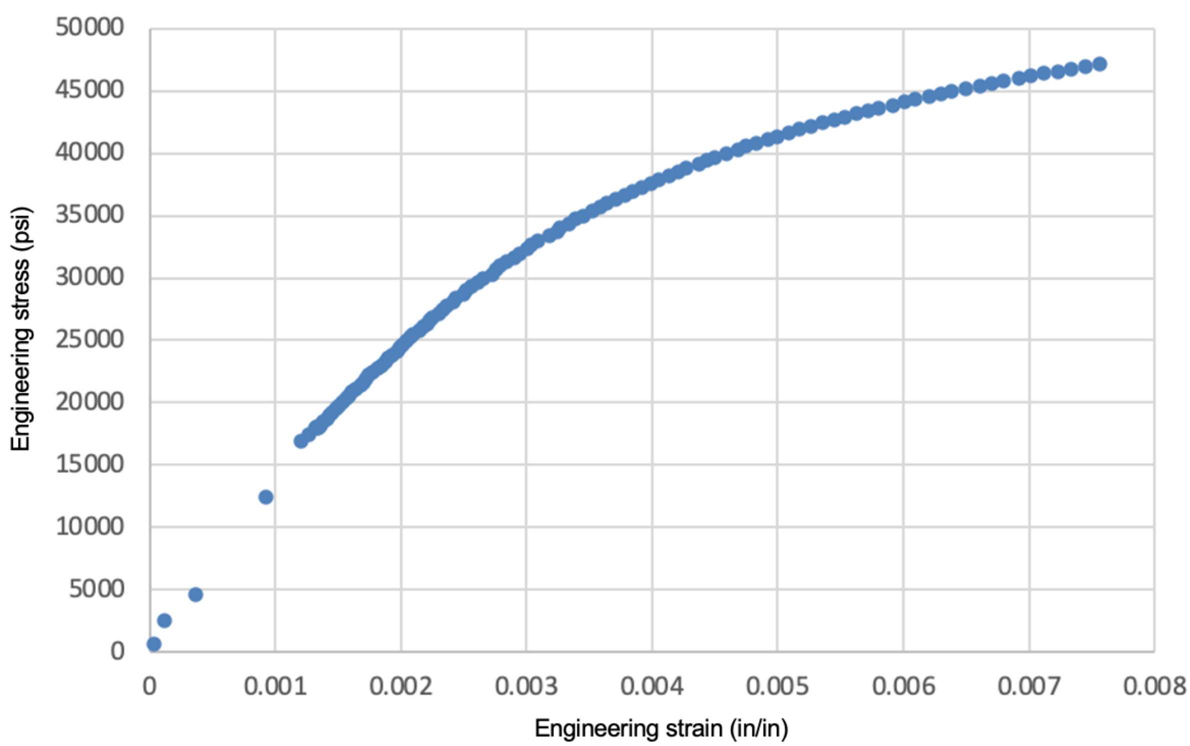

Figure 6.2 Engineering stress-strain curve for cast iron

The ultimate stress (maximum in the stress-strain graph) of A36 steel and cast iron samples can be determined from Figure 6.1 and 6.2 respectively. The ultimate stress for A36 steel was determined to be 63125psi, while that for cast iron was 47141.52psi.

The elastic modulus was determined from linear regression analysis of the experimental stress-strain data in the second linear region. This region is shown in Figure 6.3 along with the predicted regression line. Elastic modulus of A36 steel sample was determined to be 26580.96ksi (183GPa). This estimate is consistent with a typical value for modulus of A36 steel (~190 GPa). Stress-strain plot for cast iron sample was also analyzed. Elastic modulus of this sample was determined to be 12841.12ksi (88GPa).

The 0.2% offset yield strength is 43980.12 pounds per square inch (psi) for A36 steel and 42798.34 psi for cast iron.

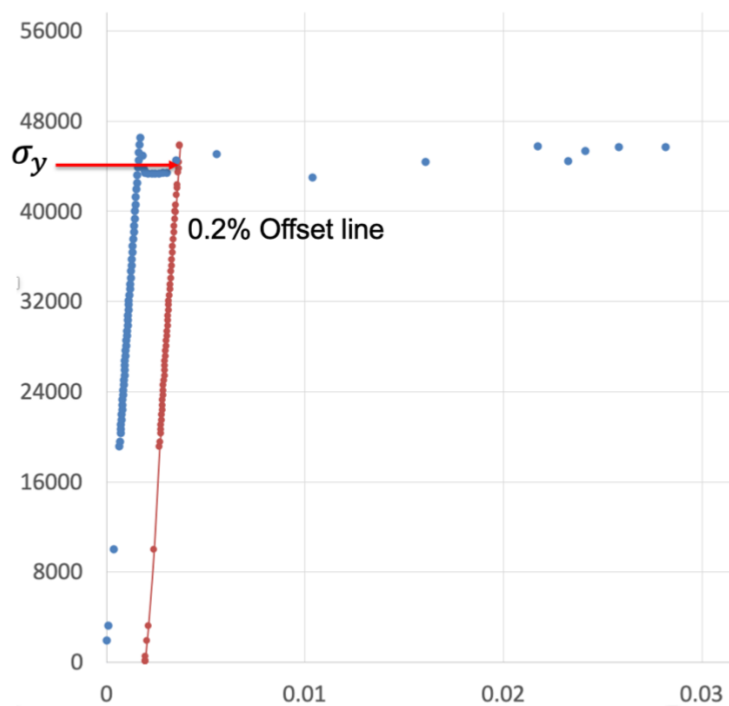

Figure 6.3 Low strain region of the stress-strain plot of A36 steel showing two linear regions and predicted regression line.

Ture stress and true strain can be calculated by Equation 5.4.3 and 5.4.4 respectively. True stress and true strain curve of A36 steel is shown in Figure 6.4. True stress and true strain curve of cast iron is shown in Figure 6.5.

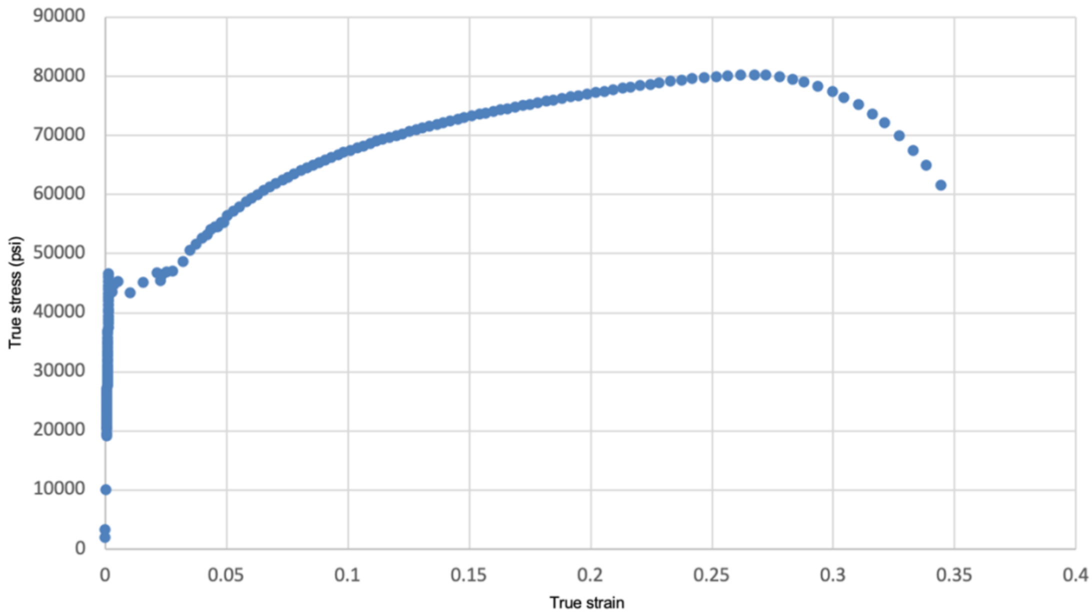

Figure 6.4 True stress-true strain curve for A36 steel

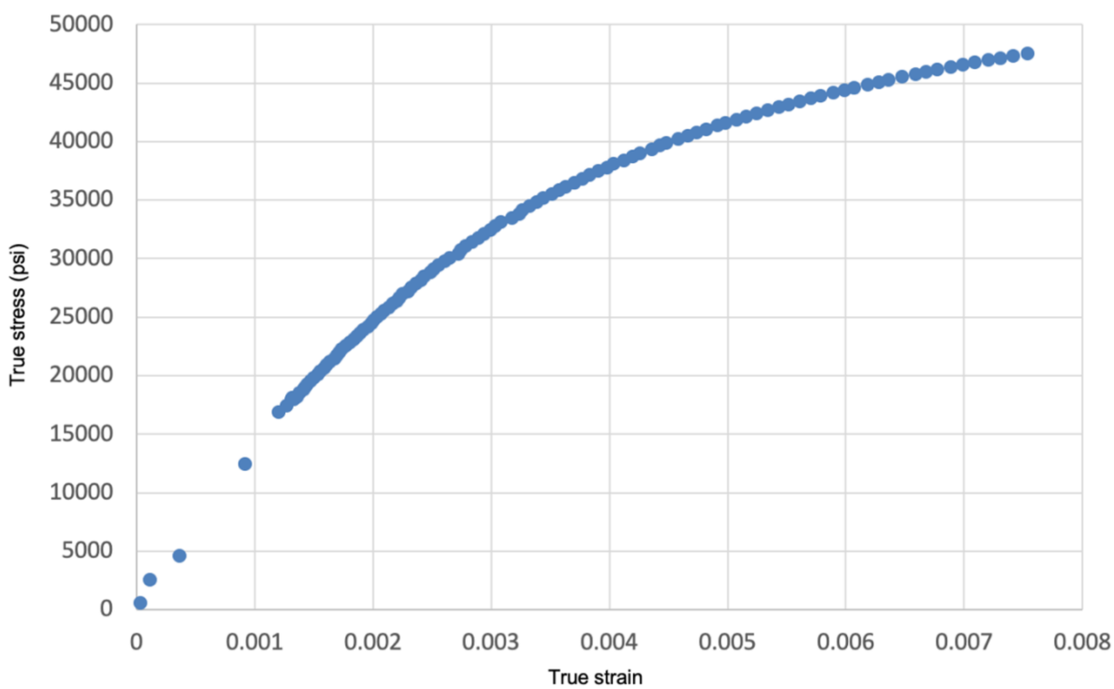

Figure 6.5 True stress-true strain curve for cast iron

Percent elongation and percent reduction of area of two samples can be calculated by Equation 5.3.1 and 5.3.2. A summary of elastic modulus, yield strength, ultimate strength, percent elongation and percent reduction of area of two samples was shown in Table 6.2. Ductility can be measured as a percentage of elongation or of diameter reduction. From Table 6.1 we can see A36 stretched in gauge length from 1.99 inches to 2.809 inches, a 41.2% increase. The cross-section area shrunk from 0.2006 to 0.0689 in^2, a 65.7% reduction. The cast iron, however, had a relatively small change in diameter, and its length changed from 1.99 inches to 2.005 inches, a 0.76% increase. This increase may even be zero, because the change is so small as to be within the margin of error. The fracture of the A36 steel occurred only after stretching and necking, a visible process. The point of fracture demonstrated a perfect cup and cone fracture surface. During the test, the A36 behaved much like predicted. The deformation could be seen, the stretch and the necking watched. Its fracture was expected at the time. The deformation was significant, with a measured ductility of 41.2%. The cast iron, on the other hand, no deformation could be witnessed visually, no necking occurred, and it fractured very suddenly away from the expected point of failure.

Table 6.2 Elastic modulus, yield strength, ultimate strength, percent elongation and percent reduction of area of A36 steel and cast iron samples.

Sample material	Elastic Modulus E (ksi)	0.2% Yield Strength σ_y (psi)	Ultimate Strength σ_u (psi)	Percent Reduction of Area	Percent Elongation
A36 Steel	26580.96	43980.12	63125	65.7%	41.2%
Cast iron	12841.12	42798.34	47141.52	~0%	0.76%

7. Conclusion

The uniaxial tension test was used to qualitatively evaluate the mechanical properties of A36 steel and cast iron under static load. From the results we could find the elastic modulus, ductility, yield strength and ultimate strength of two samples. The plastic range of the A36 was very long and where the most strain changing occurred. The fracture surface of A36 steel was the cup and cone type fracture while that for cast iron was basically flat. The data gathered in this lab concludes that the A36 steel was a ductile material, whereas the cast Iron was a brittle material. As future work, we recommend testing A572 steel and compare its results to A36 steel with respect to Tensile Strength (MPa), Yield Strength (MPa), Percent Reduction and Elongation (%). In addition to testing the thermal conductivity and expansion, since they also influence the material behavior under load.

8. Acknowledgments

We want to thank XXX for teaching and lecturing about the necessary theory in order to grasp the purpose and scope of this experiment. We would also like to thank XXX for helping perform the experiment.

9. References

[1]. Jonas McCurdy. *Fundamentals of Modern Manufacturing*. John Wiley & Sons, Inc. Slide resource: https://slideplayer.com/slide/3815309/.

[2]. World Material. *ASTM A36 Steel properties, modulus of elasticity, yield strength, material density, hardness and equivalent*. Retrieved from: https://www.theworldmaterial.com/astm-a36-steel/.

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10.Appendices

Appendix 1: Sample computations

This section will include sample computations that were done to reduce the data down to the final results.

Sample Areas:

$$A = \pi\left(\frac{D}{2}\right)^2$$

for A36 Steel. $A_o = \pi\left(\frac{D_o}{2}\right)^2 = \pi\left(\frac{0.505}{2}\right)^2 = 0.2006 \text{ in}^2$

$A_f = \pi\left(\frac{0.296}{2}\right)^2 = 0.0689 \text{ inch}^2$

Cast iron: $A_o = \pi\left(\frac{D_o}{2}\right)^2 = \pi\left(\frac{0.504}{2}\right)^2 = 0.1996 \text{ in}^2$

$A_f = \pi\left(\frac{0.5039}{2}\right)^2 = 0.1995 \text{ in}^2$

$$\text{Elongation \%} = \left(\frac{L_f - L_o}{L_o}\right) \times 100\%$$

$$\text{Reduce Area (RA\%)} = \left(\frac{A_o - A_f}{A_o}\right) \times 100\%$$

for A36 steel: $EL\% = \left(\frac{2.809 - 1.99}{1.99}\right) \times 100\% = 41.2\%$

$RA\% = \left(\frac{0.2006 - 0.0689}{0.2006}\right) \times 100\% = 65.7\%$

Cast iron: $EL\% = \left(\frac{2.005 - 1.99}{1.99}\right) \times 100\% = 0.76\%$

$RA\% = \left(\frac{0.1996 - 0.1995}{0.1995}\right) \times 100\% \approx 0$

Appendix 2: Experimental data

The following chart shows recorded data for A36 steel from the experiment.

Load Cell

Load (Lbs)	Extensometer (inches)	strain	stress (lbs)
7	-0.00004	-1.77963E-05	35.99307
8	-0.00001	-5.75096E-06	39.40289
7	-0.00001	-5.45658E-06	33.3602
7	-0.00002	-1.03471E-05	35.40759
6	-0.00001	-6.90571E-06	30.42785
116	0.00008	3.84455E-05	580.9927
507	0.00024	0.000119931	2541.557
918	0.00073	0.00036727	4597.991
2478	0.00184	0.000922761	12413.93
3366	0.00240	0.001208272	16865.12
3472	0.00253	0.001271963	17396.75
3608	0.00264	0.001325313	18074.58
3580	0.00262	0.001317002	17935.27
3580	0.00266	0.001337944	17935.83
3601	0.00268	0.001347115	18038.67
3622	0.00271	0.00136264	18144.52
3680	0.00275	0.001383587	18437.69
3736	0.00282	0.001416867	18715.56
3783	0.00285	0.001433203	18951.48
3838	0.00289	0.001452723	19226.12
3893	0.00295	0.001481151	19502.15
3941	0.00300	0.001505534	19746.87
3998	0.00306	0.001539082	20028.5
4054	0.00311	0.001562341	20308.34
4103	0.00316	0.001589576	20554.12
4159	0.00320	0.001610549	20839.04
4215	0.00326	0.001636924	21119.47
4265	0.00334	0.001679402	21366.19
4320	0.00338	0.001698035	21642.05
4376	0.00343	0.001723023	21925.21
4427	0.00347	0.001743675	22177.8
4485	0.00353	0.001773497	22468.93
4541	0.00361	0.001811941	22752.47
4591	0.00367	0.001844378	22998.77
4647	0.00373	0.001872786	23283.13
4704	0.00377	0.001896623	23566.86
4756	0.00383	0.001924729	23825.36
4812	0.00391	0.001966314	24110.11
4869	0.00397	0.001995587	24392.97
4915	0.00401	0.002015996	24625.8

4975	0.00406	0.00204038	24924.67
5033	0.00412	0.002070785	25215.63
5083	0.00418	0.002100052	25467
5141	0.00426	0.002142784	25755.07
5198	0.00433	0.002178376	26044.36
5248	0.00439	0.002208217	26292.03
5306	0.00443	0.002226316	26581.46
5363	0.00449	0.002254431	26867.38
5414	0.00459	0.002306087	27123.88
5477	0.00464	0.002333025	27440.66
5541	0.00472	0.002369777	27761.72
5596	0.00480	0.002413979	28034.04
5662	0.00486	0.00244037	28364.33
5727	0.00497	0.002495437	28691.56
5785	0.00501	0.002518662	28982
5852	0.00510	0.002561447	29320.76
5921	0.00520	0.002613958	29662.91
5980	0.00528	0.002653557	29958.47
6049	0.00543	0.002729274	30305.42
6118	0.00548	0.002754264	30652.48
6180	0.00555	0.002790672	30959.81
6250	0.00566	0.0028449	31312.94
6320	0.00577	0.002899498	31662.8
6382	0.00586	0.002944548	31974.19
6452	0.00597	0.003001898	32324.52
6521	0.00605	0.003041234	32670.55
6583	0.00615	0.003091195	32979.25
6655	0.00634	0.003185888	33341.68
6723	0.00646	0.003247248	33683.52
6786	0.00651	0.003270481	33995.9
6856	0.00664	0.003337359	34348.9
6926	0.00676	0.003394761	34701.24
6986	0.00687	0.003452128	34999.63
7056	0.00701	0.003522425	35349.48
7124	0.00713	0.003583252	35692.28
7183	0.00724	0.003640098	35984.87
7251	0.00739	0.003711501	36328.42
7318	0.00753	0.003783244	36662.56
7376	0.00765	0.003846382	36953.19
7443	0.00779	0.003914391	37289.76
7508	0.00795	0.003993617	37612.89
7563	0.00806	0.004049822	37891.73
7628	0.00823	0.004136527	38214.72
7693	0.00838	0.004211132	38541.03
7748	0.00850	0.004270204	38816.58
7808	0.00870	0.00436952	39118.47
7871	0.00884	0.004439799	39436.17

7924	0.00894	0.004494078	39697.2
7983	0.00914	0.004594743	39996.56
8042	0.00931	0.004680821	40291.01
8093	0.00945	0.004749454	40547.22
8150	0.00962	0.004833253	40830.79
8207	0.00981	0.004928236	41117.09
8255	0.00995	0.004998533	41356.42
8312	0.01013	0.005089753	41641.04
8367	0.01029	0.005172995	41918.05
8412	0.01048	0.005265296	42144.32
8467	0.01066	0.005357132	42421.84
8519	0.01085	0.005452963	42680.14
8562	0.01101	0.005535118	42894.27
8613	0.01120	0.00562891	43153.76
8665	0.01139	0.005722488	43412.02
8706	0.01155	0.005805093	43616.29
8754	0.01178	0.005917874	43857.4
8802	0.01196	0.006010199	44098.86
8842	0.01212	0.006092073	44299.4
8890	0.01235	0.006207325	44538.26
8936	0.01255	0.006304943	44770.41
8976	0.01271	0.006385805	44971.09
9020	0.01294	0.006500672	45190.69
9064	0.01316	0.006613087	45409.65
9100	0.01334	0.006702638	45588.72
9143	0.01354	0.006801922	45806.15
9185	0.01377	0.006917201	46018.7
9220	0.01396	0.007013683	46190.13
9261	0.01417	0.00711958	46396.59
9299	0.01440	0.007234352	46589.54
9333	0.01460	0.007335586	46759.68
9372	0.01482	0.007445203	46953.06
9409	0.01506	0.007565774	47141.52

The following chart shows recorded data for cast iron from the experiment.

Load (Lbs)	Displacement (inches)	strain	stress (lbs)
7	-0.00004	-1.77963E-05	35.99307
8	-0.00001	-5.75096E-06	39.40289
7	-0.00001	-5.45658E-06	33.3602
7	-0.00002	-1.03471E-05	35.40759
6	-0.00001	-6.90571E-06	30.42785
116	0.00008	3.84455E-05	580.9927
507	0.00024	0.000119931	2541.557
918	0.00073	0.00036727	4597.991
2478	0.00184	0.000922761	12413.93
3366	0.00240	0.001208272	16865.12
3472	0.00253	0.001271963	17396.75

3608	0.00264	0.001325313	18074.58
3580	0.00262	0.001317002	17935.27
3580	0.00266	0.001337944	17935.83
3601	0.00268	0.001347115	18038.67
3622	0.00271	0.00136264	18144.52
3680	0.00275	0.001383587	18437.69
3736	0.00282	0.001416867	18715.56
3783	0.00285	0.001433203	18951.48
3838	0.00289	0.001452723	19226.12
3893	0.00295	0.001481151	19502.15
3941	0.00300	0.001505534	19746.87
3998	0.00306	0.001539082	20028.5
4054	0.00311	0.001562341	20308.34
4103	0.00316	0.001589576	20554.12
4159	0.00320	0.001610549	20839.04
4215	0.00326	0.001636924	21119.47
4265	0.00334	0.001679402	21366.19
4320	0.00338	0.001698035	21642.05
4376	0.00343	0.001723023	21925.21
4427	0.00347	0.001743675	22177.8
4485	0.00353	0.001773497	22468.93
4541	0.00361	0.001811941	22752.47
4591	0.00367	0.001844378	22998.77
4647	0.00373	0.001872786	23283.13
4704	0.00377	0.001896623	23566.86
4756	0.00383	0.001924729	23825.36
4812	0.00391	0.001966314	24110.11
4869	0.00397	0.001995587	24392.97
4915	0.00401	0.002015996	24625.8
4975	0.00406	0.00204038	24924.67
5033	0.00412	0.002070785	25215.63
5083	0.00418	0.002100052	25467
5141	0.00426	0.002142784	25755.07
5198	0.00433	0.002178376	26044.36
5248	0.00439	0.002208217	26292.03
5306	0.00443	0.002226316	26581.46
5363	0.00449	0.002254431	26867.38
5414	0.00459	0.002306087	27123.88
5477	0.00464	0.002333025	27440.66
5541	0.00472	0.002369777	27761.72
5596	0.00480	0.002413979	28034.04
5662	0.00486	0.00244037	28364.33
5727	0.00497	0.002495437	28691.56

5785	0.00501	0.002518662	28982
5852	0.00510	0.002561447	29320.76
5921	0.00520	0.002613958	29662.91
5980	0.00528	0.002653557	29958.47
6049	0.00543	0.002729274	30305.42
6118	0.00548	0.002754264	30652.48
6180	0.00555	0.002790672	30959.81
6250	0.00566	0.0028449	31312.94
6320	0.00577	0.002899498	31662.8
6382	0.00586	0.002944548	31974.19
6452	0.00597	0.003001898	32324.52
6521	0.00605	0.003041234	32670.55
6583	0.00615	0.003091195	32979.25
6655	0.00634	0.003185888	33341.68
6723	0.00646	0.003247248	33683.52
6786	0.00651	0.003270481	33995.9
6856	0.00664	0.003337359	34348.9
6926	0.00676	0.003394761	34701.24
6986	0.00687	0.003452128	34999.63
7056	0.00701	0.003522425	35349.48
7124	0.00713	0.003583252	35692.28
7183	0.00724	0.003640098	35984.87
7251	0.00739	0.003711501	36328.42
7318	0.00753	0.003783244	36662.56
7376	0.00765	0.003846382	36953.19
7443	0.00779	0.003914391	37289.76
7508	0.00795	0.003993617	37612.89
7563	0.00806	0.004049822	37891.73
7628	0.00823	0.004136527	38214.72
7693	0.00838	0.004211132	38541.03
7748	0.00850	0.004270204	38816.58
7808	0.00870	0.00436952	39118.47
7871	0.00884	0.004439799	39436.17
7924	0.00894	0.004494078	39697.2
7983	0.00914	0.004594743	39996.56
8042	0.00931	0.004680821	40291.01
8093	0.00945	0.004749454	40547.22
8150	0.00962	0.004833253	40830.79
8207	0.00981	0.004928236	41117.09
8255	0.00995	0.004998533	41356.42
8312	0.01013	0.005089753	41641.04
8367	0.01029	0.005172995	41918.05
8412	0.01048	0.005265296	42144.32
8467	0.01066	0.005357132	42421.84
8519	0.01085	0.005452963	42680.14
8562	0.01101	0.005535118	42894.27
8613	0.01120	0.00562891	43153.76
8665	0.01139	0.005722488	43412.02
8706	0.01155	0.005805093	43616.29

8754	0.01178	0.005917874	43857.4
8802	0.01196	0.006010199	44098.86
8842	0.01212	0.006092073	44299.4
8890	0.01235	0.006207325	44538.26
8936	0.01255	0.006304943	44770.41
8976	0.01271	0.006385805	44971.09
9020	0.01294	0.006500672	45190.69
9064	0.01316	0.006613087	45409.65
9100	0.01334	0.006702638	45588.72
9143	0.01354	0.006801922	45806.15
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9220	0.01396	0.007013683	46190.13
9261	0.01417	0.00711958	46396.59
9299	0.01440	0.007234352	46589.54
9333	0.01460	0.007335586	46759.68
9372	0.01482	0.007445203	46953.06
9409	0.01506	0.007565774	47141.52