Technical Memorandum

To: Prof. XXX
From: XXX, XXX, XXX
Subject: Lab1 Tensile test of different materials
Date:
Date of Experiment:

<u>Abstract:</u>

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, we simulated a tension type load where we fixed our button head round bar samples of A36 steel and cast Iron in such a way that that the sample could be pulled from both the top and bottom. Load experienced by the sample up until the point of failure and specimen's final length and diameter were recorded to develop a strain stress diagram. A36 steel experiences high deformation prior to failure, while on the other hand, cast Iron Steel experienced only a small deformation. The fracture surface of A36 was a perfect cup and cone structure. The cast iron, however, simply cracked and the surface was nearly flat. From these results, it can be seen that A36 is a ductile material, and cast iron is a brittle one.

<u>Introduction:</u>

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 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 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 tensile testing laboratory was conducted using a Universal Testing Machine (UTM). 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 1. Samples were already machined to the proper dimensions required for the test, according to ASTM standards. 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 behaviors of the material can be seen graphically. The following pages outline this information.

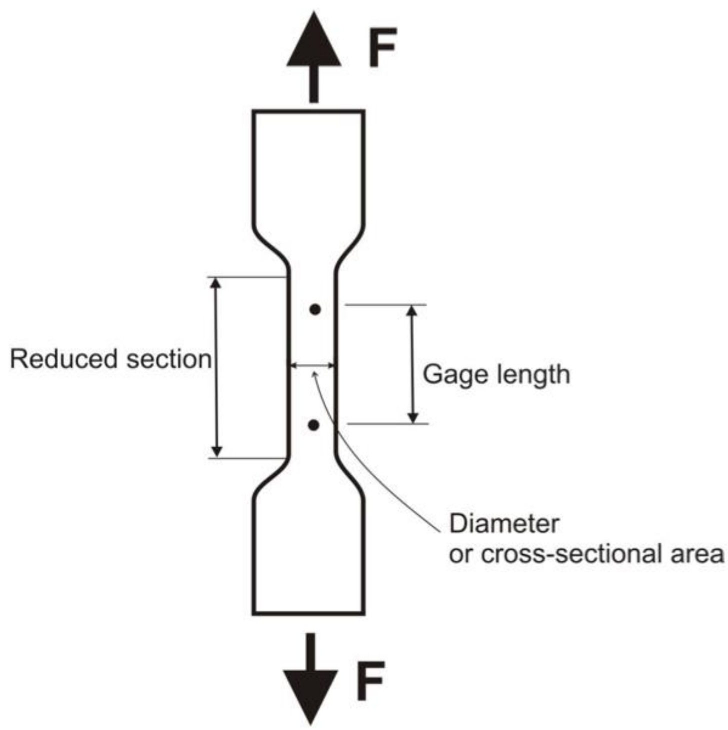

Figure 1. “Dog-bone” sample geometry used for tensile test

The rest of the memorandum will include 5 sections. The experimental procedure section will introduce equipment and steps to complete the lab. Results section will display the results of the experiment and present the plots and graphs of data. Discussion section will analyze data generated in the experiment. Question section will answer the specific questions listed in the lab manual. The final summary section will conclude the experiment and important results.

Procedure:

1) Experiment equipment

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

2) Summary of lab procedures
    a) Measure the dimensions (gauge length, initial diameter) of the sample.
    b) Use the marking jig and hammer to place two indentations in the narrow section of the specimen, centered, spaced exactly two inches apart.
    c) Load specimen into Instron Universal Testing Machine, tightened grips.
    d) Mount extensometer to center of specimen.
    e) Start machine, note graph of elastic range until extensometer would go no further.
    f) Stop machine, detached extensometer.
    g) Reset extensometer, continued experiment until fracture.
    h) After fracture, remove specimen.
    i) Measure final length and cross-sectional area of fractured specimen.

Results:

(1).

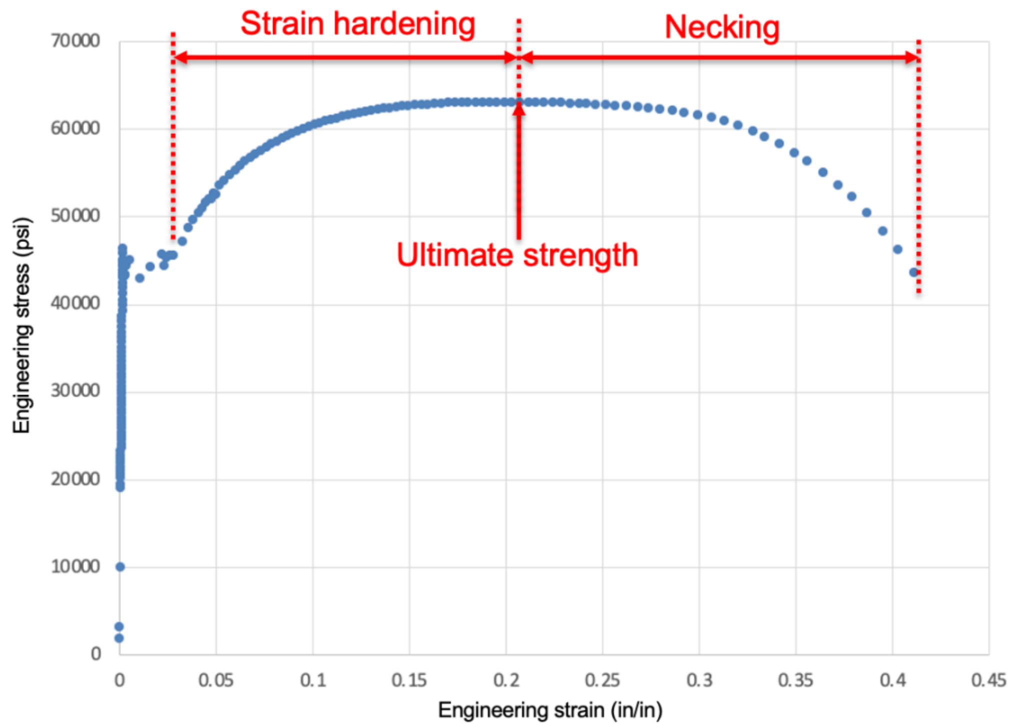

Figure 2. Engineering stress-strain curve for A36 steel

(2).

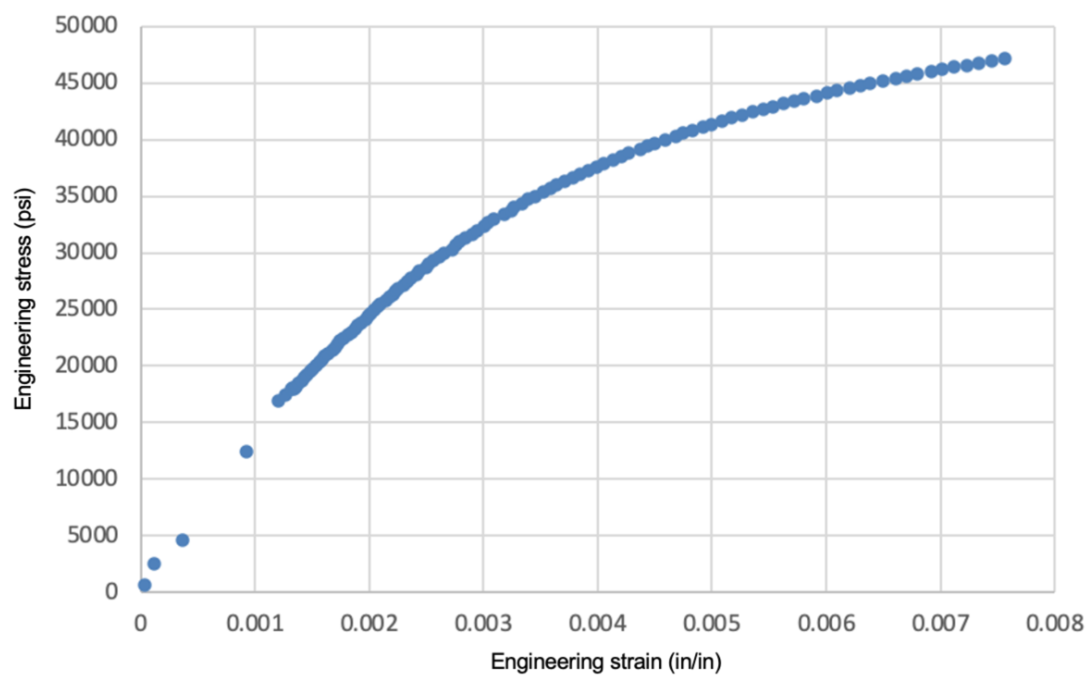

Figure 3. Engineering stress-strain curve for cast iron

(3).

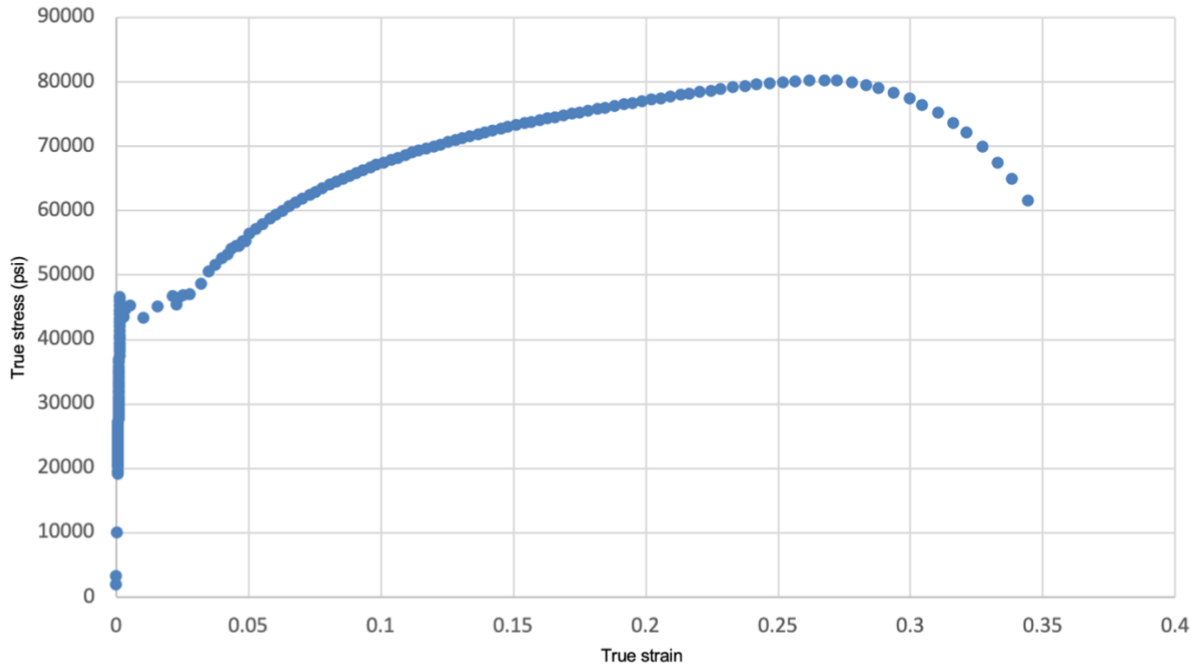

Figure 4. True stress-strain curve for A36 steel

(4).

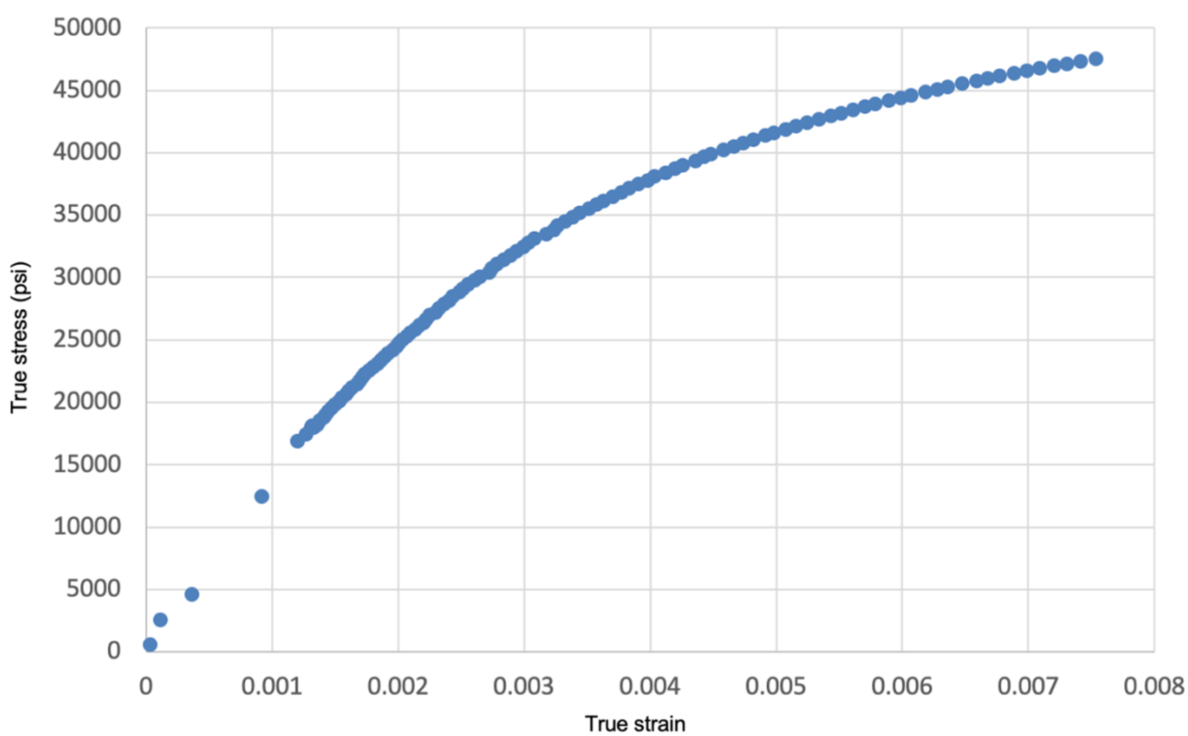

Figure 5. True stress-strain for cast iron

Table 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

Table 2. Mechanical properties for 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%

Discussion:

The ultimate stress (maximum in the stress-strain graph) for A36 steel was determined to be 63125psi, as seen in Figure 2, while that for cast iron was 47141.52psi (Figure 3). The elastic modulus was determined from linear regression analysis of the experimental stress-strain data (linear region in Figure 2 and Figure 3). 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) [1]. 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.

Ductility can be measured as a percentage of elongation or of diameter reduction. A36 stretched in gauge length from 1.99 inches to 2.809 inches, a 41.2% increase as seen in Table 1.

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. No measurable ductility could be measured or calculated. The data gathered in this lab concludes that the A-36 steel was a ductile material, whereas the cast Iron was a brittle material.

Questions:

1) Shear modulus (G) is defined as the ratio of shear stress to the shear strain. Bulk modulus (K) describes material's response to hydrostatic pressure (like the pressure at the bottom of the ocean). Poisson's ratio (υ) describes the expansion or contraction of a material in directions to the direction of loading. For small values of changes, υ is the amount of transversal expansion divided by the amount of axial compression. Most materials have υ values ranging between 0-0.5. These moduli are not independent, and for isotropic materials they are connected via following equations.

$$E = 2G(1+\upsilon) = 3K(1-2\upsilon) \qquad \text{(Equation 1)}$$

2) Fracture is the separation of a material into two or more pieces under the action of stress. There are two types of fractures:
    a) Brittle fracture (cast iron): no apparent plastic deformation takes place before fracture. In this lab, cast iron fracture surface was nearly flat and it had very less elongation before fracture.
    b) Ductile fracture (A36 steel): necking takes place before fracture. A36 steel experienced a high degree of plastic deformation before fracture, and its fracture

surface was the cup and cone shape. Ductile and brittle fracture surface is shown in Figure 6 [3].

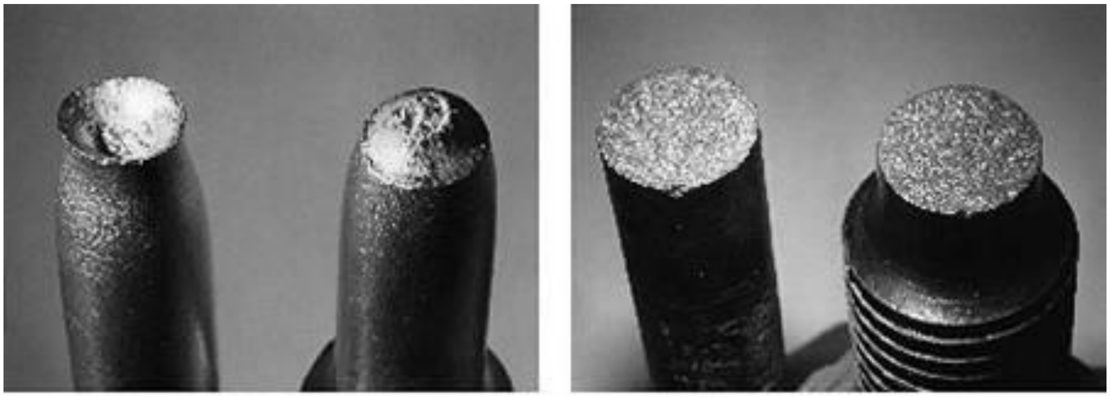

Figure 6. Left: ductile fracture surface of Al; Right: brittle fracture in mild steel [3]

<u>Summary:</u>

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 properties that will be measured or calculated include the stress, strain, true stress, true strain, modules of toughness, elasticity, and resilience, ductility, yield strength, and ultimate strength.

To test a material's strength and measure its inelastic properties, a half inch "button-head" round bar will be placed in a tension machine, which will apply a slowly increasing axial load until the bar fractures. Two marks 2 inches apart are made on the bar, and the change in their distance is constantly measured throughout the test.

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 A-36 steel was a ductile material, whereas the cast Iron was a brittle material. The accuracy of the experiment can be improved by increasing the number of tests of each kind of sample.

References:

[1]. Database retrieved from:

https://www.makeitfrom.com/compare/Grey-Cast-Iron/SAE-AISI-1018-G10180-Carbon-Steel

[2]. MAE XXX Laboratory Manual

[3]. Liron Ben. (Fall 2012). MD simulation of crack propagation in brittle crystals. Retrieved from: http://phelafel.technion.ac.il/~bbliron/Theory.html.

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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: $A_0 = \pi\left(\frac{D_0}{2}\right)^2 = \pi\left(\frac{0.505}{2}\right)^2 = 0.2006\ in^2$

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

Cast iron: $A_0 = \pi\left(\frac{D_0}{2}\right)^2 = \pi\left(\frac{0.504}{2}\right)^2 = 0.1996\ in^2$

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

$$\text{Elongation \%} = \left(\frac{L_f - L_0}{L_0}\right) \times 100\%$$

$$\text{Reduce Area (RA\%)} = \left(\frac{A_0 - A_f}{A_0}\right) \times 100\%$$

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
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3608	0.00264	0.001325313	18074.58
3580	0.00262	0.001317002	17935.27
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4975	0.00406	0.00204038	24924.67
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5083	0.00418	0.002100052	25467
5141	0.00426	0.002142784	25755.07
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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