CVG 2141

Civil Engineering Materials

Lab 1: Tension Test of Steel and Aluminum

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Lab Date: 22/9/17

Report Date: 6/10/17

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Abstract

This report shows how a tensile strength test can be used to formulate stress-strain curves for a metal. The metals are pulled apart and measured using calipers. The cross-sectional areas and gaps between markings are then measured and plotted to form stress-strain curves. These curves can then be observed to determine values such as yield strength, toughness, and modulus of elasticity. This gives answers as to which materials are the toughest, strongest, and most ductile between hot-rolled steel, cold-rolled steel, and aluminum.

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Objective

The objective of this lab is to use a tensile strength test to determine multiple characteristics of 3 samples of metal. The 3 samples are hot-rolled steel, cold-rolled steel, and aluminum and the characteristics to be determined are the stress-strain relationship, the modulus of elasticity, the elastic limit, the tensile strength, the rupture strength, the resilience, the toughness, the percentage of elongation, and the decrease in cross-sectional area.

Theoretical Background

The theory behind this lab is that a material will have multiple stages as more force is applied. A material will first go through the elastic phase where if the load is released, the material will return to its original length. Then the material will enter the plastic stage where the damage is permanent. The material will then each the strain-hardening area in which the material strengthens because of the plastic deformation. This area goes until the material begins necking and then eventually fails. The results from testing can be used to calculate the characteristics described in the objective using various formulas. The modulus of elasticity is calculated by the equation:

$$E = \frac{\sigma}{\varepsilon}$$

σ: Stress on the metal

ε: Strain on the metal

as well as by taking the slope of the linear portion of the stress-strain curve. The yield strength (σ_y) is the moment at which the metal changes from elastic deformation to plastic deformation. The proportional limit is where the stress strain curves stops being linear which means that in these graphs, the yield strength will have the same value as the proportional limit. The ultimate strength (σ_u) is the moment at which the material is experiencing the most amount of stress. The tensile strength at failure ($\sigma_{failure}$) is the stress the metal is experiencing when failure occurs. Resilience is the area under the elastic region of the stress strain curve. Toughness is the area under the entire curve. Percent elongation is calculated by the following formula:

$$\%\ Elong. = \left(\frac{Final\ Length - Initial\ Length}{Initial\ Length}\right)*100$$

Materials and Equipment

- Hot-rolled steel sample
- Cold-rolled steel sample
- Aluminum sample
- Universal testing frame
- Micrometric adjustment caliper
- Extensometer

Experimental Procedure

For each sample, determine the dimensions of the cross section near the center of the sample by using a caliper. Measure the actual distance between each marking on the metal which is marked at each 25mm. Insert the sample into the test machine. Apply an initial load (200-500 N). Set the test machine at the speed of service required. The load levels are 5000 N for hot-rolled steel and aluminum, and 10 000 N for cold-rolled steel. An extensometer will record the sample elongation (mm) and the applied load (kN) until it fails. Record the load and elongation at the yield point. Continue to apply load until the sample fails. Record the ultimate load and the failure load. After failure, measure the change in length between the reference distances as well as the dimensions of the cross section at failure.

Analysis of Data

Table 1: Original Dimensions for 3 Samples of Metal

	Hot Rolled Steel	Cold Rolled Steel	Aluminum
Width at Center (mm)	19.29	19.12	12.13
Thickness at Center (mm)	6.35	6.35	6.62
CSA (mm^2)	122.49	121.41	80.30
Gap length 1 (mm)	24.99	24.87	25.00
Gap length 2 (mm)	24.99	24.88	25.00
Gap length 3 (mm)	25.00	24.86	25.00
Gap length 4 (mm)	24.60	24.88	25.00
Gap length 5 (mm)	24.80	24.88	25.00
Gap length 6 (mm)	25.12	24.94	25.00
Gap length 7 (mm)	25.11	25.13	25.00
Gap length 8 (mm)	24.99	24.98	25.00
Gap length 9 (mm)	24.99	24.90	25.00

Table 2: Final Dimensions for 3 Samples of Metal

	Hot Rolled Steel	Cold Rolled Steel	Aluminum
Width at Center (mm)	13.06	15.40	7.38
Thickness at Center (mm)	4.36	5.09	5.50
CSA (mm^2)	56.94	78.39	40.59
Gap length 1 (mm)	28.56	25.65	26.51
Gap length 2 (mm)	29.09	26.16	26.77
Gap length 3 (mm)	29.27	27.65	26.87
Gap length 4 (mm)	29.59	30.75	26.47
Gap length 5 (mm)	37.78	30.75	26.87
Gap length 6 (mm)	30.05	26.07	26.87
Gap length 7 (mm)	30.00	26.20	27.04
Gap length 8 (mm)	29.68	26.05	27.25
Gap length 9 (mm)	28.59	25.73	30.17

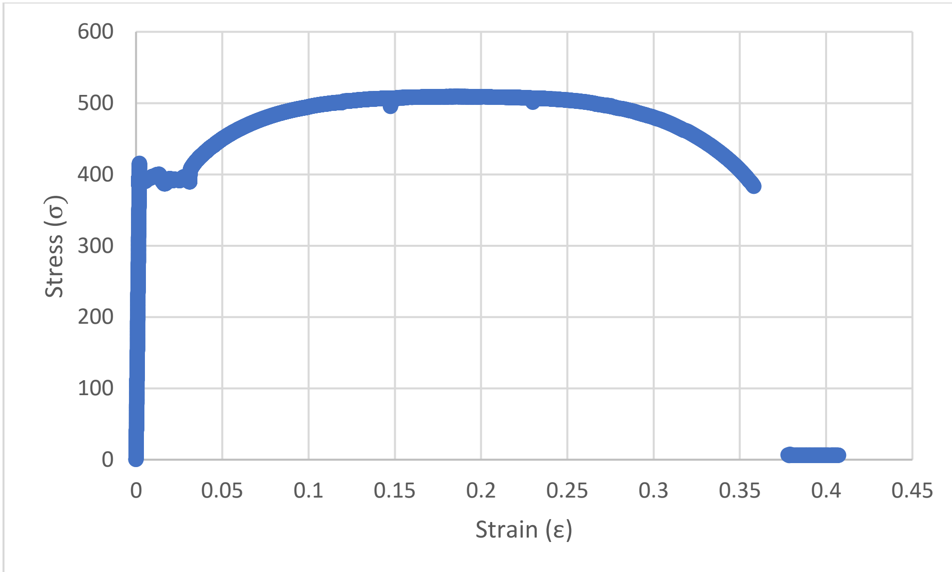

Figure 1: Stress-Strain Curve for Hot-Rolled Steel

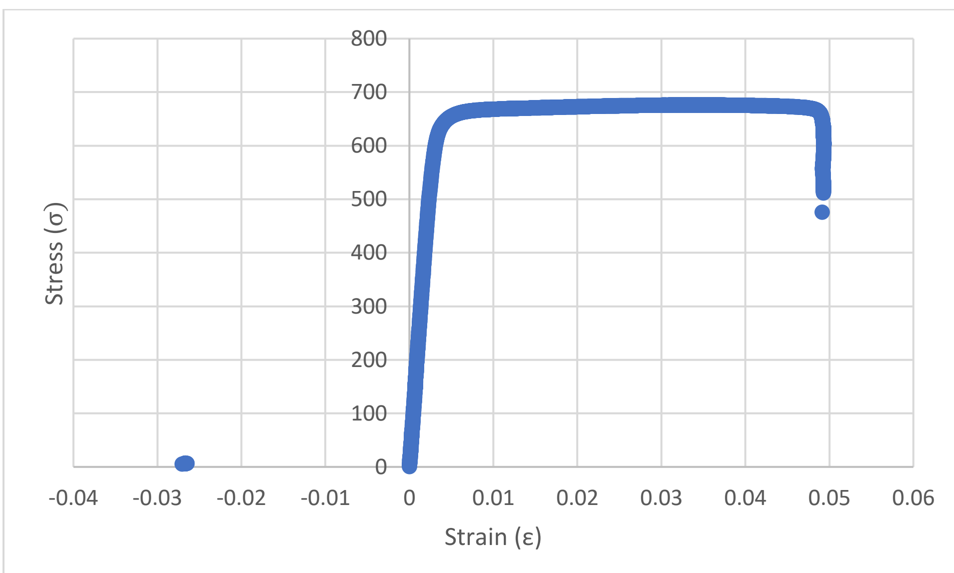

Figure 2: Stress-Strain Curve for Cold-Rolled Steel

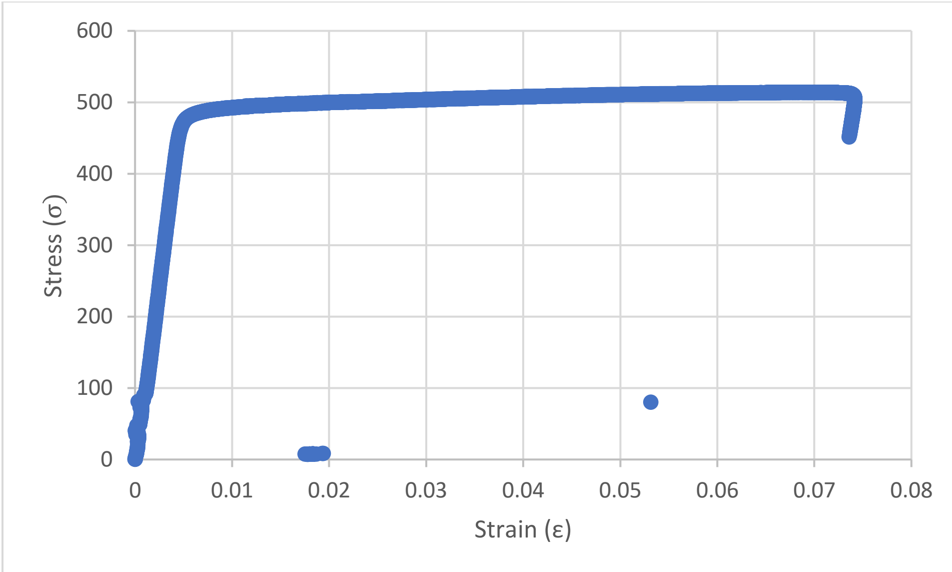

Figure 3: Stress-Strain Curve for Aluminum

Table 3: Characteristics of 3 Samples Obtained from their Stress-Strain Curves

	Hot Rolled Steel	Cold Rolled Steel	Aluminum
Modulus of Elasticity (MPa)	212410	191824	96014
Yield Strength (MPa)	407.01	638.76	481.81
Proportional Limit (MPa)	407.01	638.76	481.81
Ultimate Strength (MPa)	509.14	675.77	513.904
Strength at Failure (MPa)	383.32	660.50	510.22
Resilience	0.5	1.42	0.72
Toughness	80.35	60.27	38.8
% of Elongation	52.34	23.59	20.68
Reduction of CSA (mm^2)	**65.55**	**43.02**	**39.71**

% of elongation for Aluminum:

$$\%\ Elong. = \left(\frac{Final\ Length - Initial\ Length}{Initial\ Length}\right)*100$$

$$\%\ Elong. = ((30.17-25)/25)*100$$

% Elong.=20.68

CSA Reduction for Aluminum:

CSA Red.= CSA – CSA Final

= 80.30 – 40.59

= 39.71 mm^2

Discussion

The data obtained in the experiment provided stress-strain curves which made sense when compared to curves observed in class. Through the data collected from these curves, it was observed that cold-rolled steel has the strongest yield strength, ultimate strength, and strength at failure which shows that it is the strongest material out of the 3. The modulus of elasticity obtained for the 3 metals were very close to the acceptable values with the hot-rolled steel having an accepted value of 190000 MPa while the value obtained in the lab was of 212410 MPa which gives a percent error of 11.79% which is an acceptable error. The toughest material was hot-rolled steel while cold-rolled steel had the highest resilience. Hot-rolled steel also had the greatest percent elongation as well as the largest reduction of cross-sectional area. More observations that were made from the stress-strain curves were that hot-rolled steel was the stiffest material and that aluminum was the most ductile because it had the highest strain value of the 3 metals. The fact that aluminum is the most ductile goes along with what was discussed I class in that aluminum is a light metal therefore should be more ductile than a heavier metal like steel. There were some errors that came about while performing the measurement of the gap length of aluminum involving not resetting the calipers to the right value. Thus, the values of each gap are set to the expected value of 25.00 mm to avoid further errors. This was the only major error that occurred apart from there being certain negative values for the strain of cold-rolled steel because of zeroing issues with the measuring equipment. Both of these errors can be remediated by being more familiar with the equipment being used in the lab.

Conclusion

Finally, in this lab multiple characteristics of hot-rolled steel, cold-rolled steel, and aluminum were determined through a tensile strength test. These values helped observe that cold-rolled steel was the strongest material, hot-rolled steel was the toughest, and aluminum was the most ductile.