Experiment #1

Tension Test Lab

Mechanical Properties

Stress-Strain Curve

MECH 237-007

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Abstract

It is important to understand the mechanical properties of materials for engineers to construct safe projects that will withstand the test of time. So, the main objective of this lab is to observe the stress-strain curve for hot rolled steel and aluminum as well as to determine the mechanical properties for both metals. Afterward, these values should be compared to the reference values and the formulas that approximate the modulus of elasticity, resilience, and toughness. In order to complete the experiment, an Instron, an extensometer, a caliper, and a cylindrical piece of aluminum and steel with an initial length of 1 inch and an initial diameter of 0.5 inches are needed. After conducting the experiment, a stress-strain curve is shown with values that are placed onto an excel sheet with the extension vs load of the metal which was used to find and stress and the strain. It was referenced that the Modulus of Elasticity is about 29,000 ksi for hot rolled steel and 10,000 ksi for aluminum. In the experiment, however, the Modulus of Elasticity was shown to be 31,400 ksi for the hot rolled steel and 1624 ksi for aluminum.

Introduction

The objective of this experiment is to observe the relationship between stress and strain for hot rolled steel and aluminum. The values found on this Stress-Strain curve will be compared to the formulas that approximate elasticity, resilience, and toughness. Afterward, the mechanical properties of the materials will be determined, including the proportional limit, yield and ultimate strength, young's modulus, modulus of resilience, toughness, percent reduction of area, and the percent elongation in one inch. These values will then be compared to the results with reference values. Finally, the validity of the axial deflection formula with be assessed and the characteristics of tensile failure will be observed.

In order to develop safe engineering designs for all products, engineers must understand the behavior of mechanical properties for different materials. To do this, one important concept that should be understood is the relationship between stress and strain and the curve it produces. When metals are ductile (as is steel and aluminum), they produce a straight line in the stress-strain curve at low-stress levels according to Hooke's Law. The slope of this line is known as *Young's Modulus* or the *Modulus of Elasticity* (E). Therefore, Young's Modulus can be found using the equation which can be derived from Hooke's Law. As stress continues to increase, the linear portion of the stress-strain curve will end because the material will no longer "snap back" into its original shape. From this point on, if the stress continues to increase, the material will undergo permanent damage known as plastic deformation. Unlike plastic deformation, elastic deformation is the point at which the material can be stretched and will return to its original length. This point on the curve where the elastic deformation ends and plastic deformation starts is known as the *Proportional Limit* and the *Yield Point* and occurs because of the increasing stress. The strength at this point is known as *Yield Strength*. This is different from the *Ultimate Stress*, which is that the maximum amount of stress a material can take without failure. The maximum amount of energy that can be absorbed without plastic deformation occurring is known as the *Modulus of Resilience*. Toughness, however, is the amount of energy per unit volume that an object can handle without rupturing.

The engineering stress (σ) for any typical ductile material can be calculated by dividing the force (P) applied by the original cross-sectional area (A): $\sigma = P/A$. The engineering strain (ε), however, can be found by using dividing the elongation (*δ*) by the original length of the member (*L*): $\varepsilon = \delta/L$. Therefore, by using Hooke's Law, we can calculate the elongation by using the formula: $\delta = \varepsilon L = \sigma L/E = PL/AE$.

Procedure

Data Acquisition:

1. First measure initial diameter of the hot rolled steel.
2. Set up the tensiometer and calibrate the machine. Place the rod into the test apparatus.
3. Start the software to collect the data of the test.
4. Begin the test by initiating the test.
5. Once the rod fails, record the final diameter and save the data from the test as an excel file.
6. Repeat steps 1-5 for aluminum.
7. Create 3 graphs of data:
    a. Elongation vs. Force
    b. Strain vs. Stress
    c. Proportional limit of Strain vs. Stress (the graph should be a straight line)
8. Form the Proportional limit graph find:
    a. Proportional limit
    b. Yield Strength
    c. Ultimate Strength
    d. Modulus of Elasticity
    e. Percent Elongation
    f. Percent reduction in Area
    g. Modulus of Resilience
9. Repeat steps 7-8 for aluminum.

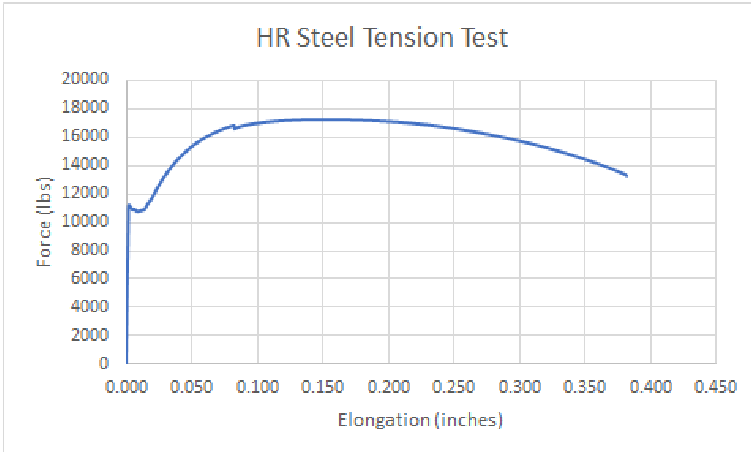
Laboratory Equipment: (See Appendix for visual representation of Equipment)

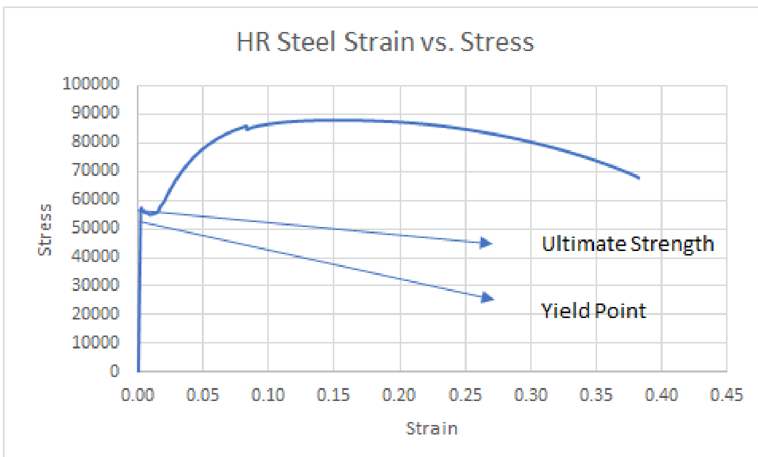
1. Instron Tension Testing Machine
2. Aluminum T6061 Rod
3. Hot Rolled Steel A36 Rod

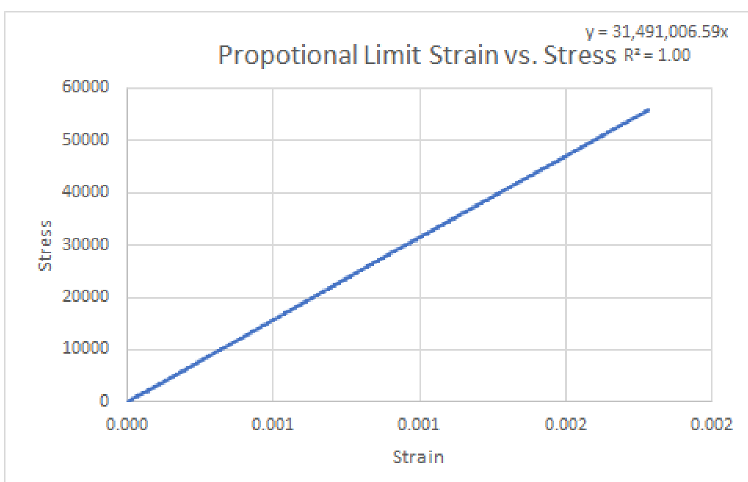
Safety Precautions:

1. Eye Hazard: Safety glasses required since sharp pieces may fly off of the material undergoing fracture
2. Crushing Hazard: Hands and other body parts should not be placed in the crush zone
3. Sharp Edges: Handle fractures specimens with caution to avoid any cuts since the specimen may have sharp edges

Data


HR Steel Tension Test
Force (lbs)
20000
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
0.000
0.050
0.100
0.150
0.200
0.250
0.300
0.350
0.400
0.450
Elongation (inches)

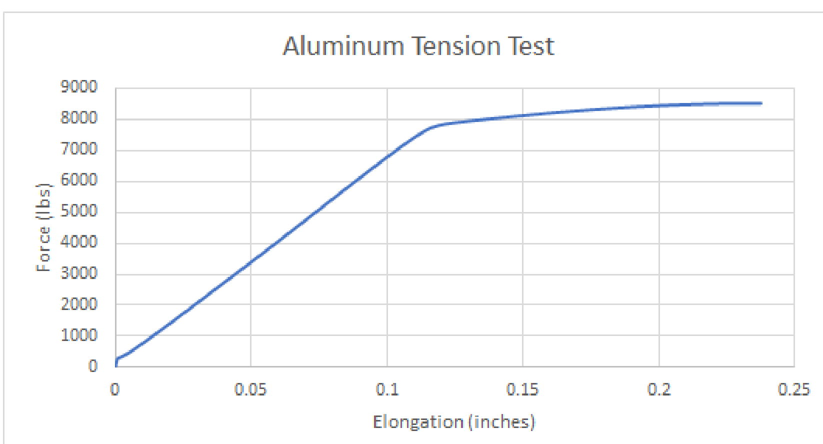

HR Steel Strain vs. Stress
Stress
100000
90000
80000
70000
60000
50000
40000
30000
20000
10000
0
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
0.45
Strain
Ultimate Strength
Yield Point

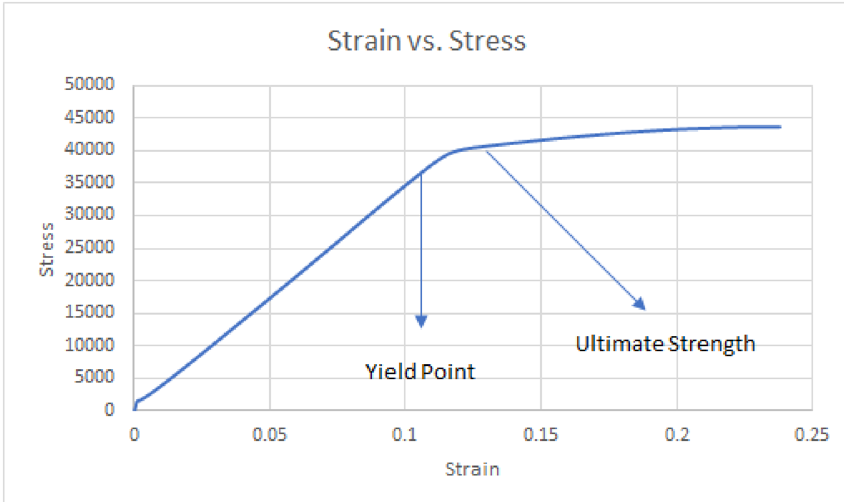

y = 31,491,006.59x
Propotional Limit Strain vs. Stress
R² = 1.00
Stress
60000
50000
40000
30000
20000
10000
0
0.000
0.001
0.001
0.002
0.002
Strain

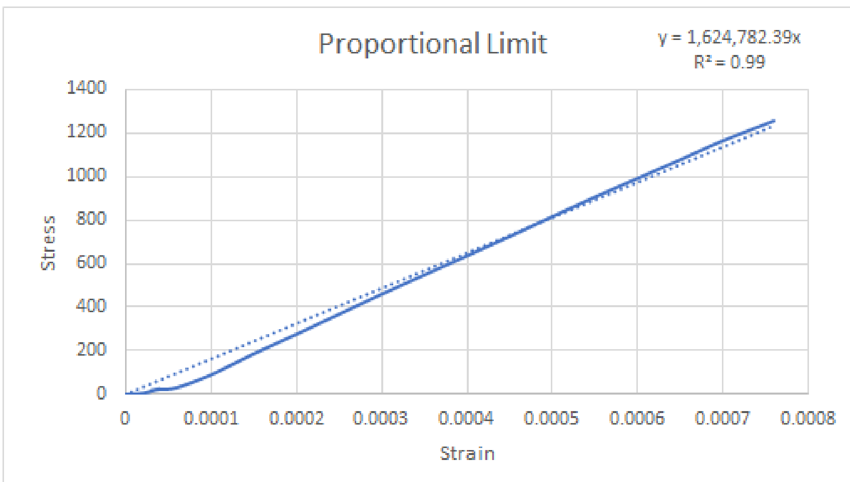
- Steel Data Points:

Measurements	Value
Initial Load	0 lbs.
Max Load	17284 lbs.
Initial diameter	.5 inches
Final diameter	.37 inches
Initial gauge length	1 inch
Final length	1.38 inches

Property	Experimental	Refrence	Calculated	% Error
Proportional Limit	56,554 psi		N/A	
Yield Strength	57,424 psi	36,300 psi	N/A	58.19%
Ultimate Strength	88,183 psi	58,000 psi	N/A	52.04%
Modulus of Elasticity	31400 ksi	29,000 ksi		8.28%
Modulus of Resilience	50.90	N/A	56.85	11.69%
% Reduction in Area	45.20%	45.24%	N/A	0.09%
% Elongation of gauge length	38.00%	22.00%	N/A	72.73%
▲=PL/AE	0.38 inches	N/A	0.00303	12441.25%







- Aluminum Data Points:

Measurements	Value			
Initial Load	0 lbs.			
Max Load	8536 lbs.			
Initial diameter	.5 inches			
Final diameter	.42 inches			
Initial gauge length	1 inch			
Final length	1.238 inches			
Property	Experimental	Referenc e	Calculate d	% Error
Proportional Limit	1255 psi		N/A	

Yield Strength	40100 psi	8000 psi	N/A	401.25%
Ultimate Strength	43550 psi	17,000 psi	N/A	156.18%
Modulus of Elasticity	1624 ksi	10000 ksi	N/A	83.76%
Modulus of Resilience	0.4769	N/A	3.20	548.02%
% Reduction in Area	29.40%	29.44%	N/A	0.14%
% Elongation of gauge length	23.80%	30%	N/A	20.67%
▲=PL/AE	.238 inches	N/A	0.01021	2231.05%

-

Analysis

From this lab we learned how to calculate various helpful data from a basic tensile test. We figured the stress, strain and modulus of elasticity from the force vs elongation graph. Our data for hot rolled steel was very similar to the references with our percentages ranging from 0% to 80%, which shows that this material was tested way better than aluminum's data. Our aluminum data had very high error percentages indicating that the test was not conducted in a right manner.

- Sample Calculations:
  - Steel:
  - Modulus of Resilience = (σ^2)/2E = 57,424psi/2(29,000ksi) = 56.85
  - **δ**(Steel)= PL/AE = 17,284lbs.(1in)/(.1963in^2)(29,000ksi) = .00303 inches
  - Ainitial = (pi/4)d^2 = pi(.5^2)/4 = .1963inches^2
  - Afinal = (pi/4)d^2 = pi(.37^2)/4 = .107inches^2
  - % reduction in area = (Ainitial-Afinal/Ainitial)*100% = (.1963-.107/.1963)*100% = 45.5%
  - % elongation = (Lf-Li/Li)*100% = (1.38-1/1)*100% = 38%
- The slope line for the modulus of elasticity was computed by using the trendline function in excel
- The modulus of resilience is calculated by finding the area under the proportional limit line. The formula used $A = 1/2bh$

Discussion and Conclusion

Discussion:

The objective and purpose of the experiment one was to educate students on the stress-strain relation for Aluminum T6061 and Hot Rolled Steel A36. Both the materials were placed under tension until failure. The first sample tested was the Aluminum T6061 and after graphing the stress vs strain graph, a modulus of elasticity of 1624 ksi with an ultimate strength of 43550 ksi. When the Hot Rolled Steel A36 was tested, it had a modulus of elasticity of 31,400 ksi with an ultimate strength of 88,183 psi. In comparison, it can be seen that the hot rolled steel A36 is far superior to Aluminum T6061 in both the aspects of modulus of elasticity and ultimate strength. Aluminum T6061 withstood a load of 1,255 psi before plastic deformation started to occur while hot rolled steel A36 withstood a load of 56,554 psi before plastic deformation occurred. Once again, the hot rolled steel A36 shows superior properties in comparison to aluminum T6061. Additionally, hot rolled steel A36 is more ductile than aluminum T6061 since it withstands more deformation until fracture. Hot rolled steel withstands 0.38 inches of deformation while aluminum A36 withstands 0.238 before deformation. The experimental values all indicate that hot rolled steel is stronger and more flexible material than aluminum T6061.

The calculations for the results section were straight forward, but when the experimental values were compared to the theoretical values, some of the percent errors were very small while others were unreasonably high. For example, the percent error for the modulus of elasticity for hot rolled steel A36 was 8.28%, which is a reasonable error. However, the percent error for the yield strength of hot rolled steel A36 was 58.19%, which is a high percent error. The group tried our best to follow the instructions and correct formulas, but it is possible that we could have made a mistake doing our calculations, even though we checked them multiple times.

Conclusion:

Although some of the percent errors may have been too high, the objective of the lab was confirmed through conducting the experiment. The stress-strain curves were observed for the two materials and the properties of the metals were determined. Additionally, the results were compared to the reference values to see how the experimental values compare to theoretical values. As a result of this experiment, students have a better understanding of the mechanical properties of materials in real life scenarios.

Bibliography

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Appendix

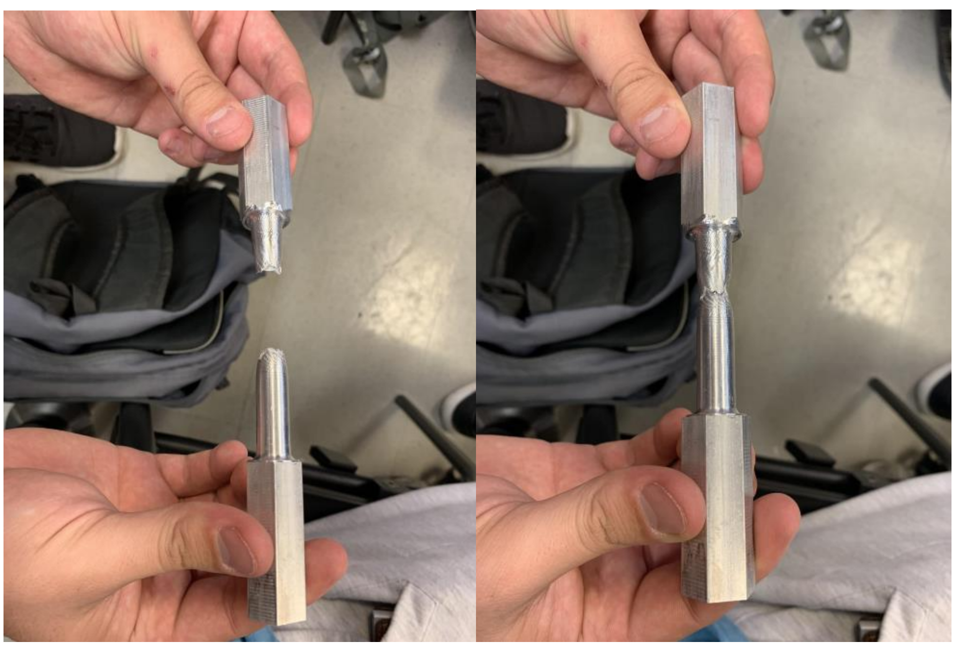
Calculations:

- **δ**(Aluminum)= PL/AE = 8,536lbs.(1in)/(.1963in^2)(10,000ksi)= .00434
- Modulus of Resilience = (σ^2)/2E = 8,000psi/2(10,000ksi) = 3.2
    - Aluminum:
- Ainitial = (pi/4)d^2 = pi(.5^2)/4 = .1963inches^2
- Afinal = (pi/4)d^2 = pi(.42^2)/4 = .1385 inches^2
- % reduction in area = (Ainitial-Afinal/Ainitial)*100% = (.1963-.1385/.1963)*100% = 29.44%
- % elongation = (Lf-Li/Li)*100% = (1.238-1/1)*100% = 23.8%
- % error = (Experimental- Reference/Reference)*100%
    - Steel:
- ((57424-36300)/36300)*100% = 58.19%
- ((88183-58000)/58000)*100% = 52.04%
- ((31400-29000)/29000)*100% = 8.28%
- ((56.85-50.90)/50.90)*100% = 11.69%
- ((45.24-45.20/45.24)*100% = 0.09%
- ((38.0-22.0)/22)*100% = 72.73%
- ((.38-.00303)/.00303)*100% = 12441.25%
- % error = (Experimental- Reference/Reference)*100%
    - Aluminum:
- (40100-8000)/8000)*100% = 401.25%
- ((17000-8536)/17000)*100% = 49.79%
- ((10000-1624)/1624)*100% = 515.76%
- ((3.2-0.4769)/0.4969)*100% = 548.02%
- ((29.40-29.44)/29.44)*100% = 0.14%
- ((23.80-30)/30)*100% = 20.67%
- ((0.238-0.00434)/0.00434)*100% = 5383.9%

Performing the Experiment:

Machine Used: Instron Tensile Testing Machine

Aluminum T6061 Fracture:



Steel A36 Hot Rolled Fracture: