UNIVERSITY OF COLORADO BOULDER

ASEN 1022: MATERIALS SCIENCE FOR AEROSPACE ENGINEERS

ASEN 1022 Lab: Tensile Test

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Tensile testing is a common procedure in materials manufacturing that provides useful information about strength, ductility, and failure properties. Tensile testing is performed by subjecting a specimen of a given material to a tensile load that gradually increases until the specimen fractures. Stress data is collected by the Universal Testing Machine while the strain data is collected by an extensometer which is attached directly to the specimen itself. We performed testing on two different materials, one ductile and one brittle, and used MATLAB to analyze the data and calculate final results for Young's Modulus, Yield Strength, and Ultimate Tensile Strength. Our testing yielded values of E, Y.S., and T.S. of 12660 ksi, 40.474 ksi, and 43.710 ksi for the ductile material and 10689 ksi, 20.237 ksi, and 21.311 ksi for the brittle material, respectively. These results most resemble the properties of Aluminum 6061 T6 and MIC 6 Aluminum and therefore these are the materials we believe we were given for this lab experiment.

Nomenclature

$T.S.$ = Ultimate Tensile Strength
$Y.S.$ = Yield Strength
E = Modulus of Elasticity
σ = Normal Stress
ϵ = Normal Strain

Equations

$$\sigma = \frac{P}{A} \tag{1}$$

$$\epsilon = \frac{l - l_o}{l_o} \tag{2}$$

$$E = \frac{\sigma}{\epsilon} \tag{3}$$

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I. Introduction

This lab focuses on the analysis of materials properties for the purpose of exposing students to the process of testing that is commonly used in the selection of engineering materials. The properties that we calculated, along with the testing and data processing methods we used, are important aspects of engineering. The basic skills gained during this lab can be applied to materials selection for much larger scale projects of all types.

The specific objectives of this lab were to determine the Yield Strength, Ultimate Tensile Strength, and Young's Modulus of two unknown materials in order to predict what these materials are. Yield Strength is defined as the point at which elastic deformation reaches a maximum and plastic, or permanent, deformation begins when additional loading is applied. Ultimate Tensile Strength is the maximum stress which a sample material can be subjected to. Beyond T.S. any additional loading will not result in a higher stress and the material will begin necking. Necking is a high concentration of both lateral and longitudinal strain that is located in a small region of the material that is being tested. Young's modulus is a measure of the elasticity of a material and is equal to the slope of the stress vs strain diagram in the linear elastic region. This lab report will discuss in further detail the process of our testing, methods of data analysis, and results of our testing.

II. Experimental Apparatus/Procedure

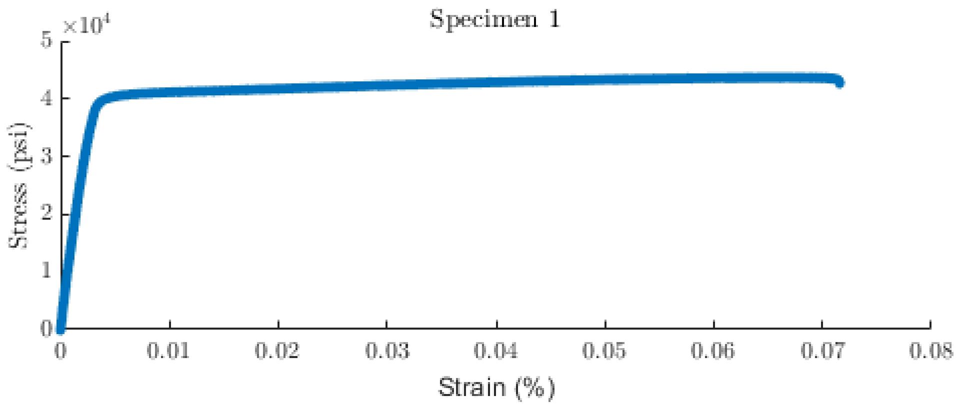
The purpose of this lab was to test the mechanical properties of unknown metals by analyzing the stress strain relationship and collecting data that yield different properties of the metals. In order to do this, metal must be experimentally tested and examined using a Instrone tensile testing machine and an extensometer.

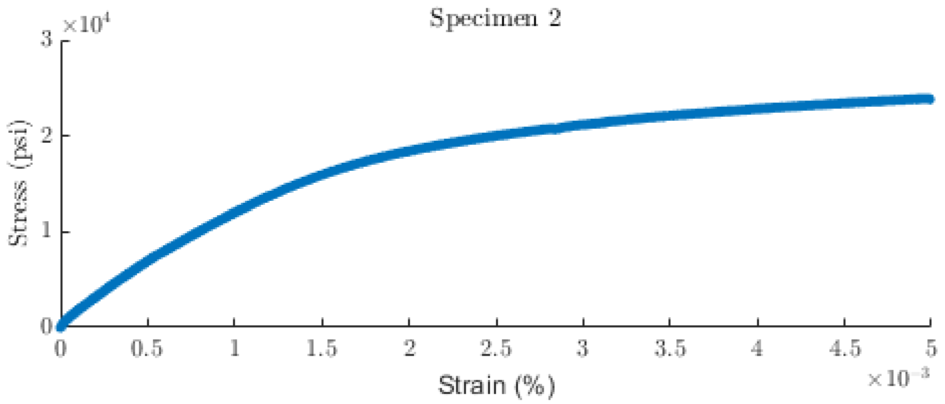
Measurements such as thickness and width of the neck of the metal is recorded before placing it in the tensile testing machine. These measurement are used to determine the stress σ of the metal. The metal is then placed in side the bottom V-clamps and tightened down. The extensometer which measures the elongation of the metal is then put on the sample. The extensometer and the machine must be zeroed before tightening the top clamp. Once the grips are set, zero pin is removed, and area is safe, the testing can begin. The tensile testing machine then applies a tensile force until the metal starts to neck and then eventually breaks. The data received from the tensile machine and the extensometer are then saved.

III. Analytical Procedure

Since the data from the experiment only includes the force and the elongation an assumption that needs to be made is that the cross-sectional area is constant. With that the stress can be found by using equation 1, the strain is found using equation 2. This provides a relationship between stress and strain and how that effects the Young's modulus. Young's modulus which is a measure of elasticity shows that as stress in increases then Young's modulus will increase where as an increase in strain, decreases Young's modulus. Young's modulus is found using equation 3. The yield strength was found using an offset of 0.2% strain of the slope of the elastic region. Finally, the tensile strength is found by looking at the maximum stress that occurs.

IV. Results





	Young's Modulus(ksi)	Yield Strength(ksi)	Tensile Strength(ksi)	Fractual Strength(ksi)
Specimen 1	12660	40.474	43.710	42.711
Specimen 2	10689	20.237	21.311	21.268
6061-T6 Aluminum	10000	40	45	NA
Aluminum 3003	10878	18.130	18.855	NA
Mic6 Aluminum	10300	15.200	23.9	NA
Aluminum 7000	10160	10 - 106	10.2 - 109	NA

The first two figures above show the stress vs. strain relationship of the two specimen. The data set for our first specimen came from our experiment, the second data set came from another group since the data from our experiment was extremely off (this was approved by Dr. Hussein). The table above shows the calculated values from the experimental data of the two specimen, as well as the 6061, 3003, Mic6, and 7000 aluminum. The data on the 7000 aluminum was given as a very large range which makes the prediction a bit harder. Additionally, there were no sources felt to be reliable enough to include for the "fractual strength" category of the four aluminum alloys, thus those cells of the table are left without data points. The four images on the next page show the visual results of our testing.

Fig. 1 Brittle Dog bone

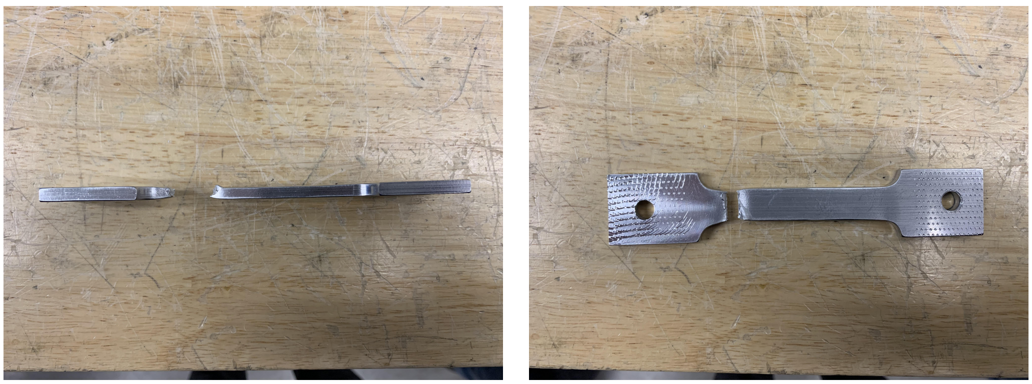


Fig. 2 Ductile Dog bone

V. Discussion

The ductile material that was tested most resembles 6061-T6 Aluminum. The brittle material that was tested most resembles Mic6 Aluminum.

When testing the data, there were a few points with erroneous data. These data points were at the beginning of the data set, where the universal test machine first started to apply a load onto the tested material. When the load was first applied, the V-clamps slipped causing the errors in the data. After time, the V-clamps were able to set into the material and avoid any slipping removing any erroneous data.

It is necessary to assume that the cross-sectional area remains the same. This was required because the change in the cross section area over time was not measured.

The Young's Modulus is a measure of the elasticity of a material. It differs for each material as different materials have different internal structures. The internal structure can very based on how and at what temperature the material was created. The modulus of elasticity for the ductile material is 12,660 ksi. The Young's modulus of 6016-T6 Aluminum is 10,000 ksi. The calculated modulus of elasticity makes sense because the material was able to take a large load while elongating, causing a large slope in the stress strain line. The modulus of elasticity for the brittle material that was tested is 10689 ksi. The Young's modulus of Mic6 Aluminum is 10,300 ksi. The calculated modulus of elasticity makes sense because the brittle material could only take a small load before elongating and eventually breaking, meaning there is a smaller slope in the stress strain line.

The yield strength for the ductile material is 40.474 ksi. The yield strength of 6061-T6 Aluminum is 40 ksi. There is only a 1.19% difference in the yield strength of these to materials. The yield strength for the brittle material is 20.237 ksi. The yield strength of Mic6 Aluminum is 15.200 ksi. There is only a 24.890% difference in the yield strengths of the material. While our ductile specimen data lines up accurately with the data for 6061 T6 aluminum, the brittle specimen data contains slight discrepancies with Mic6 aluminum. In the industry, significantly more tests would be run on a certain material, as using solely one specimen's data leaves considerable room for errors arising from specimen-specific imperfections. Given more samples of the brittle metal received and given more opportunities to test, our brittle data should eventually average out to the material properties for Mic6 aluminum with substantially less error.

The brittle material and ductile material have many different physical properties. The modulus of elasticity of the ductile material was 18.439% higher than the modulus of elasticity of the brittle material. This means that the ductile material would stretch less as the load applied increase compared to the brittle material. The yield strength of the ductile material was higher than the brittle material by 97.890%. This means that the ductile material can take a stress of 19.810 ksi more than the brittle material before experiencing elastic deformation. The tensile strength of the ductile material was 105.104% larger than the tensile strength of the brittle material. The ductile material could experience a stress of 22.399 ksi higher than the brittle material before experiencing permanent deformation. The ductile material was able to neck before breaking unlike the brittle material. The ductile material elongated by 1355.265% more than the brittle material.

VI. Conclusions

Metals have signature properties that pertain to its specific alloy. These properties can be determined experimentally through finding the cross sectional area of a specimen and the application of a measured load, followed by manipulation of elongation versus load data to find the stress-strain relationship, Young's Modulus, yield strength, and ultimate tensile strength.

The testing of materials, especially tensile testing, is an effective method of answering necessary questions about a structural material, namely the strength of the material and the amount of deformation expected given a certain load. Applications of tensile testing include the determination of tensile strength of various fasteners to the strengths of seat belts to the joint strengths of IV connectors. The importance of materials testing cannot be overstated; every major industry and beyond must be confident in their material's ability to uphold to the tasks they were designed for.

Acknowledgements

The authors would like to acknowledge and thank the ASEN 1022 teaching assistants for preparing the Universal Testing Machine and running the experiment as well as their assistance in answering any and all questions. Also acknowledged and thanked are the members of the 9am Friday lab group for their assistance in providing additional raw data.

References

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[2] ASEN 1022 Testing Procedure PDF

"ASEN 1022 Universal Testing Machine Test Procedure," March 15, 2019

[3] 6061 T6 Aluminum Alloy Material Properties

"6061 T6 Aluminum - Material Notes." Glemco.com, Glemco Inc.

[4] Aluminum 3003 Alloy Material Properties

"Aluminum/Aluminium 3003 Alloy (UNS A93003)." Azom.com, Azo Materials.

[5] Aluminum Alloy MIC 6 Material Properties

"Mic6 Aluminum Cast Plate Mechanical Properties." upmet.com, United Performance Materials.

[6] Aluminum 7000 Alloy Material Properties

"Overview of Materials for 7000 Series Aluminum Alloy." Matweb.com, MatWeb Material Property Data.

Appendix

```
function [load,exten] = getData(filename)
data = xlsread(filename);

load = data(:,2);
exten = data(:,4);
```

```
[~,Imax] = max(exten);

load = load(1:Imax);
exten = exten(1:Imax);

Lmin = min(load);
load = load-Lmin;

Emin = min(exten);
exten = exten-Emin;

end

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set(groot, 'defaulttextinterpreter', 'latex');
set(groot, 'defaultAxesTickLabelInterpreter', 'latex');
set(groot, 'defaultLegendInterpreter', 'latex');

clear,clc,close all

[load1,strain1] = getData('Data1.csv');
[load2,strain2] = getData('brittleOriginal.csv');

cross1 = 0.1835*0.492;
cross2 =  0.1645*0.4975;

stress1 = load1./cross1;
stress2 = load2./cross2;

Ymod1 = stress1(133)/strain1(133)
Ymod2 = stress2(430)/strain2(430)

YstrengthLine1 = Ymod1.*(strain1-.002);
YstrengthLine2 = Ymod2.*(strain2-.002);

[~,I] = min(abs(YstrengthLine1 - stress1));
Ystrength1 = stress1(I)
[~,I] = min(abs(YstrengthLine2 - stress2));
Ystrength2 = stress2(I)

Tstrength1 = max(stress1)
Tstrength2 = max(stress2)
Fstress1 = stress1(end)
Fstress2 = stress2(end)

subplot(2,1,1);
grid on
scatter(strain1,stress1,15,'filled')
ylim([0 50000])
title('Specimen 1')
xlabel('Strain (%)')
ylabel('Stress (psi)')
```

```
subplot(2,1,2);
grid on
scatter(strain2,stress2,15,'filled')
title('Specimen 2')
xlabel('Strain (%)')
ylabel('Stress (psi)')
ylim([0 3e4])
```