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TCM 218

Responses of bone material to ethanol soaking

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Abstract

Three-point bending is when an object is put under a lot of force in the middle of it while it is being held up by its endpoints. This is mostly to test the strength and the elastic modulus of the object. This research was used on skinned mice bones, specifically the right and left femurs and tibias. The four bones were put into a tester to see how much force it takes to break them and to see how much each bones bent while in the tester. The tests showed that the materialistic properties in the ethanol-soaked bone increased, but no other conclusion can be drawn accurately.

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Introduction

Three-point bending is when an object is put under a lot of stress in the middle while being held up by its endpoints. Three-point bending is most used for polymers so that the elastic modulus and strength can be tested. For strength, this testing puts the object under many newtons of force to see if it will break or not and, for elastic modulus, it's to see how much it can bend before it breaks.

In our research, we were using three-point bending by putting the left and right femur and tibias of mice and seeing how much force and how high the elastic modulus is when the bones break. To calculate the stress and strain these equations were used.

$$\sigma = \frac{FLc}{4I} \quad (1) \qquad\qquad \varepsilon = \frac{12cd}{L\text{^}2} \quad (2)$$

Equation 1 is used to calculate the stress of the bone while taking respect to the force put on the bone. It is then divided by four multiplied by the inertia in order to take into account the cross-section of the bones. Equation 2 is the strain upon the bones taken with respect to the displacement. Both of these equations are used in order to calculate the toughness, elastic modulus and stiffness the bones.

Methods and Materials

Four bones were laid out, two femurs, left and right, and two tibias, also left and right. The right bones were soaked in 70% ethanol and the left were soaked in PBS, phosphate-buffered saline. The bones were then measured for thickness and length and then put under bending and tested to see how much force it takes to break the bones and how much the bone would bend before breaking.

Results

The results shown were taken from a mechanical tester on rat bones in three-point testing. The right-side bones were soaked in PDMS, and the left side bones were soaked in an ethanol solution.

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TCM 218

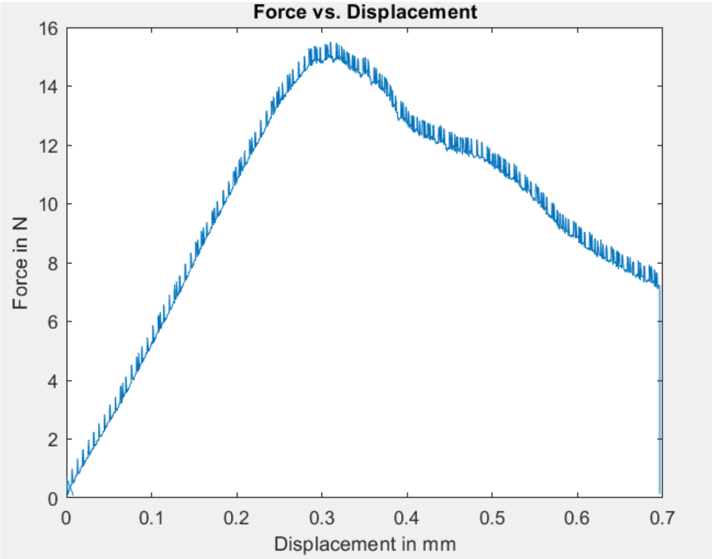

Figure 1: Force vs displacement in the Right femur

As seen in Figure 1, the maximum force is 15.5 newtons, however the bone broke at 7.15 newtons with a displacement at .69 mm with an elastic modulus of 38.507 N/mm.

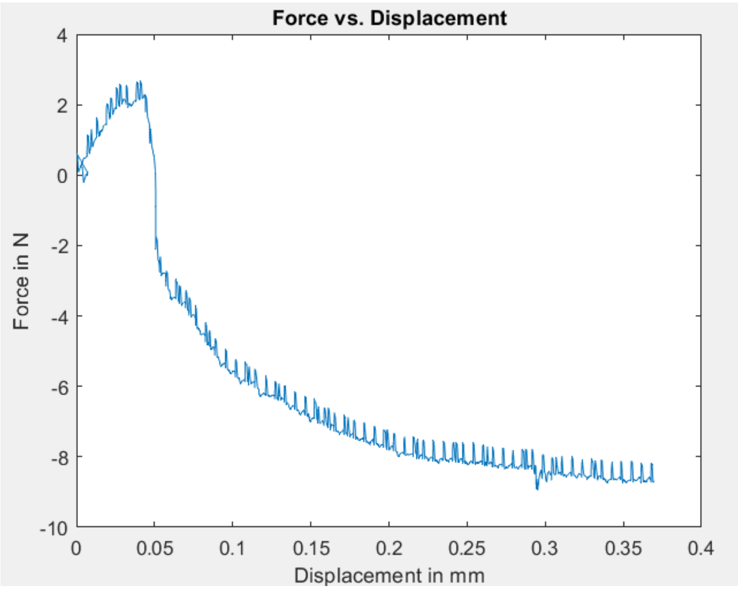

Figure 2: Force vs. Displacement in the Right Tibia

As seen in figure 2, the maximum force is 2.68 newtons with the failure force at -8.7 newtons at a displacement at .37 mm and an elastic modulus at 50.462 N/mm. This is an outlier due to the machine most likely not being set home correctly

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TCM 218

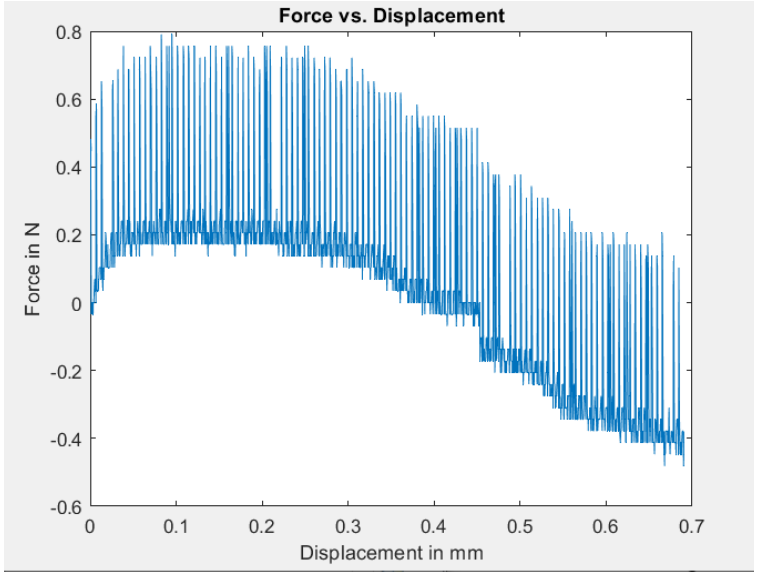

Figure 3, Load vs. time in the Left femur

As seen in figure 3, the maximum force is .791 newtons, and broke at .01 newtons at a displacement of .08 mm with an elastic modulus at 7.36 N/mm. This is an outlier due to it most likely breaking when it was placed on the tester, causing the tester to produce negative force numbers.

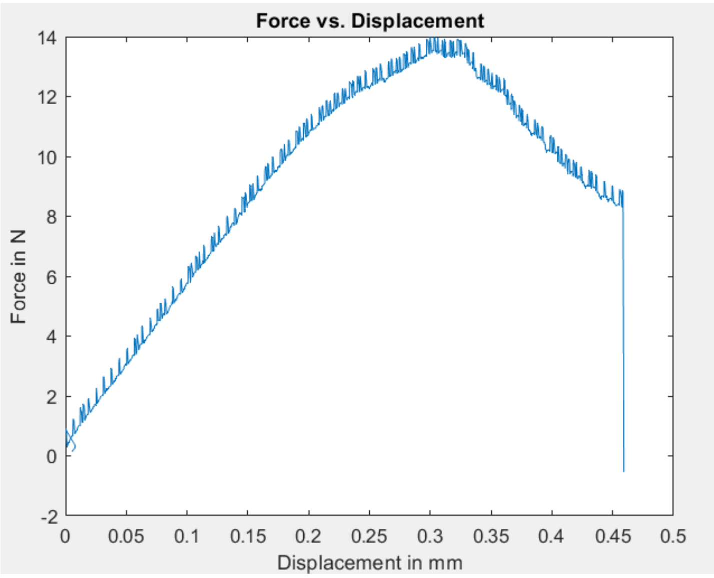

Figure 4, Force vs. Displacement in the Left tibia

As seen in figure 4, the ultimate force is 13.99 newtons with the failure force being at 8.8 newtons with the displacement being at .45 mm. The elastic modulus is 54.469 N/mm

Using all the collected data from the two bones, without taking the two outliers into account, the average ultimate force was at force was found to be 14.69 +/- 1.48 newtons with the failure point being at 8.54 +/- 6.5 newtons. The average displacement was at 1.03 +/- .65 mm. The average elastic modulus was 46.488 +/- 7.981 N/mm

Discussion

Though half the data was proven to be outliers, they can still be used to prove the hypothesis. The right bones were dried by ethanol which made them brittle, which makes them take more newtons of force to break compared to the bones that were soaked in PDMS. This is shown by how the right femur took almost 2 more newtons of force to break compared to the left tibia.

Another comparison can be about the sizes of the bone. This is seen in the fact that it took the femurs almost 3 more newtons, in the left and right sides, compared to the tibias. This is most likely due to the cross section of the bones, with the tibia having a lower cross section than the femur.

After drawing these conclusions, there was much evidence to determine that there was error in the experiment. This was most likely due to the bones breaking on the tester before the tests started, causing the tester to produce a negative force vs. displacement graph. Another issue could have been human error. This could be along the lines of stopping the tester too early, and then restarted, or the tester was started when it wasn't zero 'ed currently, causing the tester to believe it was going down and produced a negative force graph.

Appendix/Matlab

```
%Jacob Letterman
%10/1/2021
%BME 243
clc;
clear;
close all;

m=uigetfile('*.csv')
d1=readmatrix(m);
D=d1(:,3);
F=d1(:,2);

plot(D,F)
hold on
title('Force vs. Displacement')
xlabel('Displacement in mm')
ylabel('Force in N')
hold off
```

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TCM 218

```
disp('Please select the rightmost point if the linear
region')
[x2,y2]=ginput(1)
disp('Please select the leftmost point of the linear
region')
[x1,y1]=ginput(2)

slope=((y2-y1)/(x2-x1));
stiffness=slope;
[y_max, index] = max(F);
x_max = D(index);

area_RT=2.08;
area_LT=1.8;
area_RF=2.73;
area_LF=2.4;
length_RT=1.6;
length_LT=2.1;
length_RF=1.8;
length_LF=2;

ult_f=y_max;
ult_d=x_max;
ult_ss=y_max/area_RT;%LF can be replaced with the other
bones
ult_st=x_max/length_RT;
els=ult_ss/ult_st;
fail_ss=y2/area_RT;
fail_st=x2/length_RT;

Name=["Ultimate Force";"Ultimate Displacement";"Ultimate
Stress";"Ultimte Strain";"Stiffness"];
Numbers=[ult_f;ult_d;ult_ss;ult_st;stiffness];
Ult_1=table(Name,Numbers)

Name_2=["Failure Force";"Failure Displacement";"Failure
Stress";"Failure Strain";"Elastic Modulus"];
Numbers_2=[y2;x2;fail_ss;fail_st;els];
Ult_2=table(Name_2,Numbers_2)
```