Internal Forces Lab

Part 1: Tensile Yield Curve Test

You will be testing bolts made from different materials to see the yield curve of each material. The bolts you will be testing are M7x1.0, and each material is a different color.

<u>Procedure</u>

1. Measure each bolt length before starting any yield testing, since you will need the information. The bolts should all roughly be the same length. You can also calculate the cross sectional area of the bolts since this will be a constant throughout the experiment.

2. Start by placing one of the colored bolts in the bolt holder. Make sure that it is threaded into both the top holder and bottom holder such that the top and bottom holder are touching, or nearly touching.. The idea is going to be to pull it apart using the force from the jack, but we need the threads of the bolt to be engaged. This is a rather challenging task because the 3D printed bolts may be slightly larger than the threads.

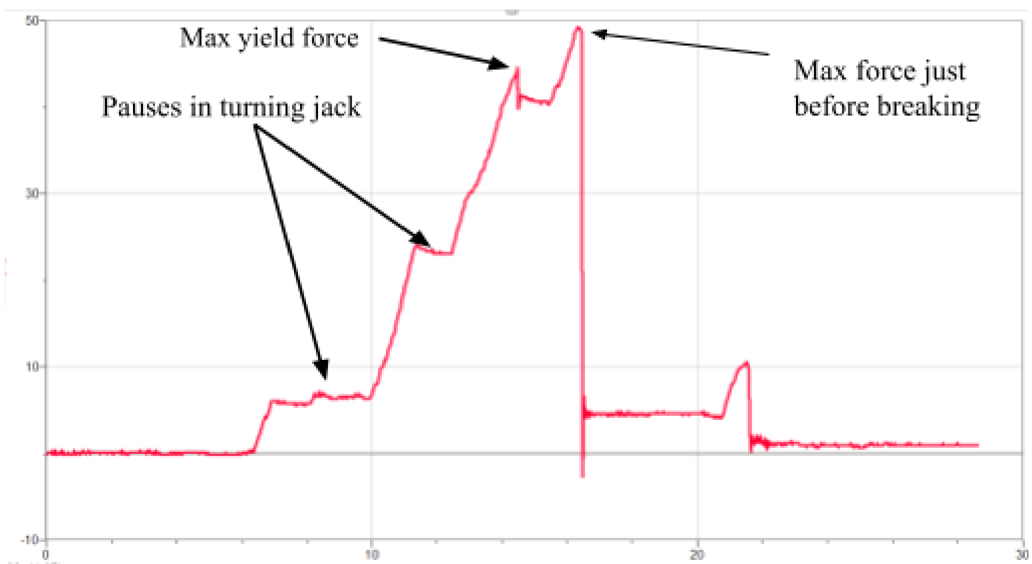
   Note: To thread a new bolt, you will have to undo the thin metal strips holding the top bolt holder.

3. Once you have the new bold threaded into the two holders, set up the jack to put a very slight amount of pressure on the force transfer arm. Also, pull down the caliper arm so it touches the top of the force transfer arm. This caliper will measure the length of the bolt at the break point (elongation in the data table below).

4. You will be using the program Logger Pro to do most of the data collection. Things to consider before applying force to the bolt.
   a. Zero out the force scale. Go to "Experiment" then down at the bottom there will be "zero…"
   b. The data collection time should be about a minute or more.
   c. Once Logger Pro collects data, do NOT hit "collect" a second time before you have collected your data because your current data will be erased.
   d. Take a picture of the yield curve right away once it has been created.

5. Start the data collection in Logger Pro and begin applying force to the bolt by twisting the scissor jack so it separates the bolt. This will not take a lot of force, so go slowly and smoothly for best results.

6. Once the bolt breaks completely, highlight the sections of the graph that are of interest. This will be an initial slope and a maximum yield point. The graph may look strange if you paused between turning the jack. An example is below.



7. To get the max force at the yield point, you must highlight the data where you believe it to be, then go to **Analyze>statistics** and it should display the correct information. Place the force into the appropriate data table below. Also, be sure to collect the elongation data before the caliper is moved. You will have to calculate the difference between the starting and final caliper reading. Be sure to have a member also calculate the stress and strain when all information is collected.

8. You will need to get the bolt out of the threads. To do this, you will have to undo the two metal bolts holding the thin metal strips. The top bolt holder will come loose and you can extract the broken 3D bolt. This may be difficult, so patience is key. Mr. Eckhart can assist if it gets too challenging.

9. Place a new bolt into the tester. The bolt must be threaded into both the top and bottom holder as the first bolt was. Repeat until you have all three materials tested.

Material: PLA (Blue)						
Bolt Size	**Force/Load at yield (lb.)**	**Cross Sectional Area ($in.^2$)**	**Stress (psi)**	**Original Length (in.)**	**Elongation (in.)**	**Strain**
M7x1.0	22.3	0.0573	389.18	1.169 in	0.174	0.149

Material: PETG (Clear)						
Bolt Size	**Force/Load at yield (lb.)**	**Cross Sectional Area ($in.^2$)**	**Stress (psi)**	**Original Length (in.)**	**Elongation (in.)**	**Strain**
M7x1.0	18.49 lb	0.0560	330.38 psi	1.182	0.044	0.0372

Material: ABS (Black)						
Bolt Size	**Force/Load at yield (lb.)**	**Cross Sectional Area ($in.^2$)**	**Stress (psi)**	**Original Length (in.)**	**Elongation (in.)**	**Strain**
M7x1.0	8.1 lb	0.0525	154.29 psi	1.184 in	0.0465	0.0393

Yield Strength Questions

1. Which color bolt had the highest yield strength?

Blue

2. Which material had the largest modulus of elasticity?

Clear (PETG) had the highest with

3. Look up the modulus of elasticity of PLA. Does it match with your modulus of elasticity? If there is a discrepancy, explain why this might be the case.

The modulus of elasticity of PLA is around 3500, which is slightly different from the 2612 that we found.This might be caused due to the elongation being overestimated and thus a higher strain and lower elasticity.

Part 2: Shear Strength Test

You will now test the shear strength of the bolts provided to you, which should range from M4x0.7 to M10x1.5, each with their own color. The purpose is to test the proportionality relationship of shear strength as the cross sectional area of the bolt increases. It is important to have each bolt made of the same material, so please double check that is true for the bolts you're testing.

Procedure

1. Measure the radius of the bolt and calculate the cross sectional area of the bolt for all of the different sizes, while another team member begins setting up the device.

2. Set up the device by threading in the smallest bolt to BOTH plates with the appropriate sized hole. Those will be the threaded holes in the plate, rather than the smooth holes in the plate. **Be sure to give the bolt consistent pressure when threading it into the hole.**

3. Once you have a bolt threaded through both plates, they should both be ready to be pulled a part by turning the nuts at the top plate.

4. Put a very small amount of tension on the scale by turning the 4 nuts on the top plate clockwise. Do your best to keep each rod roughly even with the others.

5. When a small amount of tension is detected on the force scale, zero the scale.

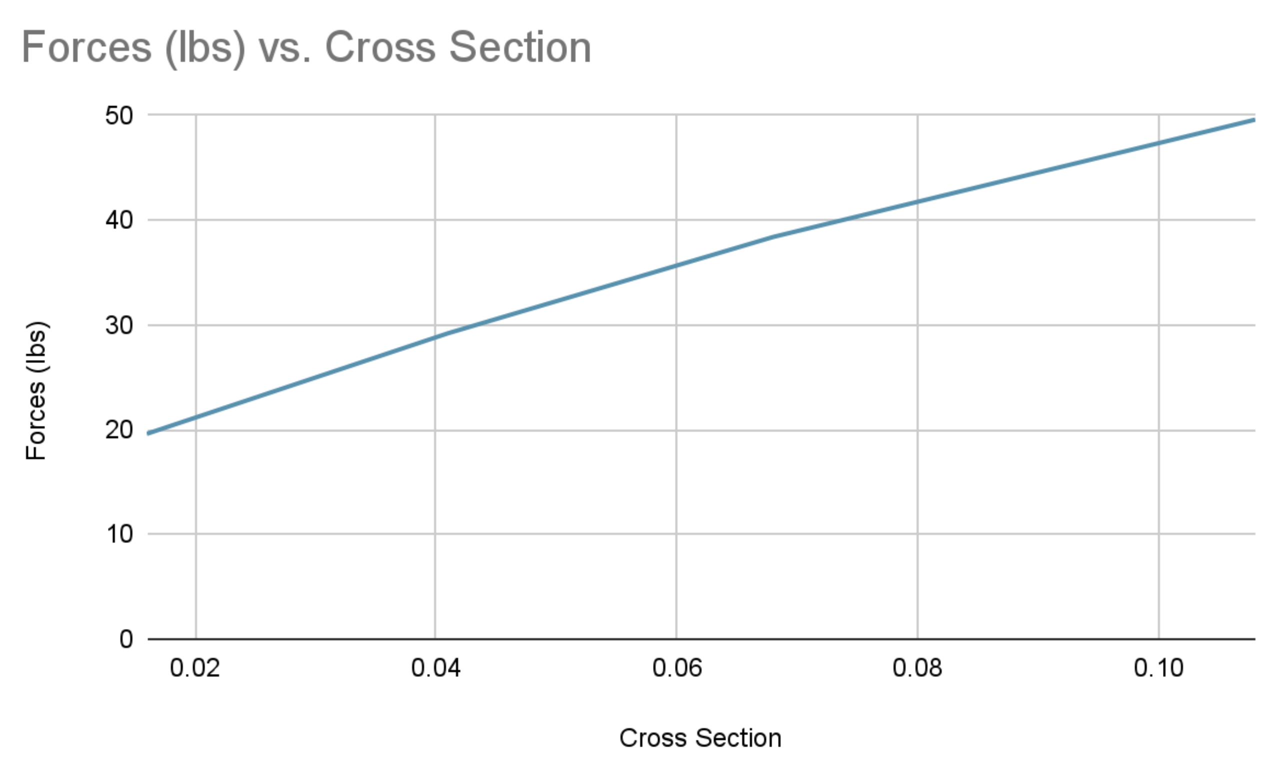
6. Begin turning the nuts on the top plate clockwise, with your best effort to keep them roughly even. A good strategy for this is to turn each nut a full turn, then go to the next nut.

7. Have one group member watch (or video) the force scale and record the maximum force shown on the scale. This is the shear force.

8. Go through the rest of the sizes in the same manner, one at a time. When you have finished, do your best to take out the broken bits of the 3D printed bolts. Let Mr. Eckhart know if you are unable to get any of the broken bits out.

Bolt Material	Bolt Size ID	Bolt Radius	Bolt Cross-sectional Area	Force needed to Shear (lb)
PLA	**M4x0.7 (do this one last)**	**0.0715**	**0.016**	**19.6 lb**
PLA	**M6x0.8**	**0.114**	**0.041**	**29.2 lb**
PLA	**M8x1.25**	**0.14705**	**0.068**	**38.4 lb**
PLA	**M10x1.5**	**.185**	**0.108**	**49.6lb**

9. Put the data into Google Sheets and create a graph of Shear Force vs cross sectional area for the bolt. Make the graph a scatter plot and place a line of best fit on the graph. Place the graph below.



Shear Force Questions

1. What trendline fits your data best?

A linear trendline

2. What is the equation of the trendline?

y = 325x + 15.3

3. Based on your graph, roughly what diameter bolt would you expect to need to withstand 200 lb of force?

(200 - 15.3)/325 = x
x = 0.568 cross section
pi(d/2)^2 = x
d = 0.85 in