TENSILE TESTING OF 3D PRINTED PARTS WITH VARYING INFILL PERCENTAGES AND PATTERNS

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Intro:

3D-printing is central to scientific applications in biology, mechanical engineering, and even rock mechanics. Strength of printed parts is an important consideration. We analyze the effects of different infill percentages and patterns on the Young's modulus and material strength.

Theory

- Stress S is defined as the applied force F divided by the area of cross-section A.

$$S = \frac{F}{A}$$

- Strain T is defined as the change in length of the object Δx divided by its original length L.

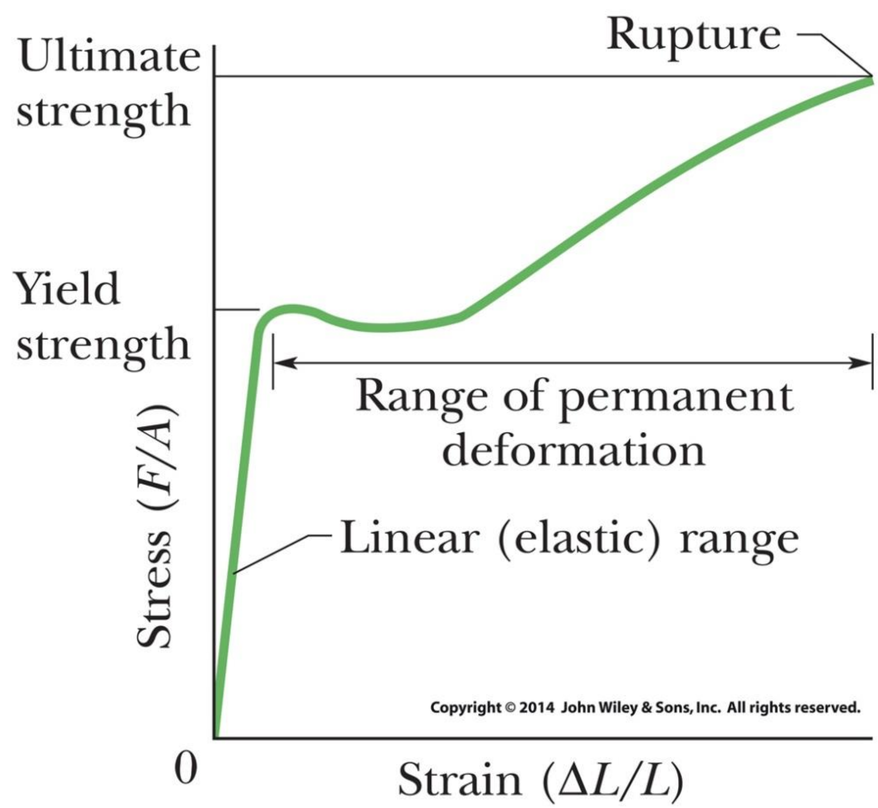
$$T = \frac{\Delta x}{L}$$

- The Young's Modulus E is the ratio of stress to strain.

$$E = \frac{S}{T}$$

- Ultimate strength is defined as the force F_B that breaks the part.

Idealized Visualization of Young's Modulus and Tensile Strength



3D – Printing Materials

- 3D – Printing Materials range from plastics to powders, resins to metals, ceramics to food.
- Most 3D-Printers use 'Fused filament fabrication (FFF)', which is printing by filament.
- Here are some common plastics used:
  - PLA (Poly-lactic Acid) – environmentally-safe, it is a biodegradable thermoplastic that is made of renewable resources.
  - ABS (Acrylonitrile butadiene styrene) – very safe and strong, and applications include car parts and Lego's.
  - PVA (Polyvinyl Alcohol Plastic) – water soluble polymer, used primarily for papermaking and textiles.

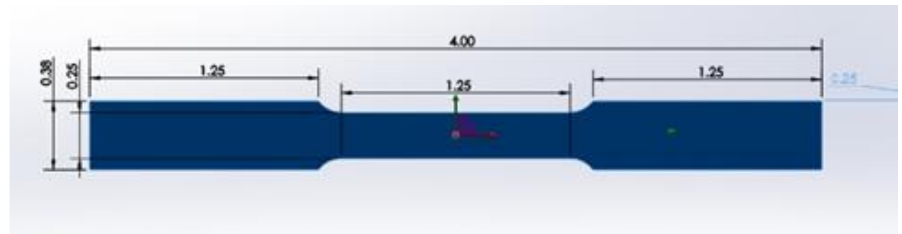
Source: http://www.3dprinterhelp.co.uk/what-materials-do-3d-printers-use/

Experiment

Procedure

1. Test strip placed in Dillon LW Tensile Test Machine.
2. Test strip centered and secured in the center of the clamps.
3. The force scale adjusted to the “0” mark.
4. Elongation knob rotated to extend the part by 0.0625 inches and recorded the force (lb.) on the part.
5. We kept rotating until the part broke.
6. Broken pieces removed and process repeated at three trials total for each set.

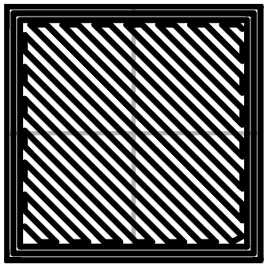
SolidWorks drawing of test part.



Tensile Test Machine and Apparatus

Rectilinear

Rectilinear infill pattern



Source: http://manual.slic3r.org/expert-mode/infill

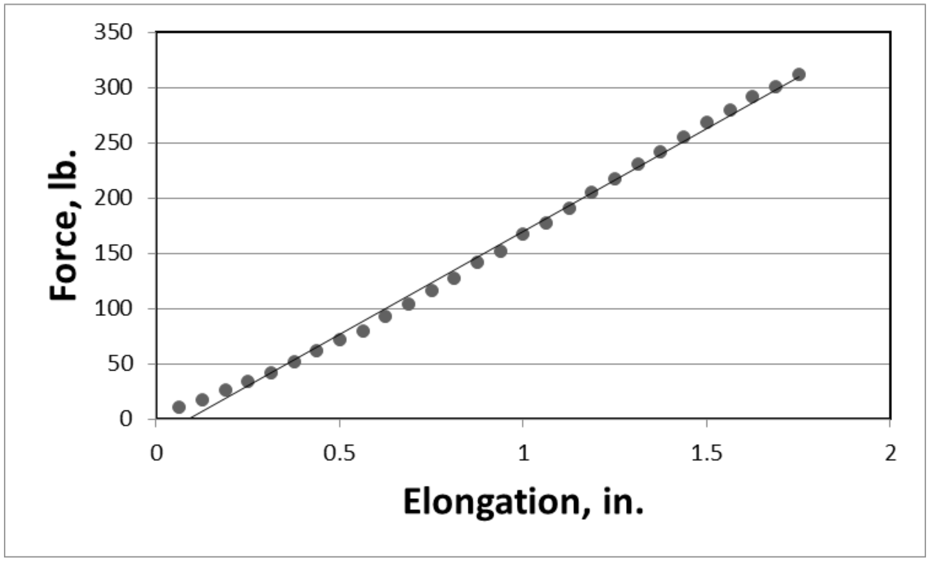


Figure 1: The force required to pull a test part with 100% infill and a rectilinear infill pattern. The test part failed at $F_B =$ 340 lbs.

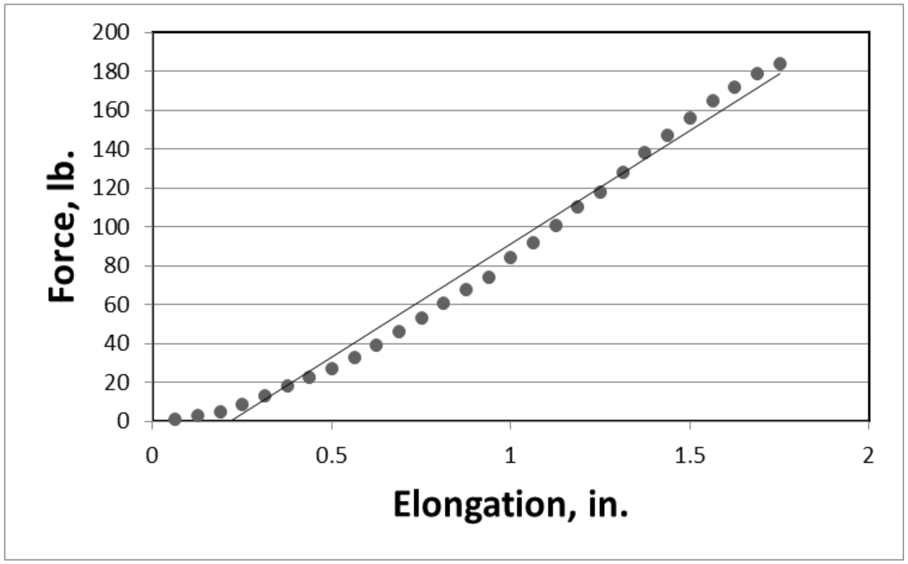
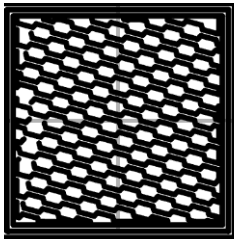


Figure 2: The force required to pull a test part with 90% infill and a rectilinear infill pattern. The test part failed at $F_B =$ 180 lbs.

Honeycomb

Honeycomb infill pattern



Source: http://manual.slic3r.org/expert-mode/infill

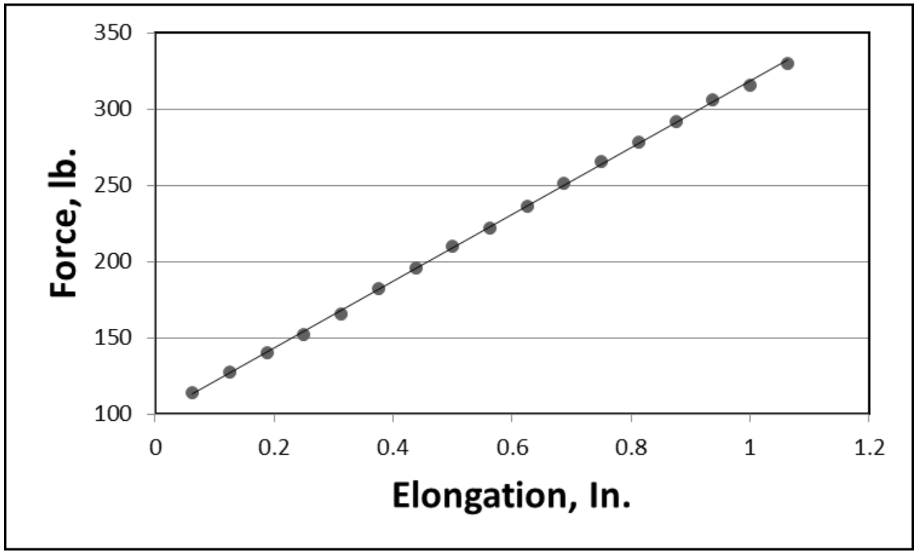


Figure 3: The force required to pull the test part with 100% infill and honeycomb infill pattern. The test part failed at $F_B = 340$ lbs.

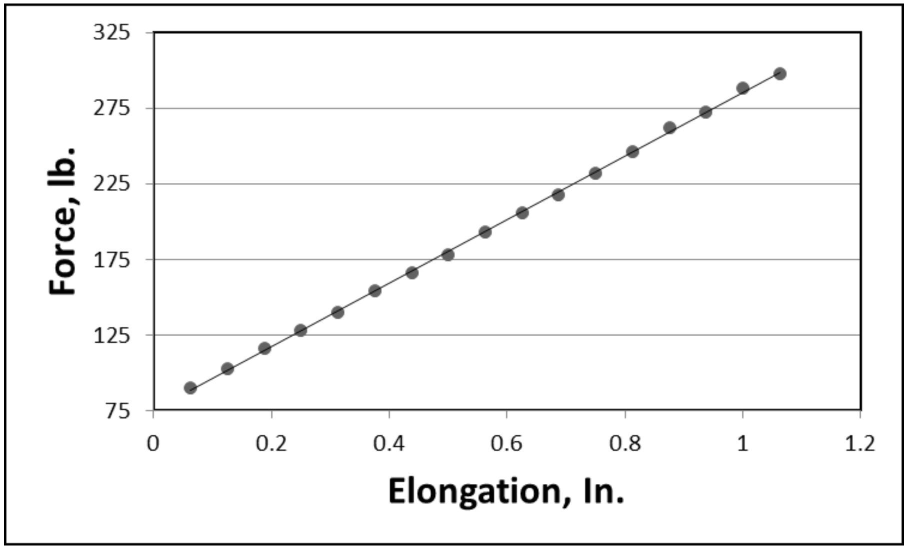
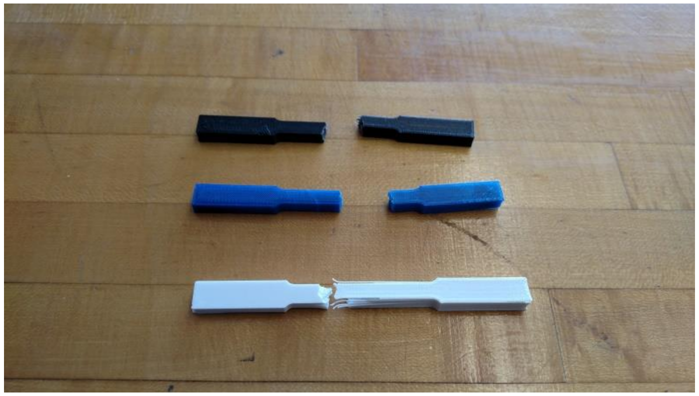


Figure 4: The force required to pull the test part with 90% infill and honeycomb infill pattern. The test part failed at $F_B = 330$ lbs.

Results

Pattern	Infill Percentage	Young's Modulus [10^3 lb/in^2]	Ultimate Strength [lb]
Rectilinear	100	3.73	340
Rectilinear	90	2.33	180
Honeycomb	100	4.37	340
Honeycomb	90	4.20	330

Samples of Broken Test Parts



Conclusion

- Honeycomb infill pattern tends to be stronger than rectilinear infill pattern.
- Applications:
  - Cost-effective analysis
  - Material design for tools and machinery
- Further research:
  - Examine Young’s modulus with Concentric, Archimedean Chords, etc., infill patterns.
  - Experiment with compression strength.
  - Analyze bending, which uses both extension and compression.

Acknowledgements/References

- I would like to acknowledge Dr. Starling, Assistant Professor of Physics at Penn State Hazleton, in mentoring me in this research project.
- Also, I would like to thank Dr. Joseph Ranalli, Assistant Professor of Engineering at Penn State Hazleton, for demonstrating how to properly operate the Tensile Test Machine.
- Lastly, I am grateful for Mr. Ronald Harman, Information Resources and Services Supervisor, in assisting me in operating the 3D printer.

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