Material Properties of 3D Printed Parts

Subject Area(s) Science and Technology, Measurement

Associated Unit 3D Printing

Lesson Title Material Properties of 3D Printed Parts

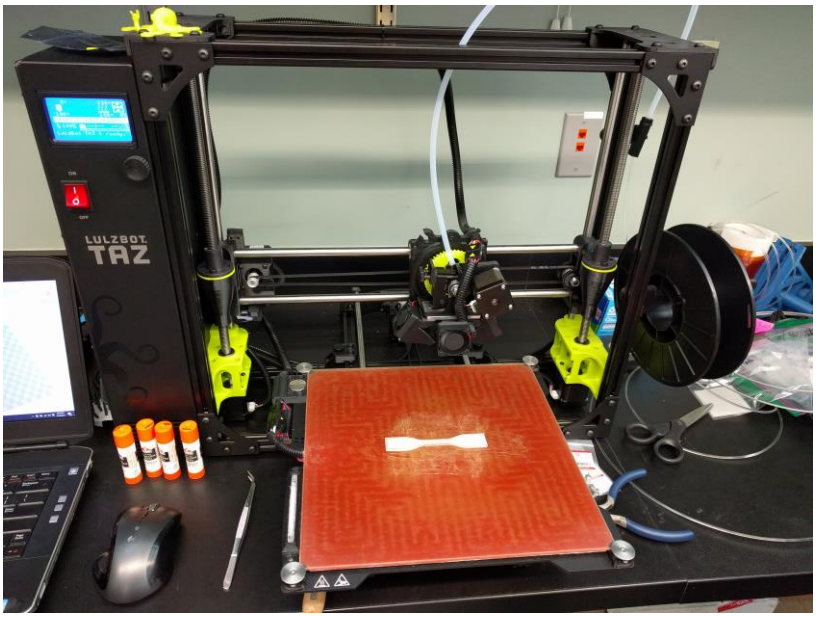

Image 1
A Lulzbot TAZ 6 3D printer with a print on the printbed. This print is for mechanical testing to determine the strength of the object.

Grade Level 9 (9 - 12)

Time Required 150 minutes (three 50 minutes classes)

Summary

In this lesson students will be introduced to basic engineering properties of materials like strength, toughness, and elasticity. They will start with a demo of the teacher standing on two different 3D printed objects, one of which will break and another of which will be able to hold the teachers weight. This will spark a discussion on why one will work and the other won't. Then it will lead into discussing material properties. From there students will learn about various mechanical properties like strength, toughness, and elasticity. Once these principles have been established students will choose a material and test the mechanical properties of that material with a series of 3D printed objects and testing apparatuses. Once the data from their tests have been obtained, students will create a small 8 ½" X 11" poster summarizing their results to be hung in the classroom as a reference for material choice in the future. Finally, students will repeat the process but now with objects that have had some sort of post-processing like vapor smoothing or heat treating to determine the effect of post-processing on material properties.

Engineering Connection

As engineers are designing and building objects it is essential that they use materials that have the desirable properties for their application. If an engineer uses a material that is too weak, brittle, or heavy for the particular application then they end up with a high risk of failure. As future engineers, it is

important for students to begin thinking about what the different mechanical properties are, how to determine them in a controlled manner, and now to apply them to future designs and material choice.

Engineering Category =
Choose the category that best describes this lesson's amount/depth of engineering content:
1. Engineering analysis or partial design

Keywords
3D printing, mechanical testing, strength, toughness, elasticity, post-processing

Educational Standards (List 2-4)
State STEM Standard

LAFS.910.RST.1.3 – Follow precisely a complex multistep procedure when carrying out experiments, taking measurements, or performing technical tasks, attending to special cases or exceptions defined in the text.

LAFS.910.RST.3.7 – Translate quantitative or technical information expressed in words in a text into visual form (e.g., a table or chart) and translate information expressed visually or mathematically (e.g., in an equation) into words.

LAFS.910.WHST.3.7 – Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation.

MAFS.K12.MP.1.1 – Make sense of problems and persevere in solving them.

MAFS.K12.MP.5.1 – Use appropriate tools strategically.

CTE Standard (Applied Engineering Technology)

06.0 Demonstrate basic computer-aided design (CAD) knowledge and skills.
07.0 Demonstrate foundational knowledge and skills associated with the design of engineering systems (e.g. mechanical, fluid, thermal, electrical, and electronic systems).
15.0 Demonstrate safe and appropriate use of tools.
22.0 Demonstrate fundamental math and science knowledge and skills for mechanical, fluid, thermal, and/or electrical/electronic systems.
23.0 Demonstrate safe and appropriate use of basic tools and machines.
29.0 Use tools, materials, and processes in an appropriate and safe manner.
30.0 Demonstrate an understanding of design and development of solutions involving mechanical engineering, their environments, and their associated design constraints.
31.0 Design and build a mechanically engineered solution suitable for a particular application in a defined environment.

ITEEA Standard

Standard 2. 9-12. Z. Selecting resources involves trade-offs between competing values, such as availability, cost, desirability, and waste.

Standard 2. 9-12. AA. Requirements involve the identification of the criteria and the constraints of a product or system and the determination of how they affect the final design and development.

Standard 3. 9-12. G. Technology transfer occurs when a new user applies an existing innovation developed for one purpose in a different function.

Standard 3. 9-12. H. Technological innovation often results when ideas, knowledge, or skills are shared within a technology, among technologies, or across other fields.

Standard 9. 9-12. L. The process of engineering design takes into account a number of factors.

Pre-Requisite Knowledge

Knowledge of how to operate a slicing program and 3D printer to print out parts using a 3D printer.

Learning Objectives

After this lesson, students should be able to:

- Investigate material properties for any designated 3D printing material and/or treatment method.
- Use data from a completed research project to select a material and/or treatment method to optimize the properties of a 3D print based on its use.

Introduction / Motivation (5E – Engage)

Begin by standing on two different 3D printed parts, one that will fail and shatter when stood on and another that support your weight. This model of a diamond lattice when printed with the right infill and with the right material should work depending on the weight of the teacher (https://www.thingiverse.com/thing:13601). Have a discussion with the class on why they think one supported my weight and the other didn't. Follow up with discussing material choice when making a product. Spur discussion by asking, "would you make a bridge out of paper mache?" "Why not?" "How about steel in a piñata?" This will get students thinking about what makes a material appropriate to use in various situations. Then ask, "how can we know what properties various materials have before we use them?" This will be the setup for the explanation.

Lesson Background & Concepts for Teachers (5E – Explain)

- Discuss typical material properties characterized in engineering.
- Talk about strength, toughness, elasticity, and, in the case of 3D printing, ease of use.
- Then discuss how we can test these various properties.
- Use YouTube clips to explain the testing methodologies.

Yield Strength - https://youtu.be/nlIFMy4vIeM?t=3m51s

Toughness - https://youtu.be/YcQHbaVeD7I?t=3m4s

Flexibility - https://youtu.be/nlIFMy4vIeM?t=5m34s

Ease of use – Print a 3D Benchy (https://www.thingiverse.com/thing:763622) or any of the other 3D printing stress tests out there

Figure 2

This is an example of a 3D Benchy print, a simple small boat with some windows, doors and smoke stack, that can be used to examine the quality and ease of use of a filament on a 3D printer.

Vocabulary / Definitions

Word	Definition
Strength	The ability of a material to withstand an applied load without failure or plastic deformation.
Yield strength	The point at which applying a load to an object causes a failure or plastic deformation.
Toughness	The ability of a material to absorb energy and deform without breaking.
Elasticity	The rigidity of an object, how much an object can deform when a force is applied without permanent deformation.

Associated Activities (5E – Explore)

At this point students will pick a type of plastic to print with (PLA, ABS, nGenn, HIPS, etc.) and print their strength, toughness, and elasticity test samples. Students will then use the provided equipment to determine the yield strength, toughness, and stiffness of their chosen filament using the provided testing apparatus as outlined previously. The files to print for the testing apparatus as well as the test samples themselves can be found here (**https://cad.onshape.com/documents/3d33c47f2d3443594dde6e4c/w/8406b1dee751877172d83f24/e/29d0010c0da50abb06598696**).

Assessment (5E – Evaluate)

Students will make a simple 8 ½" X 11" page poster outlining the physical properties of their chosen filament along with pictures of the completed prints. These posters will then be hung up in the classroom as a reference for the available materials and their properties. These will be used later in the semester as

students are designing and printing parts so they can visually see the properties of materials and know which filament to choose for their application.

Pre-Lesson Assessment
Discussion about material properties of objects and why knowing them is important.

Post-Introduction Assessment
Discussion on how to test the material properties of various materials.

Observation as students are conducting experiments to determine material properties.

Lesson Summary Assessment
One page poster on the results from their investigations.

Lesson Extension Activities (5E – Extension)

Once students have chosen, printed, tested, and reported on their desired plastic they can then repeat the process after doing some sort of post-treatment to their prints. This investigation will give data showing how various post-treatment techniques effect the final mechanical properties of a material. These treatments could include but are not limited to things like vapor smoothing, solvent welding, or heat treating/baking. Students can then produce a second 8 ½" poster about the results of their post-treatment process.

Additional Multimedia Support

https://youtu.be/YcQHbaVeD7I?list=PLDJMid0lOOYl8TZJV9xHznKFq5yA5ZTi2

https://youtu.be/nlIFMy4vIeM

References

Thomas Sanladerer - *#Filaween methods – How I will be torturing filaments!*

https://youtu.be/YcQHbaVeD7I?list=PLDJMid0lOOYl8TZJV9xHznKFq5yA5ZTi2

Thomas Sanladerer – *The next generation of Filament reviews: This is Filaween 2.0*

https://youtu.be/nlIFMy4vIeM

Attachments

File for printing a diamond lattice work for demo

https://www.thingiverse.com/thing:13601

File for printing a 3D Benchy

https://www.thingiverse.com/thing:763622

3D Files to print parts needed for testing equipment and test subjects themselves.

https://cad.onshape.com/documents/3d33c47f2d3443594dde6e4c/w/8406b1dee751877172d83f24/e/29d0010c0da50abb06598696

Contributors

John H. Meyers (mrmeyersmakerspace@gmail.com)

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