The Bending Test

Materials testing is a fundamental part of Materials Science and Engineering, in understanding the limits of materials through determining their physical and mechanical properties. The information collected during laboratory experimentations are useful to engineers and researchers in helping to determine the appropriate materials for various applications.

For Stage 6 Engineering Studies, this experiment covers the following syllabus points: P/H1.2, P/H2.1 and P/H3.1

There are many tests that can be performed on materials to determine their properties. The tests can be either destructive or non-destructive. Destructive tests are often conducted to determine a specific property of the material/component being tested. They usually require a specifically shaped test piece to be made and this is damaged/destroyed during testing. Examples of destructive tests are tensile tests, bending tests, impact tests, and fatigue tests. Hardness tests are also done on test pieces (destructive). Additionally, hardness tests are often done on actual components (non-destructive). Non-destructive testing, as the name suggests, does not damage the material or component during testing and it can still be used following tests without changes in quality or property. These tests are usually done during service of the component to ensure the material properties haven't changed over time and is still safe to use in its application. Examples of non-destructive tests are dye penetrant testing, X-ray testing, gamma ray testing, magnetic particle testing and ultrasonic testing.

The 3-point bending test, also known as flexural testing or transverse beam testing, measures the behaviour of materials in a simple beam loading geometry. This type of testing provides information on how materials respond to a combination of tension, compression and shear forces, and the results are useful in structural and civil engineering. Properties that can be calculated from the bending test include flexural stress, flexural strain, elastic modulus and the fracture toughness. It should be noted that the material properties collected from the bending test will be different to the data collected from other forms of testings, such as tensile and compressive, due to different loading geometries. Like the 3-point bending test, 4-point bending test and the cantilever bending test are other techniques that can be used to study the flexural stress of materials. In particular, if the material is not homogenous, ie. composites, the 4-point bending test provides a more complete study of the stress behaviour by increasing the loading region on the material.

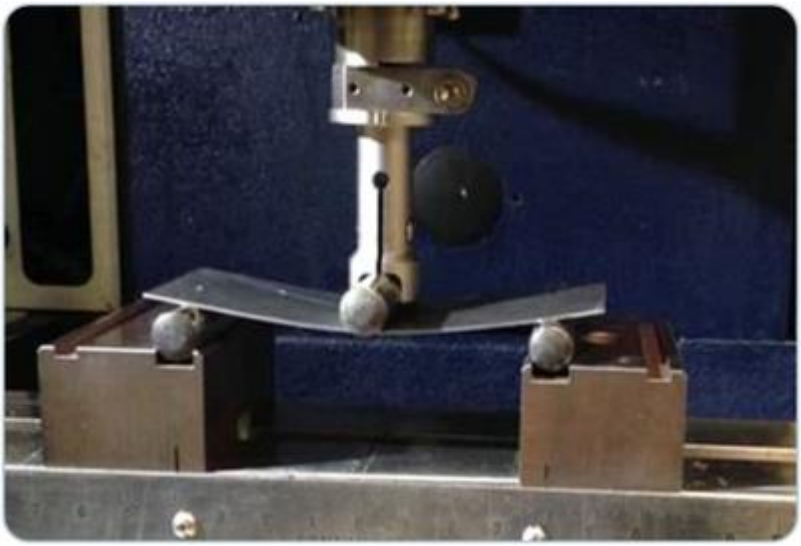

image source: Bruker.com

Following standards is important when performing tests to ensure objective, consistent and comparable results and minimising errors. Standards in materials testing help make sure each test being carried out is exactly the same, whether it is being conducted in your lab or in a high-tech facility such as ANSTO, and the only variations are due to the property of the material.

ISO 178 is the standard describing the 3-point bending test method for plastic/polymer materials and ASTM D6272 for 4-point bending test of polymers. The samples being tested also have to follow standards to ensure the mechanical property results collected are comparable between tests of different material compositions.

The 3D printed bending test rig design follows the criteria outlined in ISO 178. The material property that can be collected from this set up are the elastic modulus, flexural stress, strain and the bending moment.

1. Safety:

Safety in science and engineering is important for everyone, whether you are the one running the experiment or an observer. Understanding methods of fracture and failure is a major component of Materials Science and Engineering. Therefore, with the Bending Test, it is expected some samples will break. To ensure the safety of everyone involved with the experiment, everyone in the room where the Bending Test is being conducted should wear safety glasses and enclosed shoes. Other than the 1-2 persons setting up the experiment – loading the sample, adding weights – other persons should be at least one metre away from the Bending Test jig. If available, a clear acrylic shield should be placed in front of Bending Test jig, with observers standing behind this shield and not to the side.

2. Method:

This experiment is about investigating how mechanical property changes for different materials, ie. polymer, metal and wood. This experimental setup is designed to simulate tests that are conducted on materials to understand their strength in a beam loading geometry. The results will provide information on the material and mechanical properties. The different materials behaviour can help scientist and engineers determine the best types of materials for different applications.

What you need:

- 3D printed Bending Test jig – found at: https://www.thingiverse.com/thing:4609818
- A sample 110 - 130 mm long and no wider than 25cm or thicker than 10mm and you should also be able to bend it fairly easy with your hands. You can use a variety of materials, from plastic, thin sheets of metal, wood and even confectionary, just make sure you avoid brittle materials like glass that are likely to shatter.
- Hanging weights, such as water bottles or metal graded weights.

Testing Procedure:

Ensure safety goggles are worn at all times during the experiment. Be careful of sample fragments flying when the sample fractures.

Jig and Sample Set up

1. Place the Bending Test jig in between 2 tables (to allow space for the ruler and weights to hang), ensuring the jig is stable (using blu-tac to stick it down, since the jig is fairly light).
2. Place a sample on the jig. Centre the sample between the bottom support pins.
3. Insert the ruler and align the 0 marking to the bottom of the bending sample and stick the ruler to the jig (using blu-tac).
4. Slide the top loading pin onto the sample, centring it between the bottom supports. Thread the string through the bottom of the jig.

Mechanical Property Tests

1. Attach weights to the string connected to the top loading pin until a substantial deflection is observed (approximately 5 mm).
2. Record the weight and resulting deflection by the sample.
3. Repeat for different materials, keeping the weight constant. Observe how the amount of deflection varies between different materials for the same weight.
4. Convert weight to force for mechanical property calculations.

Maximum Weight Test – fracture behaviour of materials

1. Use the same sample set up as the previous.
2. Continue adding weights until sample fractures.
3. Observe and describe the appearance of the fracture surface.
4. Repeat for different materials. Compare the facture surface for different samples. Discuss how this relates to the material property of the sample.

3. *Results:*

Material	***Elastic Modulus***	***Flexural Stress and Strain***	***Bending Moment***	***Fracture Surface***
Example: ***PLA*** ***Cross-section area: XXX***				*Rough surface* *No change in cross-section area* *Brittle fracture*

4. *Discussion:*

Question time
Question 1: What was interesting about each material? How do they compare to each other? (Hints: deflection length, elastic modulus, brittle / ductile behaviour)
Question 2: Why do some materials have a higher elastic modulus? How does this impact their applications? (Hints: stiffness, load bearing beams, buildings, planes)
Question 3: Will the mechanical property of the sample change if the cross-section was different? If yes, how so? (Hint: solid rectangular beam, hollow rectangular beam, I-beam)
Question 4: What are the sources of errors in this experiment? What are the limitations of this testing method? (Hint: sensitivity of measurements, stiff materials, small scale)

5. *Acknowledgements*

This project builds on the open source 3 point bending test platform created by Stefan Hermann of CNC kitchen. You can download the original files at the link below and check out his YouTube channel for some awesome material science videos relating to 3d printing!

Original files at: https://www.thingiverse.com/thing:3142077

Stefan's YouTube channel: https://www.youtube.com/watch?v=te0Wwf7Dxj4&feature=youtu.be

6. *Appendix: Testing in industry*

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<tr><th colspan="2">Varied testing samples</th></tr>
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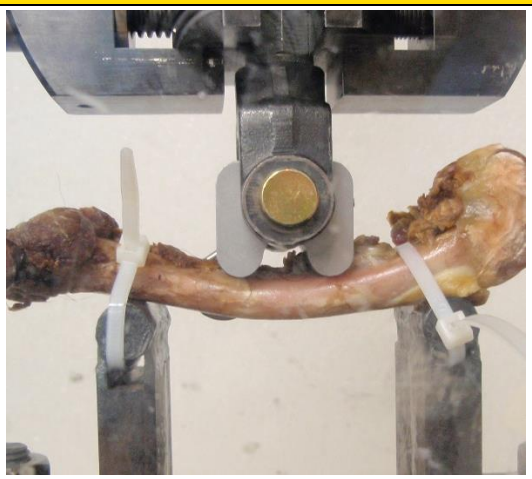
</td><td>  </td></tr>
<tr><td>Bending tests are used extensively in the electronics industry to determine the suitability of components and whole products.
Source: azom.com</td><td>Bending tests are used to determine the stiffness of bones, so implants can have the same properties.
Source: camal.ncsu.edu/</td></tr>
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<tr><td>Bending test are used in food science to ensure the consistency of products and favourable textures and properties like 'crispiness'.
Source: foodtechcorp.com</td><td>Bending tests for large items like wooden beams have to be very large and powerful and are usually done over a wide span.
Source: admet.com</td></tr>
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