Practical 1P10

Fabrication and Tensile Testing

What you should learn from this practical

Science

Some of the most important mechanical properties of a material can be determined by means of a simple tensile test. This practical introduces tensile testing of metals and plastics and demonstrates the meaning of often-used mechanical property specifications, giving a comparison of actual values for a variety of real materials.

Practical skills

The first part of the practical involves the preparation of metal tensile specimens by machining, giving valuable practical experience of some workshop technology. The second part of the practical deals with testing of the mechanical properties of a range of materials.

Overview of practical

After instruction from the Students' Workshop technician in the Engineering Department, students will each fabricate one tensile specimen from mild steel using a lathe.

> **Safety note:** You **must not** use any equipment in the students' workshop without first attending the safety talk there. You must not use any equipment in the students' workshop without supervision from the workshop Technician or a Teaching Assistant. You must be especially careful of your own, and others', safety in the workshop.

This will occupy one day of the practical.

On the subsequent days the metal alloy specimens (mild steel, copper and brass) and a range of polymers are to be tested to failure in a bench top tensile testing machine.

Experimental Details

1) Testing of metals

Mechanical testing of metals is carried out on a bench top tensile testing machine. You should measure the dimensions of each sample before and after each test. Test one sample of each material to failure.

The results obtained from the tensile testing machine are put out in the form of a load-extension plot.

Convert this into an engineering stress-strain plot, using the following relationships:

$$\text{Engineering stress}, \quad \sigma = \frac{\text{applied load}}{A}$$

$$\text{where } A \text{ is the original cross} - \text{sectional area,}$$

$$\text{Engineering strain}, \quad \varepsilon = \frac{\text{extension}}{\text{original length}}$$

There are two important mechanical properties that can be calculated from the plot obtained:

1. Yield point = point at which plastic deformation begins, i.e. end of linear region of plot.
2. Ultimate tensile strength, $\text{UTS} = \frac{\text{maximum load}}{A}$

Also measure and compare the % reduction in area and % elongation values for each sample. Calculate these and record in a table such as on the next page.

Take a second sample of mild steel.

Step 1: Start the test as before, but stop when a small amount of plastic deformation has taken place.

Step 2: Unload the sample, then reload to produce further plastic deformation

Step 3: Remove the sample and place it in boiling water for approximately 30 minutes (heat treatment), then reload the specimen and test to failure

Obtain the stress strain curves for each step, describe them in your lab book and explain the observations. How do these results differ from the previous steel sample?

Caution: use tongs for handling the sample in boiling water and avoid scalding yourself.

Material	**Young's Modulus (Nm^{-2})**	**Yield Stress (Nm^{-2})**	**U.T.S. (Nm^{-2})**	**% elongation**	**% reduction in area**
60/40 brass					
Copper					
Mild steel					
Mild steel (heat treated)					

The Young's modulus is the ratio for σ/ε for the initial elastic region of the plot.

2) Testing of Polymers

Strip specimens of various plastics are supplied; The Teaching Assistant will show you how to operate the tensile testing machine. Suitable conditions are: cross head speed 0.5mm/min and chart speed 50mm/min. The polystyrene specimen should be taken to fracture, but the other specimens should merely be taken past yielding as fracture may take an excessively long time. Note the appearance of the polystyrene and butadiene-toughened polystyrene just before fracture.

It will be seen that for small strains, the load-extension relationship is not precisely linear. These are the results expected in this type of test for a viscoelastic material, i.e. a material in which the recoverable strain increases with time after a fixed load is applied. The fundamental viscoelastic properties cannot be evaluated from this test; but from the maximum slope of the load-extension curve an apparent elastic modulus (stress/strain ratio) can be derived which gives a useful indication of the practical stiffness of the material in relation to other plastics or other types of material.

Compare the apparent moduli of the plastics with one another and with the Young's modulus of a typical metal.

Calculate also the fracture stress of fractured specimens and the approximate yield stress of others, and make a comparison with the metal yield stresses.

What should be in the lab notebook

This practical is assessed using your lab book.

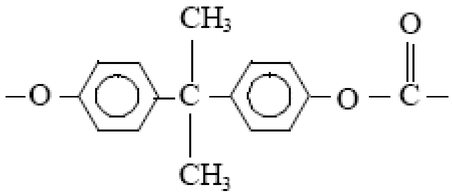
Please see the general guidance for lab book reports on Canvas, but in particular your lab book should contain the following:

- Copies of all your group's load-extension curves
- The specific measurements and calculations mentioned in the “experimental details” section for metals and polymers.
- Stress-strain curves for the steel (the one loaded directly to fracture), copper and brass. Comment on what forms of curves should be expected and those that you observed.
- Stress-strain curves of the second steel sample, with steps 1, 2+3 plotted in one figure.
    - Comment on what ways the steels behave differently and what is happening microstructurally.
    - Comment on why the Young's modulus obtained for the metal samples underestimate the real value, and your suggestion for how you would take a more accurate measurement
- Stress-strain curves for all the polymer samples, with explanations for any different behaviours and how necking is different between the polymers and metals.
    - Comment on the behaviour of the following pairs of samples and how this depends on their molecular configuration and flexibility (If possible, relate any changes in the appearance of the sample with salient features on your graphs):

- Polystyrene *vs* toughened polystyrene
- Low density polyethylene *vs* high density polyethylene
- High density polyethylene *vs* polypropylene
- Polystyrene *vs* polycarbonate

Appendix

Polycarbonate



Although of low crystallinity it has unusually high impact resistance for a plastic and is used, for example, for crash helmets.

Polystyrene: composition $(CH_2CHC_6 H_5)_n$.

An amorphous polymer, i.e. the long chain molecules are not arranged in a regular manner. Below a fairly well defined temperature, the "glass transition" temperature, the molecules of an amorphous polymer are unable to make large scale movements relative to one another. The glass transition temperature of polystyrene is about 100°C.

Butadiene-toughened polystyrene

The toughness of polystyrene can be improved by the addition of particles of rubber, such as the synthetic rubber, polybutadiene. The rubber particles are present as a fine dispersion within a matrix of polystyrene.

High density polyethylene: composition $(CH_2)_n$

In this material the long chain molecules are, in local regions, lined up in regular patterns. Such polymers are called crystalline, although they contain a much higher degree of disorder than low molecular weight crystalline materials. Many crystalline polymers can be "drawn" at temperatures well below their melting temperature. "Drawing" is a response to a tensile stress in which the molecules become oriented parallel to the tensile axis and produce a large tensile strain in doing: so. Stiffness and strength are much enhanced by drawing.

Low density polyethylene: composition $(CH_2)_n$

In low density polyethylene, a relatively large proportion of molecules contain branches instead of being single chains. The branches hinder close-packing of the chains: the material is less crystalline and less stiff than high density polyethylene.

Polypropylene: composition $(CH_2CH(CH_3))_n$

Properties are similar to high density polyethylene.