MCEN30017 Mechanics and Materials

LABORATORY - TENSILE TESTING

LABORATORY CLASSES ARE COMPULSORY!

IT IS IMPORTANT THAT SAFE WORKING PROCEDURES ARE OBSERVED AT ALL TIMES. Further details are provided in the operating instructions for individual experiments.

NO EQUIPMENT IN THE LABORATORY IS TO BE USED BEFORE RECEIVING PERMISSION AND INSTRUCTION FROM STAFF OR DEMONSTRATORS.

SMOKING, FOOD AND DRINK, BARE FEET AND OPEN SANDALS ARE NOT PERMITTED WITHIN THE LABORATORY. APPROPRIATE DRESS AND FOOTWEAR SHOULD BE WORN.

Although the testing is performed in small groups, students will submit individual reports. A4 format is recommended for these reports. *Each report should clearly show the student's name, the number and title of the experiment, the date performed and the name of the demonstrator (who will mark the report).*

Completed laboratory reports should be submitted within one week of the laboratory session. Reports should be submitted at the reception of the Department of Mechanical Engineering on the 4th floor of Building 170. Marked reports will be retained until the end of semester, when they can be collected prior to the examination period.

This manual covers the lab *Tensile Testing* and is available on LMS for downloading. You are expected to read these notes before your laboratory session so that you are ready to begin the experiment when you go into the laboratory. You need to print and bring a copy with you coming to the lab.

TENSILE TESTING OF DUCTILE MATERIALS

INTRODUCTION

In service, we usually expect materials to behave elastically, i.e. to deflect under load but to return to the original size and shape when the load is removed. However, for any component there will a limit to the load that it can take while still behaving elastically.

Some materials are brittle - when the elastic limit is exceeded they break, either suddenly, or slowly as the load is increased. Most engineering metallic and plastic materials are not brittle; when the elastic limit is exceeded they undergo permanent deformation. In this experiment we are going to look at this permanent, or plastic, deformation and learn something about how it happens and what effect it has on the material.

Plastic Deformation

We don't want large amounts of plastic deformation in service, of course, but many of the materials we use can undergo a great deal of deformation before they break. This is useful because it means that mechanical shaping processes like rolling, drawing, extrusion and forging can be used to produce the shapes that we want. It also means that the product is more tolerant of cracks and other defects in service. The materials that are capable of such large deformations are metals and polymers, though this doesn't mean that all metals or all polymers can deform in this way.

The mechanisms of deformation are different for these two classes of material. Metals deform by slip, i.e. sliding of crystal planes over one another, although other mechanisms are also possible at high temperatures (above 0.3 - 0.4 T_M, where T_M is the melting temperature in Kelvin). Polymers, in general, deform by sliding of polymer chains past one another.

Deformation of Metals

Metals are crystalline, consisting of large numbers of crystals, often referred to as grains, usually with the crystal axes randomly oriented in space. Each grain has a certain number of preferred slip systems, each consisting of a crystal plane and a direction within that plane. The preferred plane is usually the most closely-packed plane and the preferred direction in that plane is nearly always the most closely-packed direction. Thus, for example, a crystal of a metal with the fcc crystal structure has four close-packed planes and in each of these planes there are three close-packed directions; so there are twelve preferred slip systems. When the load on such a crystal is increased beyond the elastic limit, it starts to deform on the preferred slip system which has the highest shear stress.

Naturally, in a metal containing large numbers of randomly-oriented grains the deformation of each individual crystal has to conform to those of all its neighbours, and so slip on a single system is rapidly replaced by slip on several systems. This has important consequences for the way that the metal behaves, but we can leave that for discussion during lectures. Similarly, we will not discuss in these notes the role of dislocations in the deformation of crystalline materials.

However, if you are doing this experiment after dislocations have been discussed in lectures you should use the knowledge you have gained there to enhance your answers to the questions below.

Deformation of Polymers

The mechanisms of deformation in polymers are not as well understood as those for metals. Many polymeric materials are amorphous in structure (i.e. not crystalline) and deformation occurs by sliding of the irregularly-arranged chains past one another. However other polymers, particularly those that are used in load-bearing applications, are crystalline to a greater or lesser extent, being composed of crystalline and amorphous regions in varying proportions and distributions. In such cases it is more difficult to describe how the crystalline regions behave during plastic deformation.

By comparison with metals, there is one important point to note when studying the deformation of polymers. The plastic deformation of polymers is much more time-dependent. Most polymers deform gradually under quite small loads at room temperature (the phenomenon known as creep), whereas most metals at room temperature are well below the range mentioned above, where creep mechanisms come into play. Thus, if two polymers are to be compared with respect to their plastic behaviour it is desirable to make the comparison for the same rate of deformation.

EXPERIMENT

In this experiment tensile tests will be carried out on six materials, four metals and two polymers. The tensile test is a convenient way to investigate plastic behaviour, and it is widely used to obtain design data and also for quality control in manufacturing.

Your demonstrator will show you how to use the Instron testing machine and how to analyse your results.

Your report should contain the following:
(i) The objective of the experiment.
(ii) Sketches of the six load - elongation curves, with all the important features labelled.
(iii) The properties of each specimen, as listed in Table 2.
(iv) Answers to the questions below.
(v) Some brief concluding remarks about what you have learned from the experiment.

QUESTIONS

Before writing answers to these questions you should discuss your ideas with your demonstrator.

1. Why is there such a large difference between the elastic moduli of metals and polymers? If your measurement of the Young's modulus is not as expected (e.g. when compared to values in handbooks), comment on possible errors that might arise from such a measurement.
2. What feature of the load-elongation curves for metals shows that work-hardening is occurring? If you are doing this experiment after the subject of dislocations has been discussed in lectures, explain briefly what mechanisms are responsible for work hardening in metallic materials.
3. The polymeric material undergoes stable "necking" and then shows something similar to work hardening in metals. What physical processes are responsible for this behaviour? Does this explain the difference between the behaviour of the cold-drawn LDPE compared

with that of the "as-received" LDPE? (Hint: Polymer plastic deformation has not been taught, but you can refer to section 15.7 in the 6th ed of the textbook to have a brief discussion.)

4. Do you notice any difference between the tensile curves of the low carbon steel and Cu or Al around the yielding point. What term(s) are used to describe yielding in the low carbon steel, in comparison to that used to describe yielding in Cu or Al?

Table 1. Machine Settings for the Instron Tensile Tester

Specimen	**Cross Head Speed (mm/min)**	**Initial Gauge Length (mm)**
Cu, annealed		
Al, annealed		
Al, work-hardened		
Low carbon steel		
LDPE		
LDPE, cold-drawn		

Table 2. Data Required from Tensile Tests
(copy this table into your report)

Specimen	**Cross Section Aera (mm^2)**	**Elastic Modulus (GPa)**	**Yield/Proof Stress (MPa)**	**Tensile Strength (MPa)**	**Elongation at Break (%)**
Cu					
Al, annealed					
Al, work-hardened					
Low carbon steel					
LDPE					
LDPE, cold-drawn					

Marking scheme (guide only)

Aim - 5%
Method - 5%
Results - 40%
Discussion (questions) - 45%
Conclusions - 5%

Late submission: –20%