MAT1600 Laboratory Practical 2
Identification and Use of Materials

In this practical you should work in groups of four. Although your final report should be written on your own, you are encouraged to discuss the practical and the questions given at the end of this script with your colleagues during the session. In particular, you should ask the demonstrators for advice during the session when necessary as they may have information you need to identify all the materials correctly.

Sources of Extra Information

Materials Science and Engineering: W. D. Callister & D. G. Rethwisch

Aims of the Session

- Learn about the differences between several classes of material based on hardness and density
- Identify twelve unknown material samples based on laboratory measurements, provided clues and general knowledge
- Choose appropriate materials for a given application based on knowledge gained during the practical

Background

The identification and choice of appropriate materials is of critical importance in good engineering. In this practical you will use some common laboratory testing methods to identify twelve materials of different types. You will then use your results to justify material choices for a series of real world applications.

The hardness of a material is defined simply as its resistance to plastic deformation. Materials which are harder generally have stronger bonds holding the atoms or molecules together and therefore have a higher hardness value. Those with weaker bonding have a correspondingly lower hardness and are therefore softer. A hardness test measures any permanent deformation present in the sample after a specified load has been applied for a fixed time period. This permanent deformation is a plastic event (energy is dissipated away as heat during the test) as opposed to an elastic event (where energy is recovered). Hardness tests are popular because they are simple and cheap to run, non-destructive and can provide other mechanical properties (such as tensile strength).

The machines in this laboratory are brand new research grade hardness testers that use the 'Vickers' method (see Figure 1). The Vickers method has a large range and can therefore be applied to a wide variety of materials and material types (e.g. harder metals and softer polymers). It has the advantage that the hardness value is independent of the applied force, so for instance, the measured hardness of steel will be the same whether a 1 kg or 10 kg load is applied to the sample.

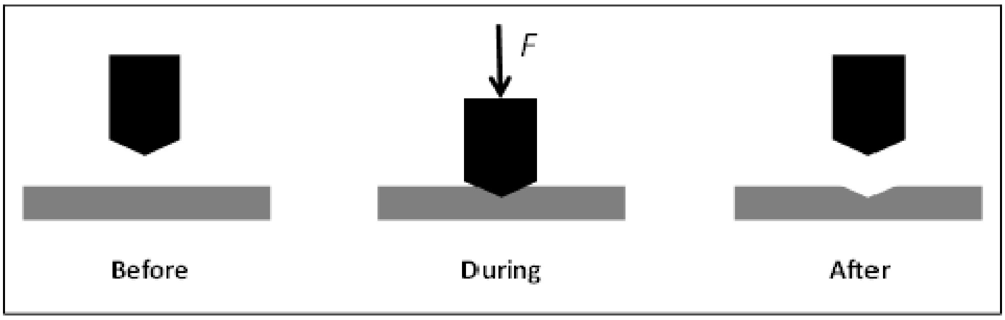

Figure 1. Vickers hardness testing method

During the test, a small indenter made of hardened steel with a diamond cross-section is applied to the sample with a fixed force, *F*, for a fixed time period (set at 10 s for this practical). The resultant indentation area, *A*, is then measured using a microscope. The Vickers hardness (*HV*) value of the sample is given by the following equation (*d* is the diagonal length of the indent):

$$HV = \frac{F}{A} = \frac{1.8544\,F}{d^2}$$

The units of *HV* are HV*x* where *x* is the load in kilos. For example, the Vickers hardness of the hardened steel test samples used to calibrate the machines under a 10 kg load is 338 HV10. The Vickers hardness of all the materials in this practical (particularly the polymers) is substantially less than this value. During this practical, the machines will be set at 5 kg so all measurements taken will be measured in HV5.

Finally, the density (ρ) of a material is defined as the ratio of mass (*M*) to volume (*V*). It is a simple test which, along with the hardness, will help you to differentiate between the materials.

$$\rho = \frac{M}{V}$$

Measurements

There are three Zwick-Roell hardness testers, 3 digital balances and several sets of callipers in the laboratory. There are 4 or 5 copies of each unknown sample (labelled A-L). Therefore, in order for everyone to be able to obtain measurements, you will have to work efficiently and be well organised. While you are waiting to make one type of measurement, you can do one of the other tests.

1) Density

Measure the dimensions of the samples using a set of callipers to the nearest 0.1 mm. Make three measurements along each dimension of the sample and take an average. Calculate the volume in cm^3. Measure the mass of the samples using a digital balance to the nearest 0.1 g. **Record** the density in g/cm^3.

2) Hardness

The hardness testers are valuable, delicate machines and should be treated with care. However, they are relatively easy to use and measurements should become routine after the first few attempts. The procedure is outlined below:

- Check the level of the sample platform. You do not want the platform or sample hitting the indenter or any of the lenses. Focusing is done via the large wheel at the bottom of the column. See Figure 2.
- Obtain a sample from the central store and place it on the platform. Move the focus wheel so that the sample platform moves up but don't let the sample touch the indenter or lens.
- Look through the eyepiece. Move the focus wheel the other way so that the platform moves down until the sample is focused. Most samples are of a similar thickness so you won't need to do a lot of focusing after this first time. Once the sample is on the platform, try not to move or knock it. However, if you can see the result of someone else's test, move the sample a small amount to get a clear section.
- Press the 'S' button to start the test. The machine will rotate to the indenter and perform the test. The display will count down from 10 s. The machine will then rotate back to the viewing lens.
- Look through the eyepiece and you should see a diamond shaped indent on your sample.
- To measure the indent, adjust the left knob on the eyepiece mount until the left black vertical line JUST touches the left vertex of the indent. Then adjust the right knob on the eyepiece mount until the right black vertical line JUST touches the right vertex of the indent. See Figure 3. Then press the red button on the eyepiece mount once.

- Now rotate the eyepiece mount 90^{o} and look through it again. Repeat the measurement using the two black lines which are now horizontal. Adjust the lower knob on the eyepiece mount until the lower black line just touches the lower vertex of the indent. Then adjust the upper knob on the eyepiece mount until the upper black line just touches the upper vertex of the indent. Press the red button on the eyepiece mount once. Your hardness measurement is displayed. **Record it**.
- Repeat the process to get 3 hardness measurements per sample. A small movement of the sample on the platform will allow you to make a hardness measurement on a clear area. When you have finished with a sample, return it to the central store.
- Assuming the machine has been set up correctly, the only buttons you will need to press are the 'S' button to perform the indentation and the red button on the side of the eyepiece mount to record the indentation size (twice per indentation).

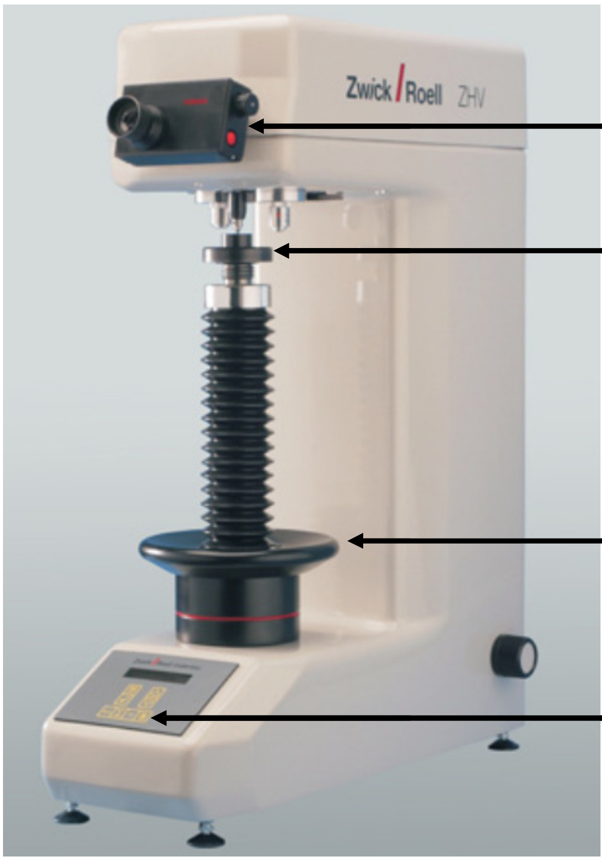

Figure 2. Zwick-Roell Hardness Tester.

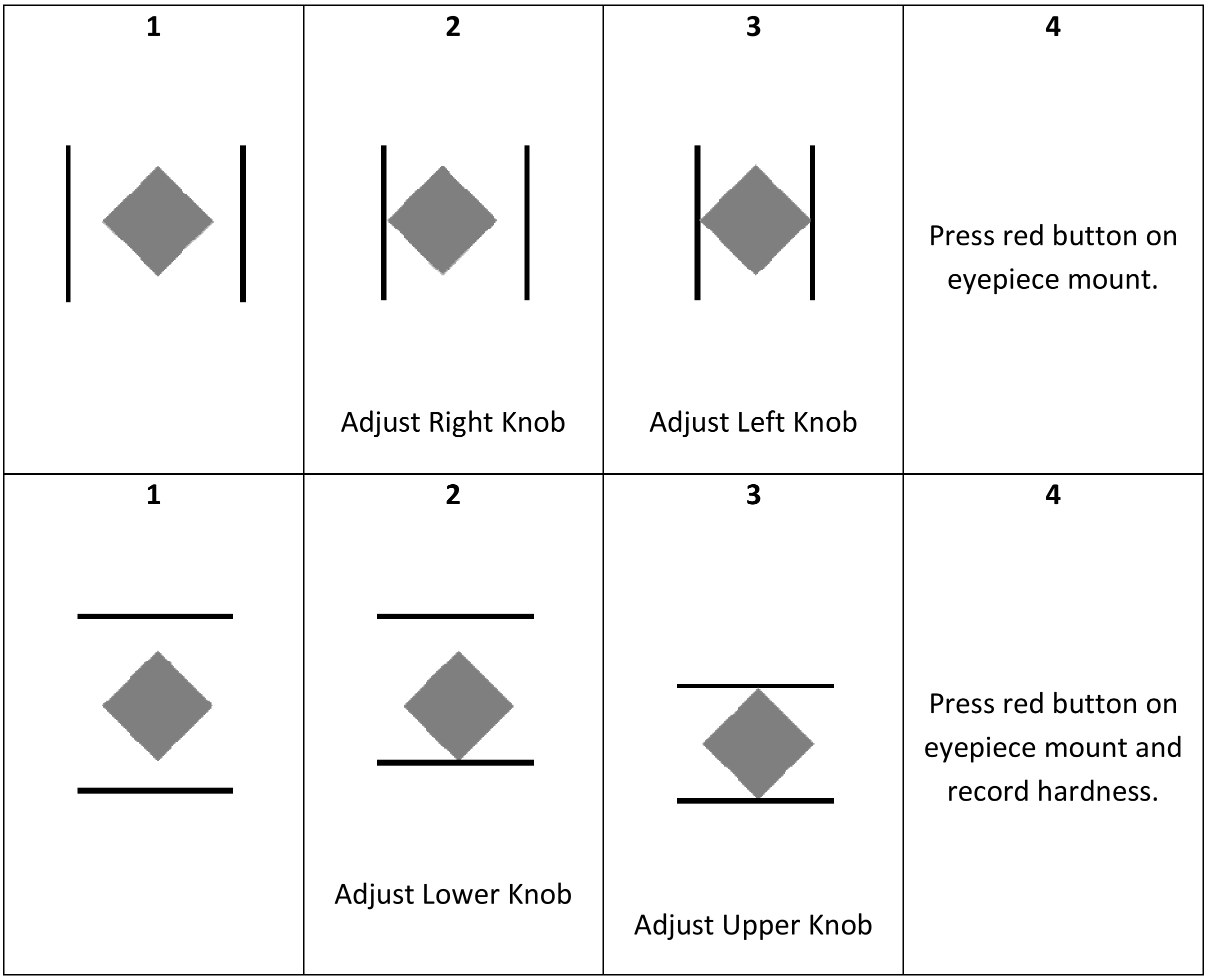

Figure 3. Measuring the size of an indent through the eyepiece.

Data

- The unknown materials consist of:

Aluminium	Brass	Copper
Mild Steel	Nylon	Poly(carbonate)
Poly(ethylene)	Poly(methylmethacrylate)	Poly(propylene)
Poly(urethane)	Tool Steel	Tufnol

- There are five metals and seven polymers.
- Two of the materials are magnetic. Mild Steel has a lower carbon content than Tool Steel.
- Brass is an alloy of Copper and Zinc.
- Two of the materials are clear. Poly(methylmethacrylate) is harder than Poly(carbonate).
- Two of the materials will float on water. Poly(propylene) is less dense than Poly(ethylene).
- Two of the materials are highly elastic. Poly(urethane) has a lower stiffness than Nylon.

Measurements you have made, your general knowledge, the data provided above and some help from the demonstrators should give you enough information to identify the materials.

The practical element of the lab is now complete.

Report

A report on this practical should be submitted within 2 weeks of your session. A cover sheet should be printed out from http://foe-coversheet.group.shef.ac.uk, and the report should be submitted to the black homework hand-in box in the Turner museum, E floor of the Sir Robert Hadfield building. This must be done by 4pm, 2 weeks after your lab session.

Your report should contain:

1) An introduction to materials identification using hardness testing. *(½ page, 5 marks)*
2) An account of the methods you used to identify the materials. *(1-2 pages, 10 marks)*
3) A table listing the sample label (A-L) with any hardness or density measurements you made and the identity of the material. *(½ page, 12 marks)*
4) A discussion, including answers to the following questions:
    a. Explain why density and hardness testing are two of the most commonly used material testing techniques. *(½ page, 5 marks)*
    b. What disadvantages does the Vickers hardness method suffer from? With these in mind, which of the materials in this practical is the Vickers hardness method most suited to and why? *(½ page, 5 marks)*
    c. Other commonly used engineering materials include ceramics and glass. Would these materials be appropriate for Vickers hardness testing? *(½ page, 5 marks)*
    d. Using the information you have acquired during this practical, suggest appropriate materials for the applications listed below. More than one answer may be correct so explain your answer for each application briefly *(one sentence per application, 8 marks)*
        i. Soles of footwear
        ii. Railway bridges
        iii. Rope
        iv. Circuit boards
        v. Aircraft fuselage
        vi. Safety glass
        vii. Water pipes
        viii. Plastic toys

This report **must not exceed 5 pages.** The report will be marked out of 50 using the scheme indicated above.

<u>Remember you can ask the demonstrators about these questions during your session.</u>