Practical 2P2
Steels

What you should learn from this practical

Science

The properties of engineering alloys depend on their composition, microstructure, and heat treatment. The iron-carbon phase diagram is complex, because of the solid-state phase transformations that take place in iron-carbon alloys. This complexity allows a very wide range of microstructures to be produced within a small family of iron-carbon alloys. The microstructures have widely differing mechanical properties. Hence the versatility of steel and cast iron and their use in many engineering applications. This short practical should enable you to gain an appreciation of the richness and diversity of these materials.

Practical Skills

You will increase your experience in metallography, especially in the application of practical, fine scale microstructures and the interpretation of complex microstructures.

Experimental details

There are six samples in total.

- Three colour-coded Tensometer test pieces of different plain carbon steels are provided; Green, Yellow and Blue, containing 0.1, 0.55 and 1.0 weight percent carbon respectively, all normalised by air cooling from a temperature in the range 830 - 900ºC.

- A steel test piece, White, has been prepared from 0.55 weight percent carbon steel, oil quenched from 840ºC and tempered at 600ºC.
- Two tensometer test pieces of cast irons are provided: C3 (pink) is a grey cast iron containing 3 weight percent carbon, 2 weight percent silicon, 0.8 weight percent manganese and 0.12 weight percent each of sulphur and phosphorus, and C4 (no colour) which is a spheroidal cast iron of similar composition to C3, with the addition of 0.05 weight percent magnesium.

For each specimen, plot a load-elongation curve, and use the head of one of the broken halves to prepare a specimen for measurement of Vickers hardness (at a load of 5kgf) and for metallographic examination.

Etching for metallographic examination should be carried out using a dilute solution of nitric acid in alcohol ('Nital'), containing about 2% acid. In order to save time during the mechanical grinding and polishing stage, you can mount more than one specimen in a single block for metallography and hardness testing. Be sure to label the specimens so that you can identify them in the block.

N.B. Make the hardness measurements before etching

Safety Note: Wear a laboratory coat, suitable gloves and eye-protection during this operation; contact with the Nital etchant would cause serious eye damage. Avoid splashing or spilling the Nital etchant as it is corrosive.

ETCHING NOTES

The Nital etchant behaves in a slightly unusual way. It begins to attack the surface at specific locations, and the etched regions then extend laterally. So an under-etched sample will look very heterogeneous - some regions will appear fully etched, while other regions remain shiny and unaffected. This under-etched structure can easily be mistaken for a two-phase material! Try out different etching times until you can produce a uniform, tinted surface.

If you mount all the plain carbon steels together in one block, and all the cast irons together in another, the etching conditions should be similar for all the specimens in a block. Higher carbon steels generally require slightly longer etching times, but if necessary, you can carefully apply Nital to an individual specimen within a block until it is uniformly etched.

The cast irons should be examined in the as-polished condition, as well as after etching. The graphite phase should be clearly visible in the as-polished state, but etching is needed to reveal the other features of the microstructure.

The microstructure of the tempered martensite, (Steel, White), is extremely fine, so you will need to use the highest resolution objective when looking at this specimen. (On the Olympus BX60M microscope, this will be the UMPlan Fl 100x, N.A. =0.95; do not use DIC!)

Data Analysis

- Tabulate values of hardness number, UTS, percentage elongation and percentage reduction in area at fracture for all the specimens. (Don't forget to quantify the measurement errors in these values)
- Plot a graph of UTS and, on the same axes, percentage elongation versus carbon content for steels Green 0.1%, Yellow 0.55% and Blue 1.0%. On the same plot mark the data for the tempered martensite, White.
- Plot a graph of UTS versus hardness number for all six specimens.

Reporting

This lab is assessed via your lab book. Please note the general guidelines that you will find on Canvas.

Background reading

In order of increasingly advanced level of treatment: available in the Department of Materials Library and most college libraries

- R A Higgins, **Engineering Metallurgy** (6th Edition, 1993), Chapters 7, 11-18.
- R E Reed-Hill, **Physical Metallurgy Principles** (3rd Edition, 1992) Chapters 16-20.
- R W K. Honeycombe and H K D H Bhadeshia, **Steels, Microstructure and Properties** (2nd Edition, 1995, publ. Arnold).
- H K D H Bhadeshia and R W K. Honeycombe, **Steels: Microstructure and Properties**. (3rd Edition, 2006, Butterworth-Heinemann – available online via SOLO)

What should be in your Lab Notebook

- Sketch the iron-carbon phase diagram, and mark on the compositions of the specimens you have examined.

- Micrographs for all seven specimens, labelled to point out the important features of the microstructures. Make sure the magnification is clearly indicated on every micrograph.

- Brief notes on how the microstructures you observe are related to the phase diagram and the heat treatment of the specimens.

- Brief comments on your results, addressing these questions
    - What materials give the highest strength / greatest hardness / highest ductility?
    - Is there a simple trend in the relationship between hardness and tensile strength?
    - What are the reasons for the trends observed in the data or any obvious outliers from the trend?