Unit 37: Structure and Properties of Metals

Unit code: T/600/0302

QCF Level 3: BTEC Nationals

Credit value: 10

Guided learning hours: 60

Aim and purpose

The purpose of this unit is to provide learners with knowledge and understanding of the relationship between the structure and properties of metals.

Unit introduction

In order to successfully work with and process metals, technicians need to have an understanding of the material properties of a range of different metals and alloys. The structure of a metal and how it reacts at different temperatures and under working will determine the choice of metal for different applications.

The purpose of this unit is to provide learners with knowledge and understanding of the relationship between the structure and properties of metals. Learners will gain a knowledge of grains and grain boundaries and common types of metal crystal structure. They will be able to read and construct a thermal equilibrium diagram and define the terms used to describe the mechanical properties of metals. The unit will also enable learners to describe the effect of working on a metal's structure and properties.

The unit provides a level of knowledge of physical metallurgy relevant to the needs of a metallurgical technician and will enable learners to better understand the processing of metals.

Learning outcomes

On completion of this unit a learner should:

1 Know about the crystal and grain structure of metals

2 Be able to construct and read the thermal equilibrium diagram of a binary alloy

3 Know the meaning of terms used to describe the properties of a metal

4 Know how hot and cold working affects the structure and properties of metals.

Unit content

1 Know about the crystal and grain structure of metals

Crystal structures: atomic arrangement types (body-centred cubic, face-centred cubic, close-packed hexagonal); structure of the more common metals; physical properties of the metal relating to crystal structure

Grain structures: atomic arrangement around grain boundaries; nucleation and growth during solidification; formation of chill, equiaxed and columnar crystals; influence of cooling rate on grain size; effect of superheat on the structure of castings and ingots

Solid solutions: substitutional; interstitial; size factor; ordered and disordered solutions; effects eg strength, ductility, Hume-Rothery rules on solubility (size factor, crystal structure, electronegativity and valency)

2 Be able to construct and read the thermal equilibrium diagram of a binary alloy

Binary thermal equilibrium diagrams: cooling curves for pure metals and alloys; phase equilibrium; liquidus and solidus; construction of diagrams; tie lines; lever rule; solid solubility; partial solid solubility; eutectic and eutectoid systems; development of two phase microstructures during cooling; effect of non-equilibrium cooling (coring, changes to precipitation)

Iron/iron carbide diagram: phases (ferrite, cementite, austenite, pearlite, delta ferrite); construction of diagram up to 1.7% carbon

3 Know the meaning of terms used to describe the properties of a metal

Properties of metals: tensile and compressive properties eg stress/strain, yield, elastic and plastic deformation, Young's modulus; use of load/extension curve to record test results and illustrate behaviour; hardness eg Vickers, Brinell, Rockwell, Rebound; further property definitions eg toughness/impact, fatigue strength, creep strength

4 Know how hot and cold working affects the structure and properties of metals

Influence of hot and cold deformation: changes (microstructure, ductility, strength and hardness); effect of annealing heat treatment on properties and microstructure

Assessment and grading criteria

In order to pass this unit, the evidence that the learner presents for assessment needs to demonstrate that they can meet all the learning outcomes for the unit. The assessment criteria for a pass grade describe the level of achievement required to pass this unit.

Assessment and grading criteria		
To achieve a pass grade the evidence must show that the learner is able to:	**To achieve a merit grade the evidence must show that, in addition to the pass criteria, the learner is able to:**	**To achieve a distinction grade the evidence must show that, in addition to the pass and merit criteria, the learner is able to:**
P1 describe the common types of metal crystal structures	**M1** explain the effect of crystal type on metal properties	**D1** assess the factors affecting solid solubility (Hume-Rothery rules)
P2 describe the formation of grains and grain boundaries during the solidification of metals	**M2** describe the effect of cooling rate and heat extraction on grain size and shape	**D2** evaluate microstructures in relation to their thermal equilibrium diagram and their cooling history.
P3 describe the atomic arrangement and properties of given types of solid solutions [IE4]	**M3** describe the relationship between the structure and properties of a metal	
P4 construct a binary thermal equilibrium diagram from cooling curves [IE1]	**M4** explain the relationship between percentage cold work and the response to annealing heat treatment.	
P5 describe the cooling of an alloy from the liquid to solid state and use the lever rule to calculate phase proportions and compositions from tie lines		
P6 describe the phases in an iron/iron carbide phase diagram		
P7 define the terms used to describe the mechanical properties of metals		
P8 describe the influence of hot and cold working on the microstructure and properties of a metal.		

PLTS: This summary references where applicable, in the square brackets, the elements of the personal, learning and thinking skills applicable in the pass criteria. It identifies opportunities for learners to demonstrate effective application of the referenced elements of the skills.

Key	IE – independent enquirers	RL – reflective learners	SM – self-managers
	CT – creative thinkers	TW – team workers	EP – effective participators

Essential guidance for tutors

Delivery

The teaching and learning strategies used to deliver this unit must enable the learner to understand the relationship between structure and properties of metals. The emphasis should be placed on well-planned and structured activities that complement and reinforce the theory.

The work on thermal equilibrium diagrams will need to be supported by microscopic examination of samples from the alloys being covered.

This unit underpins much of the subject matter in *Unit 36: Mechanical and Thermal Treatment of Metals, Unit 38: Industrial Alloys* and *Unit 39: Metallurgical Techniques* and as such examples and activities should be chosen that reinforce these links.

Note that the use of 'eg' in the content is to give an indication and illustration of the breadth and depth of the area or topic. As such, not all content that follows an 'eg' needs to be taught or assessed.

Outline learning plan

The outline learning plan has been included in this unit as guidance and can be used in conjunction with the programme of suggested assignments.

The outline learning plan demonstrates one way in planning the delivery and assessment of this unit.

Topic and suggested assignments/activities and/assessment
Whole class teaching: • introduction to unit, scheme of work and assessment • describe atomic arrangement types and the crystal structure of common metals • describe grain structures and explain solid solutions in relation to structures of metals and the different related effects.
Prepare for and carry out **Assignment 1: Structures of Metals** (P1, P2, P3, M1, D1)
Whole class teaching/practical demonstration: • explain and demonstrate the production and interpretation of binary thermal equilibrium diagrams • describe and explain the use of iron/iron carbide diagrams. *Individual or group activities:* • working in small groups to produce and read equilibrium and iron/iron carbide phase diagrams.
Prepare for and carry out **Assignment 2: Thermal Equilibrium Diagrams** (P4, P5, P6, M2, D2)
Whole class teaching: • explain the terms used to describe the tensile and compressive properties of metals • explain the terms used for hardness and other property definitions • describe the use of load/extension curve to record test results.
Prepare for and carry out **Assignment 3: Properties of Metals** (P7, M3)
Whole class teaching: • explain how hot and cold working affects the structure and properties of metals.
Prepare for and carry out **Assignment 4: Effects of Hot and Cold Working** (P8, M4)

Topic and suggested assignments/activities and/assessment
Feedback, unit evaluation and close.

Assessment

Assessment of this unit could be achieved by using a mixture of laboratory reports, assignments and time constrained tests.

The pass grade specifies the minimum acceptable level required by the learners. The assessments must cover all of the learning outcomes and the associated pass criteria. Achievement of a merit or distinction grade will require the learner to demonstrate a deeper understanding of the relationship between thermo-mechanical history, structure and properties.

To achieve a pass, learners should be able to describe the atom arrangement in common metallic crystal structures. They will be able to describe the formation of grains and grain boundaries during solidification and the atom arrangement and resulting properties of solid solutions. Learners will be able to construct a binary equilibrium diagram and explain the phases present in the iron carbon phase diagram. They will also be able to describe the cooling of an alloy from the liquid to solid state and use the lever rule to calculate phase proportions and compositions from tie lines. They will also be able define terms used to describe the mechanical properties of metals and describe the effect of working on structure and properties.

To achieve a merit the learner should be able to explain the effect of the crystal structure on the properties of metals. They need to be able to predict and describe the effect of cooling rate on grain structure, and explain the effect of working on the structure and properties of metals and their response to heat treatment.

To achieve a distinction the learner should be able to assess the factors which determine the solubility of one metal in another with reference to crystal structure, atomic size, elecro-negativity and valency. The learner should also be able to apply their understanding of ph diagrams to interpret from microstructures of binary alloys their approximate composition and thermal history.

Programme of suggested assignments

The table below shows a programme of suggested assignments that cover the pass, merit and distinction criteria in the assessment and grading grid. This is for guidance and it is recommended that centres either write their own assignments or adapt any Edexcel assignments to meet local needs and resources.

Criteria covered	Assignment title	Scenario	Assessment method
P1, P2, P3, M1, D1	Structures of Metals	A metallurgist in a large engineering company has been asked to report on the structures of metals.	Written assignment.
P4, P5, P6, M2, D2	Thermal Equilibrium Diagrams	A metallurgist has been asked to produce a thermal equilibrium diagram for an alloy.	Written assignment including equilibrium diagrams.
P7, M3	Properties of Metals	Produce an information leaflet/poster for new recruits detailing the terms used to describe the mechanical properties of metals.	Written assignment.
P8, M4	Effects of Hot and Cold Working	Produce an information leaflet/poster for new recruits detailing the influence of hot and cold working on metals.	Written assignment.

Links to National Occupational Standards, other BTEC units, other BTEC qualifications and other relevant units and qualifications

This unit forms part of the BTEC Engineering sector suite. This unit has particular links with the following unit titles in the Engineering suite:

Level 1	Level 2	Level 3
		Mechanical and Thermal Treatment of Metals
		Industrial Alloys
		Metallurgical Techniques
		Extraction and Refining of Metals
		Liquid Metal Casting Processes

Essential resources

Access to facilities and equipment for the microscopic examination of metals is essential for this unit. Learners should also have access to the internet and a range of manufacturing product data.

Employer engagement and vocational contexts

Most of the work for this unit can be set in the context of learners' work placements or be based on case studies of local manufacturers. There are a range of organisations that may be able help centres engage and involve local employers in the delivery of this unit, for example:

- Work Experience/Workplace learning frameworks – Centre for Education and Industry (CEI, University of Warwick) – www.warwick.ac.uk/wie/cei
- Learning and Skills Network – www.vocationallearning.org.uk
- Network for Science, Technology, Engineering and Maths Network Ambassadors Scheme – www.stemnet.org.uk
- National Education and Business Partnership Network – www.nebpn.org
- Local, regional Business links – www.businesslink.gov.uk
- Work-based learning guidance – www.aimhighersw.ac.uk/wbl.htm

Indicative reading for learners

Textbook

Higgins R – *Materials for Engineers and Technicians* (Newnes, 2006) ISBN 0750668504

Delivery of personal, learning and thinking skills

The table below identifies the opportunities for personal, learning and thinking skills (PLTS) that have been included within the pass assessment criteria of this unit.

Skill	When learners are ...
Independent enquirers	identifying questions to answer and problems to resolve when working with binary thermal equilibrium diagrams.

Although PLTS are identified within this unit as an inherent part of the assessment criteria, there are further opportunities to develop a range of PLTS through various approaches to teaching and learning.

Skill	When learners are ...
Independent enquirers	analysing and evaluating information relating to the structure and properties of metals, judging its relevance and value
Creative thinkers	asking questions relating to the structures and properties of metals in order to extend their thinking.

Functional Skills – Level 2

Skill	When learners are ...
English	
Speaking and listening – make a range of contributions to discussions and make effective presentations in a wide range of contexts	describing the structures and properties of metals
Reading – compare, select, read and understand texts and use them to gather information, ideas, arguments and opinions	investigating and researching the structure and properties of metals
Writing – write documents, including extended writing pieces, communicating information, ideas and opinions, effectively and persuasively	describing the structures and properties of metals.