Unit 39: Metallurgical Techniques

NQF Level 3: BTEC National

Guided learning hours: 60

Unit abstract

For every metal product or application, the choice of metal or alloy used and the means by which it is processed depends on its properties. In order to make the correct choice, technicians need to be able to examine and test metals and alloys to find out their characteristics. These include the mechanical properties (such us strength and hardness) and the microscopic and macroscopic mechanisms that cause a metal or alloy to behave in the way that it does (ie the changes that occur on an atomic level that affect the metal's properties).

This unit aims to develop learners' understanding of the range of techniques used for testing and examining metals. Learners will gain the knowledge and skills needed to measure the properties of alloys using mechanical testing techniques. They will be introduced to the macro analysis of metals and will learn how to prepare samples and use a metallographic microscope to assess a metal's structure.

The unit covers chemical analysis and learners will gain knowledge of the principles and procedures involved and the limitations of spectroscopic methods. Finally, learners will develop a knowledge of the defects found in metals and the means of detecting them using non-destructive testing techniques.

Learning outcomes

On completion of this unit a learner should:

1 Be able to use mechanical testing methods to measure the properties of an industrial alloy

2 Be able to prepare samples for macro and micro-examination and carry out a metallographic examination

3 Know the principles and procedures used in the chemical analysis of metallic materials

4 Know about non-destructive testing techniques that can be used to reveal defects in metallic components.

Unit content

1 **Be able to use mechanical testing methods to measure the properties of an industrial alloy**

Measurement of mechanical properties: tensile, hardness, impact tests; application and use of national and international standards eg BS, EN, ISO

Special purposes: other mechanical tests eg creep, fatigue, Erichsen cupping test, compression tests, torsion tests

2 **Be able to prepare samples for macro and micro-examination and carry out a metallographic examination**

Macroscopic examination: sample selection and preparation; procedures and etching reagents for macro-etching; principles and procedures for sulphur printing

Microscopic examination: sample selection and preparation; construction and operation of metallurgical microscope; identification of defects; determination of cleanliness; typical etchants for common industrial alloys; identification of grain structures and phases; measurement of grain size and phase proportions

3 **Know the principles and procedures used in the chemical analysis of metallic materials**

Chemical analysis: principles, applications, and limitations of spectroscopic methods eg spark emission, inductively coupled plasma, glow discharge, atomic absorption, atomic fluorescence, x-ray fluorescence

4 **Know about non-destructive testing techniques that can be used to reveal defects in metallic components**

Manufacturing process defects: nature, origin and influence on properties and performance of metallic components; types of defects and their causes eg porosity, shrinkage, segregation, inclusions, lamination, cracking

Non-destructive techniques: principles and applications of non-destructive testing (NDT) methods eg visual, dye penetrant, magnetic particle, eddy current, ultrasonic and radiographic inspection

Grading grid

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

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 and use suitable methods to measure the mechanical properties of an industrial alloy P2 select and describe a method to measure the suitability of an industrial alloy for a given special purpose P3 describe and carry out a procedure for the macroscopic examination of an industrial alloy P4 measure, record and identify the features observed in the microstructure of an industrial alloy P5 describe a method used for the chemical analysis of a given industrial alloy	M1 identify and explain the procedures that ensure a specified mechanical test is performed accurately and reproducibly M2 compare methods used for the chemical analysis of industrial alloys M3 explain the origin and effect of a defect observed in a metallic component M4 compare the advantages and limitations of two alternative NDT techniques in assessing the quality of a metallic component.	D1 analyse the uncertainty in the measurement of a selected mechanical property D2 evaluate the processing history of an industrial alloy from an analysis of its structure D3 select and justify a suitable NDT technique to evaluate the quality of a metallic component.

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:**
P6 identify and describe manufacturing process defects in a given metallic component P7 describe a suitable NDT technique that could be used to assess the quality of a given metallic component.		

Essential guidance for tutors

Delivery

The teaching and learning strategies used to deliver this unit must enable learners to understand the scientific principles involved in testing and examining metals. Learners will need to be aware of the applications and limitations of the test methods, be able to undertake basic mechanical testing and metallographic examination of metals, and be aware of standard test procedures for the testing and examination of metals.

Practical work and demonstrations will therefore form an essential part of the teaching and learning process. These may be undertaken in small groups or individually, since both team working and individual accountability are professional requirements of an engineering technician in this field.

Learners will benefit enormously from hands-on experience of carrying out destructive and non-destructive testing of industrial alloys, although the limited availability of specialist equipment (such as that used for chemical analysis) may mean that demonstrations are sometimes necessary.

Direct practical experience is essential to complete learning outcomes 1 and 2. In completing learning outcomes 3 and 4, use may be made of demonstrations. Where a centre does not have 'in-house' access to the techniques listed in the unit content, the centre should consider arranging visits to industrial laboratories so that learners can see the techniques first hand.

It is also important that techniques are practised on common industrial alloys rather than simple or ideal metallic systems. The type and range of alloys is not specified in the unit; they should be chosen to reflect the needs of local industry. In learning outcome 4, use should be made of industrial metallic components containing representative defects.

Learners should experience the full range of metallurgical techniques although achievement of the assessment and grading criteria may allow learners to focus on a selected few in their assessed work.

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.

Assessment

This unit can be assessed using a mixture of laboratory work and assignments/case studies. A suitable case study could involve learners in selecting, specifying and explaining suitable metallurgical techniques to evaluate a given metallic component.

To achieve a pass, learners should be able to describe and carry out routine mechanical testing (tensile, hardness and impact testing), working to relevant national and international standards. Learners will need to select and describe more specialised mechanical tests to measure such properties as formability, toughness

and resistance to creep and fatigue loading. Additionally, learners should be able to carry out and describe the macroscopic and microscopic examination of an industrial alloy, including the selection and preparation of a sample. During these processes, learners should be able to record and describe the macroscopic and microscopic structures that are seen. Learners should also be able to describe a method used to determine the chemical analysis of a given industrial alloy. Finally, learners should be able to identify and describe manufacturing process defects in a given metallic component and describe a suitable non-destructive testing technique that could be used to assess the quality of such a component.

To achieve a merit learners must be able identify and explain how to measure mechanical properties accurately and reproducibly. They should also be able to explain both the benefits and limitations of macro-etching and sulphur printing and be able to evaluate methods used for the instrumental chemical analysis of metals. Finally, they should have an understanding of the cause and effect of metal defects and be able to evaluate the alternative non-destructive methods used for revealing surface and internal defects in metallic components, taking into account defect type, component design and the alloy used in its manufacture.

To achieve a distinction, learners must be able to estimate the size and cause of uncertainty in the measurement of mechanical properties. They will be able to evaluate the macrostructural and microstructural features seen in metal samples to determine the condition of the metal (as-cast/hot worked, cold worked, heat treated) and if the metal has been worked. Learners should also be able to select and justify a technique for the non-destructive examination of a metallic component, having regard for the type of defect likely to be found, its likely location, the alloy type and the shape and size of the component.

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

This unit requires an understanding of mechanical properties and phase equilibria gained by previous completion of *Unit 37*: *Structure and Properties of Metals*. There are also links with *Unit 36*: *Mechanical and Thermal Treatment of Metal*s and *Unit 41*: *Liquid Metal Processing*, which introduce the origin and nature of defects in the casting and forming of metals. Coverage of these other units before this one is useful but not essential.

Essential resources

Access to facilities and equipment for the metallurgical testing and examination of metals is essential for the delivery of this unit. Facilities are also required for the metallographic examination of industrial alloys using macro-etching and optical microscopy, including the ability to prepare the samples. Throughout, use should be made of samples of industrial alloy systems, including examples containing 'real' defects that can be examined visually, non-destructively and metallographically.

Learners should also have access to relevant national and international standards (BS, EN, ISO and ASTM) for the testing and inspection of metals.

Indicative reading for learners

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

Ineson P — *Introduction to Practical Ore Microscopy* (Longman, 1989) ISBN 0582301408

Timings R L — *Engineering Materials, Volume 1* (Longman, 1998) ISBN 0582319285

Key skills

Achievement of key skills is not a requirement of this qualification but it is encouraged. Suggestions of opportunities for the generation of Level 3 key skill evidence are given here. Tutors should check that learners have produced all the evidence required by part B of the key skills specifications when assessing this evidence. Learners may need to develop additional evidence elsewhere to fully meet the requirements of the key skills specifications.

Application of number Level 3	
When learners are:	**They should be able to develop the following key skills evidence**
• applying methods used to measure the mechanical properties of an industrial alloy • measuring and recording the features in the microstructure of an alloy.	N3.1 Plan an activity and get relevant information from relevant sources. N3.2 Use this information to carry out multi-stage calculations to do with: a amounts or sizes b scales or proportion c handling statistics d using formulae.
Communication Level 3	
When learners are:	**They should be able to develop the following key skills evidence**
• describing suitable techniques for measuring the mechanical properties of alloys • describing chemical analysis and non-destructive testing techniques.	C3.1a Take part in a group discussion. C3.2 Read and synthesise information from at least **two** documents about the same subject. Each document must be a minimum of 1000 words long.
Working with others Level 3	
When learners are:	**They should be able to develop the following key skills evidence**
• working in the metallurgical or chemical laboratory in small teams to carry out a specified metallurgical investigation.	WO3.1 Plan work with others.