

Unit 51: Mechanical and Thermal Treatment of Metals

Unit code:	M/600/0301
QCF Level 3:	BTEC Nationals
Credit value:	10
Guided learning hours:	60

● Aim and purpose

This unit aims to provide learners with a knowledge and an understanding of the important processes used in the mechanical shaping and heat treatment of metals and alloys.

● Unit introduction

There are a range of processes and techniques that are used in the fabrication of products made from metals and alloys. These can vary from mechanical processes such as extrusion (squeezing the metal under high pressure into the desired form), to powder metallurgy (where the metal is powdered, passed through a die and treated with heat, pressure or long setting times).

Heat treatment processes such as annealing and quenching, are also used as they are an efficient way of manipulating the properties of metals and alloys through heating the metal and controlling the rate of cooling.

This unit aims to provide learners with a broad overview of the important processes used in the mechanical shaping and heat treatment of metals and alloys. Learners will also develop an understanding of the process controls used and the characteristic defects typically found in wrought and heat-treated products.

The unit can be effectively linked with other metallurgical units which consider the properties of materials in greater detail. It can be used, in conjunction with these other units, to illustrate the relationships between the structure and properties of metals and alloys and the mechanical shaping and heat-treatment processes used in the manufacture of products.

● Learning outcomes

On completion of this unit a learner should:

- 1 Know working processes for product manufacture
- 2 Know about powder metallurgy techniques for component manufacture
- 3 Understand the applications of heat-treatment furnaces and ancillary equipment
- 4 Understand process controls and typical defects in wrought and heat-treated products.

Unit content

1 Know working processes for product manufacture

Function of mechanical working: effect on shape, structure and properties of material; classification of processes as primary (the production of standard intermediate shapes from cast ingot/billet), or secondary (the production of finished shapes); choice of hot or cold working; effect of temperature on properties

Mechanical working processes: eg

- ◇ forging: open and closed die methods, use of forging hammers and presses (drop and press forging), upset forging, methods for primary and secondary forms, choice of temperature, typical product characteristics and effect on macrostructure; directionality/fibre
- ◇ rolling: flat and section rolling, mill configurations such as, two, three and four high mill stands, single stand and continuous mills, examples of primary mills (conversion of cast products to intermediate forms) and secondary mills (for production of rod, bar, section, sheet and strip), choice of rolling temperature, typical products
- ◇ extrusion: direct and indirect extrusion, production of continuous solid and hollow sections, impact extrusion, cold extrusion
- ◇ rod and wire drawing: use of single and multiple dies, role of inter-stage annealing
- ◇ sheet metal forming: deep drawing and pressing, bending, spinning

2 Know about powder metallurgy techniques for component manufacture

Manufacturing processes: types and production of metal powders; powder compaction and sintering; secondary processing and finishing

Key characteristics: advantages and disadvantages of manufacture using powder metallurgy; component design methods; suitable materials and typical component applications eg bearings, automotive parts

3 Understand the applications of heat-treatment furnaces and ancillary equipment

Function and reasons for heat treatment: typical treatment cycles (heat/soak/cool) and applications eg homogenising, annealing, normalising, hardening, tempering, stress relieving, solution treatment and aging; typical metals and alloys eg plain carbon steels, copper and its alloys, aluminium and its alloys; cooling media, quenchants and their properties; role of protective atmospheres

Heat-treatment furnace: choice of fuel and method of heating (direct/indirect); batch and continuous furnaces; construction and use of commonly used furnaces eg box, pit, bogie hearth, sealed quench, salt bath, fluidised bed, moving or mesh belt, shaker/roller/rotary hearth, walking beam; uses of above furnaces in heat-treating intermediate and finished products

Pyrometry: temperature scales; operating principles of pyrometer and construction; practical applications eg expansion thermometers, resistance thermometers, thermistors, thermocouples, optical and total radiation pyrometers

Surface hardening: principles, techniques and application eg carburising, nitriding, carbonitriding, flame and induction hardening

4 Understand process controls and typical defects in wrought and heat-treated products

Control of wrought processes: importance of control of temperature, rate and degree of deformation, dimensional accuracy, surface finish

Control of heat-treatment processes: importance of control of temperature, time, heating and cooling rates, atmosphere

Defects in wrought products: characteristic defects in rolled, forged, extruded or pressed products eg internal and external cracking, poor impression, dimensional defects

Defects in heat-treated products: eg overheating/burning, quench-cracking, distortion, scaling, decarburisation

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 function of mechanical working processes	M1 compare the advantages and disadvantages of hot and cold working processes	D1 evaluate key variables in a mechanical working, powder metallurgy and heat-treatment process and the control methods used to maintain product quality
P2 describe mechanical working processes required for the manufacture of given products	M2 compare possible forging, rolling or extrusion techniques that could be used in the manufacture of a product	D2 justify methods used to reduce defects in mechanical working and heat-treatment processes.
P3 describe the manufacturing processes required for the production of a component using powder metallurgy	M3 assess the use of bulk and surface heat-treatment processes for given products.	
P4 identify key characteristics of a product manufactured using powder metallurgy techniques [IE4]		
P5 explain the function and reasons for heat treatment of given metals and alloys		
P6 describe the required heat-treatment furnace (including pyrometry) for the heat treatment of given materials and products		
P7 describe the process of surface hardening for a given component		
P8 explain the methods used to control processes when producing both wrought and heat-treated products		

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:
P9 describe defects in wrought and heat-treated products.		

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 CT – creative thinkers	RL – reflective learners TW – team workers	SM – self-managers EP – effective participators
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Essential guidance for tutors

Delivery

A wide range of possible resources and delivery methods could be used, depending upon availability. This is particularly so in relation to laboratory-based practical activities, demonstrations and industrial visits. However, there is a reasonable amount of video material, computer based and text-based information readily available.

Use of case studies, particularly if based on processes with which learners are familiar from their places of work, is a valuable way of delivering much of this unit's content.

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. A wide range of possible resources and delivery methods could be used, depending upon availability. This is particularly so in relation to laboratory-based practical activities, demonstrations and industrial visits. However, there is a reasonable amount of video material, computer based and text-based information readily available.

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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 content, scheme of work and method of assessment
- describe the purpose and effect of mechanical working on the structure and properties of metals
- describe the choice and effect of hot and cold working on metals
- describe the different mechanical working processes.

Learner investigation:

- learners research the application of different working processes.

Prepare for and carry out **Assignment 1: Mechanical Working** (P1, P2, M1, M2)

Whole class teaching:

- describe the manufacture of metal powders, their characteristics and advantages and disadvantages.

Prepare for and carry out **Assignment 2: Powder Metallurgy** (P3, P4)

Topic and suggested assignments/activities and/assessment

Whole class teaching:

- explain typical treatment cycles and applications and the metals and alloys that heat-treatment processes are typically applied to
- explain cooling processes and the use of quenchants. Explain the role of protective atmospheres
- explain the construction and applications of different types of heat-treatment furnace and the choice and use of fuels. Describe the use of different furnaces in heat-treating intermediate and finished products
- explain the operation and construction of pyrometers and their application
- explain the principles, techniques and application of surface hardening.

Industrial visit:

- visit to local metals manufacturer to view industrial applications of heat-treatment.

Prepare for and carry out **Assignment 3: Heat Treatment** (P5, P6, P7, M3)

Whole class teaching:

- explain the purpose, importance and means of controlling wrought processes
- explain the purpose, importance and means of controlling heat-treatment processes
- explain the different defects that can occur on wrought and heat-treated products.

Practical workshop investigation:

- learners investigate a range of faulty and non-faulty wrought and heat-treated products/parts to identify the types of defects that can occur and discuss the control processes that were used.

Prepare for and carry out **Assignment 4: Process Controls and Typical Defects** (P8, P9)

Prepare for and carry out **Assignment 5: Defect Reduction in Mechanical Working and Heat Treatment Processes** (D1, D2)

Feedback, unit evaluation and close.

Assessment

Evidence of achievement could take the form of individual or group assignment reports on specific processes or groups of processes, or on work related to particular products and the way(s) in which they may be manufactured and/or heat treated. However, care must be taken when using group work to ensure that assessment and grading evidence is authentic and at an individual level, as collective or group evidence would not be acceptable.

Case study work and unseen tests could also form part of an assessment strategy. In cases where practical work, demonstrations or industrial visits have formed part of the delivery method, reports on these activities could also be structured to provide assessment and grading evidence.

To achieve a pass, learners should appreciate the principal methods of shaping metals by mechanical working and by the consolidation of powders. They should be able to identify key features of the industrial plant and equipment used and describe in outline the important characteristics of the resulting products. Learners should also be able to demonstrate an understanding of the role of heat treatment in manufacturing, identifying the most common types of heat treatment process and the plant and equipment used to carry them out. Additionally, the learner should be able to explain the methods used to control mechanical working and heat treatment processes and recognise the typical defects that may occur due to such processes.

To achieve a merit, learners should be able to compare the possible methods of manufacture of products using forging, rolling or extrusion techniques and the advantages and disadvantages associated with hot and cold working as alternatives. Learners should also be able to assess the use of bulk and surface heat treatment processes for given products.

To achieve a distinction, learners should be able to evaluate key variables within a mechanical working, powder metallurgy or heat treatment process and the control methods used to maintain product quality. The learner should also be able to justify methods used to reduce defects in mechanical working and heat treatment processes.

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, M1, M2	Mechanical Working	Learners investigate a metals manufacturer.	Case study or industry visit.
P3, P4	Powder Metallurgy	Learners investigate a metals manufacturer.	Case study or industry visit.
P5, P6, P7, M3	Heat Treatment	Learners investigate a metals manufacturer.	Case study or industry visit.
P8, P9	Process Controls and Typical Defects	Learners investigate a metals manufacturer.	Case study or industry visit.
D1, D2	Defect Reduction in Mechanical Working and Heat Treatment Processes	Metallurgical analysis reporting on ways of reducing defects in metals and alloys.	A written report based on research and information gathered.

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
		Structure and Properties of Metals
		Industrial Alloys
		Metallurgical Techniques
		Extraction and Refining of Metals
		Liquid Metal Casting Processes

The unit also links to the SEMTA Level 3 National Occupational Standards for Engineering Materials Processing and Finishing, particularly Unit 64: Heat Treating Materials for Manufacturing Activities.

Essential resources

Resources should include examples of products made by the processes referred to in the unit content along with, if possible, some containing typical defects. Manufacturers' brochures and literature should be available as should access to CD ROM and internet-based information, eg TALAT (Training in Aluminium Technologies) CD ROM available from the European Aluminium Association.

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

Textbooks

Lord Bacon J – *Forge-practice and Heat Treatment of Steel* (BiblioBazaar, LLC, 2008) ISBN 9780559521584

McDowell J – *Metals* (Chelsea House Publishers, 2008) ISBN 0791095355

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	analysing and evaluating information, judging its relevance and value when identifying the key characteristics of a product manufactured using powder metallurgy techniques.

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 ...
Creative thinkers	asking questions about mechanical and heat treatment processes to extend their thinking
Reflective learners	setting goals with success criteria for their development and work
Self-managers	working towards goals, showing initiative, commitment and perseverance.

● 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 mechanical working and heat treatment processes
Reading – compare, select, read and understand texts and use them to gather information, ideas, arguments and opinions	investigating and researching mechanical working and heat treatment processes
Writing – write documents, including extended writing pieces, communicating information, ideas and opinions, effectively and persuasively	describing mechanical working and heat treatment processes.