

Unit 21: Materials Engineering

Unit code: F/601/1626

QCF level: 4

Credit value: 15

- **Aim**

This unit will provide learners with the necessary background knowledge and understanding of the properties, selection, processing and failure of engineering materials.

- **Unit abstract**

The selection of the most appropriate materials for an engineered product and their processing is of prime importance if the product is to be fit for purpose. Engineers must thus be aware of the range of materials at their disposal. Knowledge of the structure of materials and the way in which this affects their properties is also desirable. Material properties may be determined or verified by testing and engineers should be aware of the range of standard tests and test equipment that is used and be able to interpret the test data. Materials generally need to be formed to shape, fabricated or processed in some other way, to make engineering components. The properties of the raw material can affect the choice of process and in some cases the choice of process can affect the final properties of a component. Materials also, for a variety of reasons, sometimes fail in service and engineers need to be aware of the modes and causes of such failure, as well as the preventative methods that may be used, to prolong their service life.

This unit will thus provide learners with the necessary background knowledge and understanding of the properties, testing, treatments, processing, selection, failure modes and prevention of a variety of engineering materials. In addition, this unit offers learners the opportunity to consider environmental issues related to increased productivity and sustainability that lead to less waste and to the more efficient use of energy and resources when selecting materials for particular applications.

- **Learning outcomes**

On successful completion of this unit a learner will:

- 1 Be able to determine the properties and selection criteria of materials from tests and data sources
- 2 Understand the relationships between manufacturing processes and material behaviour
- 3 Be able to select suitable materials and processing methods for a specific product
- 4 Understand the in-service causes of failure of engineering materials.

Unit content

1 Be able to determine the properties and selection criteria of materials from tests and data sources

Criteria for material selection: definitions of material properties and characteristics appropriate to the learner's programme of study eg mechanical, physical, chemical, process characteristics and costs for range of materials (metals, ceramics, polymers, and composites)

Categorise materials: an appreciation of the properties of metals, ceramics, polymers and composites; recognition of micro structural characteristics of the more commonly used engineering materials

Materials testing: tests to determine the properties of commonly used engineering materials eg metals, ceramics, polymers and composites (such as electrical conductivity/resistivity, magnetic susceptibility, mechanical strength, hardness, toughness, fatigue and creep resistance, corrosion and reactivity, wear resistance, optical and thermal properties, formability); appropriate statistical methods and the processing of test data

Data sources: published data eg British Standards, ISO, product data sheets, IT sources, standard published data sources, manufacturers' literature, job-specific information such as specifications, test data and engineering drawings; assessment of data reliability

2 Understand the relationships between manufacturing processes and material behaviour

Treatment processes: heat treatments eg quench and precipitation hardening processes, complex heat treatments (such as conjoint mechanical/thermal treatments), glass transitions; other treatment processes eg coated materials (such as CVD/vacuum coating processes), chip technology; surface treatments/surface engineering, polymer treatments, composites/powder produced materials, matrix/reinforcement relationships, dispersion strengthening

Liquid processing: metal casting and injection moulding/extrusion of polymers; effect of processing on structure and properties eg grain structure, porosity

Mechanical processing: effect on structure and properties illustrated by a range of processes eg mechanical working of metals, powder processing of metals and ceramics, extrusion and forming of polymer sheet, welding, use of adhesives; effect of processing on structure and properties eg residual stresses, work hardening

Composition and structure: eg alloying, co-polymerisation; additives, cross-linking, crystallinity, lattice structure, slip planes and their effect on properties of parent material

3 Be able to select suitable materials and processing methods for a specific product

Design constraints: eg working conditions such as applied forces, environment, electrical/magnetic requirements, shape, form and function of the product

Materials, properties and processing: inter-relationship between product design, material selection and processing methods; merit index/index of suitability; ability to be re-used

Processing limitations: effects of the manufacturing processing capabilities on the structure of materials and preventing or facilitating product design, effect on environment (such as sustainability, emissions, energy conservation)

4 Understand the in-service causes of failure of engineering materials

Causes of failure: failure of material categories (metals, ceramics, polymers and composites) eg creep, fatigue, impact, overstressing, corrosion, temperature, thermal cycling, residual stresses, stress relaxation, degradation (composition change), radiation, electrical breakdown, or combinations of these

Service life: contributory effects of service conditions to failure eg inappropriate maintenance, inappropriate use, faults in manufacture, material selection and design faults, changes in service conditions such as environment, loading and temperature

Estimation: methods of investigating failure and the preparation of estimates of product service life that require the use of calculations eg creep or fatigue failure

Improving service life: recommending remedial and/or preventative measures eg changes to material, product design, protective systems for corrosion and degradation, adjustment loading and working temperature

Learning outcomes and assessment criteria

Learning outcomes On successful completion of this unit a learner will:	Assessment criteria for pass The learner can:
LO1 Be able to determine the properties and selection criteria of materials from tests and data sources	1.1 detail the appropriate properties and criteria for the selection of a metallic, ceramic, polymer and composite material 1.2 explain the particular characteristics related to the microstructure and macroscopic behaviour of the four categories of engineering materials 1.3 generate and process test data to assess material properties for two categories of material 1.4 investigate and assess the quality of suitable data from three different sources
LO2 Understand the relationships between manufacturing processes and material behaviour	2.1 explain how one heat treatment process and two other treatment processes affect the structure, properties and behaviour of the parent material 2.2 explain how one liquid processing method and two mechanical processing methods affect the structure, properties and behaviour of the parent material 2.3 investigate how the composition and structure of metal alloys, polymers and polymer matrix composites influence the properties of the parent material
LO3 Be able to select suitable materials and processing methods for a specific product	3.1 analyse the function/s of a product in terms of the materials' constraints on its design 3.2 identify the required properties for the product and select the most appropriate materials and processing methods 3.3 identify and explain the possible limitations on the product imposed by the processing and by the need to safeguard the environment and minimise costs

Learning outcomes On successful completion of this unit a learner will:	Assessment criteria for pass The learner can:
LO4 Understand the in-service causes of failure of engineering materials	4.1 explain the common causes of in-service failure for products or structures produced from each or a combination of the four categories of engineering materials 4.2 for one product or material structure, identify and explain the in-service conditions that may contribute to early failure 4.3 explain the methods for investigating materials failure and for estimating product service life, when a product is subject to creep and fatigue loading 4.4 determine and make recommendations for remedial/preventive measures for a given product or materials structure, that will help improve its service life.

Guidance

Links

Successful completion of *Unit 8: Engineering Design* and this unit would enable learners to meet, in part, the Engineering Technician (Eng Tech) and Incorporated Engineer (IEng) requirements laid down in the UK Engineering Council Standard for Professional Engineering Competence (UK-SPEC) Competence B2, 'Identify, organise and use resources effectively to complete tasks, with consideration for cost, quality, safety and environmental impact'.

Essential requirements

Learner access to suitable materials testing equipment, specimens and test instrumentation is required. The range of tests chosen will depend on the learner's working environment and particular needs but will need to include, as a minimum, tests that involve metals and polymers. Sample materials from each of the four categories for inspection, as well as products/structures produced from these categories of material, are also required.

Employer engagement and vocational contexts

Liaison with employers would prove of benefit to centres, especially if they are able to offer help with the provision of a suitable materials testing and/or processing/fabrication environment.