Unit T14: Advanced Materials

Unit code:	L/503/7412
QCF level:	6
Credit value:	15

Aim

This unit aims to develop learners' understanding of appropriate materials and processes used to ensure the structural integrity of products that are manufactured using advanced materials. The unit also covers the environmental impact of engineering materials.

Unit abstract

Mechanical engineering components and structures require specific materials for optimal performance. Solutions to design problems might include the use of light alloys or fibre-reinforced polymer matrix composites. Enhanced functionality can be achieved through the embedding of sensors, control systems and actuators to produce smart materials and intelligent structures. This unit also explores the emerging technology of biomimetics (design informed by natural systems).

The growing population is putting increasing pressure on resources that must be used efficiently and effectively to create a sustainable economy. Lightweight materials minimise the energy requirements for transport systems and process machinery. The adoption of these engineering solutions should help the industry to grow and increase employment opportunities.

Learning outcomes

On successful completion of this unit a learner will:

1 Understand the selection, manufacturing and testing processes for light metal alloys

2 Understand the selection, manufacturing and testing processes for composite materials

3 Understand the life cycle assessment process that informs the selection of sustainable materials

4 Understand major developments in materials and associated technologies.

Unit content

1 Understand the selection, manufacturing processes and testing processes for light metal alloys

Light metals: eg aluminium, magnesium, titanium; microstructure; macroscopic behaviour

Manufacturing and joining processes: powder metallurgy; diffusion bonding; chemical vapor disposition (CVD) and physical vapor disposition (PVD) of metals; welding; fasteners

Testing mechanical properties: modulus; strength (failure modes, fracture mechanics); toughness; creep; fatigue; impact; tribology

Testing materials characterisation: porosity; non-destructive testing

2 Understand the selection, manufacturing and testing processes for composite materials

Classes of reinforcements and matrix systems: reinforcements (aramid, carbon, glass, natural fibres); matrix (thermoplastic polymers, thermosetting resins, ceramics (CMC), metal (MMC))

Mechanical properties: modulus; strength (failure modes and fracture mechanics); rules-of-mixture; toughness; creep; fatigue; impact

Materials characterisation: micro- and macro-structures; interfaces; porosity; non-destructive testing

Manufacturing processes: contact moulding; resin transfer moulding (RTM); resin infusion under flexible tooling (RIFT); pre-pregs; moulding compounds; vacuum bagging; autoclave; compression moulding; filament winding; pultrusion; sandwich structures

3 Understand the life cycle assessment process that informs the selection of sustainable materials

Sustainability: Brundtland definition (economy, environment, equity (social) and governance); health and safety

Product: materials acquisition, processing, use and disposal

Environmental impact classification factors: life cycle assessment; ISO 14040 series standards; global warming potential (GWP); stratospheric ozone depletion; human toxicity; acidification; eutrophication; ecotoxicity; land use; resource depletion; photochemical oxidation

4 **Understand major developments in materials and associated technologies**

Rapid prototyping: 3D printing (3DP); electron beam melting (EBM); fused deposition modelling (FDM); laminated object manufacture (LOM); stereolithography (SLA); selective laser sintering (SLS)

Smart materials: shape memory materials; self-healing materials; electrorheological fluids; piezo/electric and magneto/strictive materials; photochromic glass; acoustic emission

Other materials appropriate to the local context: eg engineering ceramics, laminated wood

Intelligent structures: sensors; control systems; actuators

Biomimetic principles: eg velcro, lotus-effect, gecko tape, sharkskin for drag reduction

Learning outcomes and assessment criteria

Learning outcomes On successful completion of this unit a learner will:	**Assessment criteria for pass** The learner can:
LO1 Understand the selection, manufacturing and testing processes for light metal alloys	1.1 Critically assess the microstructure and macroscopic behaviour of light metal alloys with respect to manufacturing processes 1.2 Determine the mechanical properties of light metal alloys 1.3 Justify the selection of the most appropriate manufacturing and joining processes for light metal alloys
LO2 Understand the selection, manufacturing and testing processes for composite materials	2.1 Critically assess the microstructure and macroscopic behaviour of composites with respect to the manufacturing process 2.2 Determine the mechanical properties of composite materials 2.3 Justify the selection of manufacturing process for each class of composite material
LO3 Understand the life cycle assessment process that informs the selection of sustainable materials	3.1 Discuss the economic, environmental, social, governance and safety issues associated with materials selection 3.2 Analyse environmental impacts associated with materials processing, use and disposal
LO4 Understand major developments in materials and associated technologies	4.1 Justify an appropriate rapid prototyping technology for a particular product 4.2 Critically appraise the use of smart materials and intelligent structures in engineering applications 4.3 Critically appraise the use of biomimetic principles in engineering applications.

Guidance

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

The learning outcomes associated with this unit are closely linked with:

Level 4
Unit 6: Health, Safety and Risk Assessment in Engineering
Unit 10: Manufacturing Process
Unit 11: Sustainability in Engineering
Unit 15: Design for Manufacture
Unit 21: Materials Engineering

The content of this unit has been designed and mapped against the Engineering Council's current Learning Outcomes for IEng Accreditation. The completion of the learning outcomes for this unit will contribute knowledge, understanding and skills towards the evidence requirements for IEng Registration.

See *Annexe B* for summary of mapping information for IEng Accreditation.

Essential requirements

Learners require access to suitable material specimens. Test equipment would also be of benefit. The range of tests chosen should reflect the learner's working environment and particular needs but should include, as a minimum, tests that involve metals and composites. Representative material samples from both light alloys and composites should be available for inspection, as well as products and structures produced from these materials.

Delivery

The University of Plymouth has an online resource for Composites Design and Manufacture (at level 6) with the thirty-two lectures summarised at: http://www.tech.plym.ac.uk/sme/mats324/PowerPoint/.

Resources

Books

M F Ashby – *Materials Selection in Mechanical Design* (Pergamon Press, 1992) ISBN 978-0080419077.

M F Ashby – *Materials and the Environment: Eco-informed Material Choice* (Butterworth-Heinemann, 2009) ISBN 978-1856176088.

BT Åström – *Manufacturing of Polymer Composites* (Chapman & Hall, 1997) ISBN 978-0412819605 (out-of-print, but now available from CRC Press as ISBN 978-0748770762)

Adisa Azapagic et al – *Polymers, the Environment and Sustainable Development* (John Wiley & Sons, 2003) ISBN 978-0471877417

A Azapagic, S Perdan and R Clift (eds) – *Sustainable Development in Practice: Case Studies for Engineers and Scientists* (John Wiley & Sons, 2004) ISBN 978-0470856093

MV Gandhi and BS Thompson – *Smart Materials and Structures* (Chapman & Hall, 1992) ISBN 978-0521388559

D Hull and TW Clyne – *An Introduction to Composite Materials*, 2nd edition, (Cambridge University Press, 1996) ISBN 978-0521388559

V Srinivasan and DM McFarland – *Smart Structures: Analysis and Design* (Cambridge University Press, 2000) ISBN 978-0521659772

K Worden, W A Bullough and J Haywood – *Smart Technologies* (World Scientific Publishing Co Pte Ltd, 2003) ISBN 978-9810247768