Unit 147: Composite Materials and Processing

Unit code: L/505/6011

QCF Level 3: BTEC Nationals

Credit value: 10

Guided learning hours: 60

Aim and purpose

The aim and purpose of this unit is to give learners the opportunity to gain knowledge of structures, properties and uses of composite materials. They will also gain knowledge of processing methods, including bonding, fastening and testing of composite materials.

Unit introduction

In-depth knowledge of the structure and behaviour of composite materials is vital for anyone expected to select or specify them for applications within the engineering industry. This unit gives learners knowledge of the structure and mechanical and physical properties of composite materials used in engineering. It will enable them to select composite materials for different applications.

This unit is appropriate for learners engaged in manufacturing, particularly where materials are sourced in the form of stock to be used in a production process. The unit covers a range of materials, some of which learners may not be familiar with initially.

For composite products and components to be manufactured to a required standard, the processes used to produce them need to be operated in an efficient and safe manner. This unit aims to provide learners with a detailed knowledge of composite processing techniques.

This unit will make learners aware of the effects of processing on the behaviour of composite materials and the variables that need to be controlled in order to produce a high-quality product. The unit also looks at bonding and fastening of composite components and the considerations that need to be taken into account when deciding on how to join them.

Finally, learners will study various methods of destructive and non-destructive testing used on composite components to determine physical properties and the onset of failure. Learners will gain an appreciation of how these tests work and how to analyse results.

Learning outcomes

On completion of this unit a learner should:

1 Know the structures, resins, reinforcements and properties of composite materials

2 Know the various processing methods used to produce composite components and the relevant safety considerations required

3 Know the effects of processing on composite materials, including the variables that need to be controlled

4 Know about bonding, fastening and sealing of composite components

5 Be able to test composite materials to determine their structural integrity and properties.

Unit content

1 Know the structures, resins, reinforcements and properties of composite materials

Structures: fibre reinforced, e.g. fibreglass/glass reinforced plastic, carbon fibre; polymer foams e.g. PVC, polystyrene; balsa wood; honeycombs, e.g. metal foams and expanded metals

Resins: thermosetting resins, e.g. epoxy resin, polyester, phenolic, vinyl ester, polyurethane; thermoplastic resins, e.g. polyamide, polybutylene terephthalate, polyethylene terephthalate, polycarbonate, polyethylene, polypropylene, polyvinyl chloride; gel coats and release agents; catalysts

Reinforcement: types of reinforcement, e.g. glass, carbon, aramid, quartz; characteristics, e.g. filament, tow, chopped strand, random mat, unidirectional mat, woven mat, woven performs, pre-preg

Properties: mechanical properties, e.g. strength, hardness, toughness, ductility, malleability, elasticity, brittleness; physical properties, e.g. density, melting temperature; thermal properties, e.g. expansivity, conductivity; electrical and magnetic properties, e.g. conductivity, resisitivity, permeability, permittivity

2 Know the various processing methods used to produce composite components and the relevant safety considerations required

Processes: pultrusion; filament winding and preform weaving; lay-up, e.g. wet lay-up, spray lay-up, automated tape lay-up and fibre placement; moulding, e.g. resin transfer moulding, vacuum assisted resin transfer moulding; pre-preg laminating; finishing, e.g. trimming of composites, measuring, marking and cutting/drilling of composite materials

Tooling: open moulding; closed moulding; auto-clave; vacuum bag; jigs and fixtures; mould materials and uses; mould design considerations, e.g. venting, gating and flow analysis

Safety: main safety aspects in relation to processing of composite components, e.g. contact with resin, contact with fibres, dust/fume extraction

3 Know the effects of processing on composite materials, including the variables that need to be controlled

Effects of processing: fibres, e.g. fibre alignment, de-lamination, matrix/ reinforcement ratio; voids; flow interfaces

Processing variables and their effects: processing parameters, e.g. resin viscosity, wet out, flow analysis, curing time, curing temperature; design parameters, e.g. tooling design, matrix reinforcement combination

4 Know about bonding, fastening and sealing of composite components

Bonding and fastening of composite components: types of fastener, e.g. Hi-Lok fasteners, pan head bolts, countersunk bolts, RXL radial expanding lock bolts, RXB radial expanding bolts, slave bolts, dowels, self-centring nuts and bolts, torque-controlled slave pins; applications for fasteners on composite components; effects of drilling holes in composite component structure

Sealants: types of sealant, e.g. Interfay, aerodynamic filler/sealants, fillet sealants and gap sealants, adhesion promoters and adhesives

5 Be able to test composite materials to determine their structural integrity and properties

Testing: methods, e.g. ultrasonic testing, tensile testing, compressive testing, shear testing, flexural analysis, fatigue analysis, creep analysis, moisture absorption, resin viscosity testing; analysis, e.g. data handling, graphical representation, comparison with theoretical values

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 structure associated with composite materials, including the types and applications of resins and reinforcements	**M1** Explain how the structure and properties of composite materials give advantages over non-composite materials for a given product	**D1** Justify the selection of an engineering composite for a given application, describing the reasons the selection meets the required criteria
P2 Describe the mechanical, physical, thermal and electrical and magnetic properties of composite materials and state one practical application of each property in an engineering context	**M2** Explain the advantages of different composite processing methods for a given composite component	**D2** Justify the selection of a composite processing method for a given component, describing the reasons the selection meets the required criteria
P3 Describe composite processing methods and tooling and the main health and safety considerations that need to be taken into account when producing composite materials	**M3** Explain the significance and usefulness of different tests on a composite material through the analysis of the results obtained	
P4 Describe the effects of processing and processing variables on the properties of composite materials		
P5 Describe bonding, fastening and sealing of composite components		
P6 Perform and record the results of different tests on a composite material to determine the structural integrity and properties of the material		

Essential guidance for tutors

Delivery

Ideally, this unit would be delivered using a combination of practical demonstrations and investigative assignments.

To enable learners to know about mechanical and physical properties of composite materials, workshop/lab-based tests can be used to demonstrate the properties in a practical context. For example, tensile tests could be performed on various composite material combinations to see how tensile strength etc is affected.

Delivery of the structure and properties of composite materials could be related to applications with which learners are familiar. This gives flexibility in terms of the sources of evidence used to satisfy the assessment and grading criteria.

Before supervising practical activities tutors should ensure that learners are aware of the hazards and safe working practices associated with the use of machines and tools. Learners will require instruction in the safe operation of such equipment.

The learning outcomes are designed to be integrated across a range of assignments. For employed learners, assignments could be designed to reflect different aspects of their work. Industrial visits can be used to enhance learners' knowledge of the processes carried out and the equipment used.

Centres should have access to an appropriate range of specialist equipment to allow learners to perform both destructive and non-destructive tests.

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	Learning time hours
Learning outcome 1	
Lecturing	15
Definition of composite materials, types and typical applications	
Description of the matrix and reinforcement in a composite	
Description of various composite material structures	
Description of various composite material properties	
Discussion on advantages and disadvantages of composite materials over non-composite materials	
Activities	
Learners to investigate the use of various composite materials and compare to non-composite materials.	
Assignment 1: Structure and properties of composite materials (P1, P2, M1, D1)	5
Learning outcome 2	
Lecturing	10
Description of open mould and closed mould processing	
Description of the main composite manufacturing processes	
Description of the main health and safety considerations associated with composite processing	
Advantages and disadvantages of various composite processing techniques	5
Activities	
Learners to observe and take part in a range of composite-processing methods in a workshop/lab environment.	
Learning outcome 3	
Lecturing	3
Description of the main processing variables that need to be controlled during composite manufacture.	
Description of the effects of processing on composite material properties	2
Activities	
Learners to observe and take part in a range of composite-processing techniques in a workshop/lab environment. Learners to observe the effect of altering process variables such as temperature.	

Topic and suggested assignments/activities and/assessment	Learning time hours
Learning outcome 4	
Lecturing	3
Description of various fastening and bonding techniques used on composites	
Advantages and disadvantages of the various fastening and bonding devices	2
Activities	
Learners to be given the opportunity to use a range of composite fastening techniques in workshop/lab.	5
Assignment 2: Processing and joining of composite components and safety considerations (P3, P4, P5, M2, D2)	
Learning outcome 5	
Lecturing	3
Description of various composite testing techniques	
Activities	2
Perform tests on a composite material(s) and record/analyse and explain the significance and usefulness of the results.	
Assignment 3: Testing of composite materials (P6, M3)	5
Total learning time hours	**60**

Assessment

To achieve a pass grade, all the pass criteria must be met. Centres have the option to decide on the number of tasks and the order in which the criteria are covered.

The evidence to satisfy the pass criteria P1 and P2 could be gained by means of a written assignment, following a combination of tutor-led practical and theory sessions and individual research. P1 and P2 require the range of materials given to include composite materials created from different reinforcement and matrix combinations. The use of at least three different types of reinforcement and characteristics of reinforcement are anticipated. M1 and D1 could be covered in the same assessment. To achieve M1, learners are required to explain how the structure of composite materials gives advantages over non-composite materials (such as polymers or metals) for a given product, for example aircraft wings, bicycle frames, prosthetic limbs. To achieve D1, learners must select a composite material for a given application and justify their selection in relation to material properties. Learners should compare advantages and disadvantages in order to develop a reasoned argument for the selection of their chosen composite material.

The evidence to satisfy the pass criteria P3, P4 and P5 could be gathered by means of a second written assignment, following a combination of tutor-led practical and theory sessions and individual research. To allow learners to meet P3 and P5, the tutor could perform a series of practical demonstrations to show the various composite processing and joining techniques. To meet P3 fully, learners should also describe the various health and safety considerations that need to be taken into account when processing composite materials. This could be done through the use of a case study or it could be linked to practical demonstrations. Learners could research and provide a written response or give a presentation on the processes they observed and how they were performed. To meet P5 learners could research and provide a written response or give a presentation on case studies of composite materials that have failed as a result of processing defects. To meet M2, learners are required to explain the advantages of different composite processing methods for a given composite component. The component should be quite straightforward and the correct processing method should be clearly identifiable. To meet D2, learners are required to justify a composite processing method for a given component. The component given should be capable of being processed using a number of processing techniques, allowing for advantages and disadvantages to be considered.

The evidence to satisfy the pass criterion P6 could be gathered by means of a third assignment, following a combination of tutor-led practical and theory sessions and individual research. To meet P6 and M3, learners should perform at least two material tests using given material(s). To meet P6, learners need to provide evidence of carrying out the tests and recording results, this can be gathered through observations, witness testimonies or written records. To meet M3, learners need to be able to analyse the results obtained and draw appropriate conclusions.

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 Pearson assignments to meet local needs and resources..

Criteria covered	Assignment title	Scenario	Assessment method
P1, P2, M1, D1	Structure and properties of composite materials	Structure and properties of composites considered in an industrial scenario	Written report/presentation
P3, P4, P5, M2, D2	Processing and joining of composite components and safety considerations	Processing and joining of composites considered in an industrial scenario	Written report/presentation
P6, M3	Testing of composite materials	Typical testing/sampling regime for a composite manufacturer	Observation record/witness testimony with written analysis/ evaluation of recorded results

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:

Level 2	Level 3
Unit 8: Selecting Engineering Materials	Unit 1: Health and Safety in the Engineering Workplace
Unit 23: Casting and Moulding Engineering Components	Unit 10: Properties and Applications of Engineering Materials
	Unit 20: Engineering Primary Forming Processes

Essential resources

Centres will need a selection of exemplar materials and components for viewing, tactile inspection and discussion. Degraded and failed component specimens will also be of value. Centres need access to equipment to conduct at least two destructive or non-destructive tests and related composite materials.

Employer engagement and vocational contexts

Industrial visits would give learners an opportunity to see the processing of different materials and its effects. There is a range of organisations that may be able help centres engage and involve local employers in the delivery of this unit, for example:

- Composite Skills Alliance – www.composites-skills-alliance.com
- National Composites Centre – www.nccuk.com
- Net Composites – www.netcomposites.com
- Network for Science, Technology, Engineering and Maths Network Ambassadors Scheme – www.stemnet.org.uk/content/ambassadors
- NIACE Centre – www.niace-centre.org.uk
- SEMTA – www.semta.org.uk

Indicative reading for learners

Books

Alfred C Loos and Raju S Dave – *Processing of Composites* (Carl Hanser Verlag GmbH and Co, 1999) ISBN 1569902267

Balasubramanian M – *Composite Materials and Processing* (CRC Press, 2013) ISBN 1439879354

Barbero E – *Introduction to Composite Materials Design, Second Edition* (CRC Press, 2010) ISBN 1420079158

Gibson R – *Principles of Composite Material Mechanics, Third Edition* (CRC Press, 2011) ISBN 1439850054

Matthews F L and Rawlings, R D – *Composite Materials: Engineering and Science* (Woodhead, 2003) ISBN 1855734737

Potter K – *Resin Transfer Moulding* (Springer, 2011) ISBN 9401064970

Wanberg J – *Composite Materials Fabrication Handbook #3* (Wolfgang Publications, 2013) ISBN 1935828665

sb091013Old_PD/Nationals 2010/ Engineering Units/Unit 147 BTEC Nats L3 Engineering.indd.1-11/0