Unit 73: Materials Engineering with Polymers

Unit code	**K/616/2556**
Unit level	**4**
Credit value	**15**

Introduction

This unit will provide students with the necessary background knowledge and understanding of the structure and property relationship of polymer materials to guide their selection of material and manufacturing techniques to produce a sustainable, fit for purpose product.

Polymer products are driving innovation and research around the world and are predicted to expand further to replace traditional engineering materials in a wide variety of applications. Students will be made aware of the wide range of polymer materials at their disposal and the opportunity for using the new grades that are being developed on a daily basis.

This unit will provide students with an understanding of the relationship between a polymer's structure and properties and between processing technique and product performance. The ability to determine a polymer's properties is crucial and this unit will include a review and practical application of the main testing techniques. One of the most important skills for a manufacturing engineer is the ability to distinguish between different types of polymers. This will be developed during practical sessions that will provide students with the opportunity to carry out preliminary investigations and simple identification tests. This will be supported by an overview of the main types of polymer materials.

Inadequate consideration of a specific behavioural requirement can lead to product failure and reduced service life. This will be addressed by providing techniques for material modification and learning how to use data sources for material selection. In addition this unit will consider environmental concerns and offer solutions to reduce waste and improve sustainability.

Learning Outcomes

By the end of this unit a student will be able to:

1. Examine how the fundamental aspects of the molecular structure and morphology of polymers affect their processing and performance properties
2. Distinguish between the main types of polymer materials to inform the selection of a polymer material for a given application
3. Determine how to select, modify, compound or adapt polymer material systems for a specific engineering application
4. Recognise the limitations of polymer behaviour and potential solutions to environmental concerns associated with polymers

Essential Content

LO1 **Examine how the fundamental aspects of the molecular structure and morphology of polymers affect their processing and performance properties**

Introduction

polymer concept

definition of the main terms, e.g. monomer, repeating units

classification of polymers (natural, synthetic, organic, inorganic)

Molecular Structure

structure of polyethylene chain

chain length and molar mass;

molar mass distribution;

calculations of number (average molar mass and weight-average molar mass)

significance of molar mass to processing and performance properties of polymers

configuration of the chain molecule

confirmation of the chain molecule

secondary bonds between chain molecules

cohesion

adhesion

solubility

compatibility of polymer blends

Polymer morphology

aggregational states of matter

amorphous solid state

amorphous polymers

glass transition temperature and its significance to processing and service life crystalline polymers

melting temperature, conditions for crystallinity, effect of processing on crystallinity, morphological features (lamellae and spherulites)

LO2 **Distinguish between the main types of polymer materials to inform the selection of a polymer material for a given application**

Commodity and engineering thermoplastics

e.g. polyethylenes

modified polyethylenes; polypropylene

polyamides and aramids (overview of structure, properties and processability)

Thermosets

e.g. epoxies

phenolics; polyesthers

material storage

concept of gel-point

quantitative analysis i of cross-linking (overview of structure, properties and processability)

Rubber and elastomers

e.g. natural rubber (NR)

acrylonitlile butadiene rubber (NBR); styrene butadiene rubber (SBR), butyl rubber (BR), polychloroprene rubber (CR), ethylene propylene rubber (EPR)

introduction to vulcanisation and compounding

overview of structure, properties and processability

Introduction to simple identification tests and techniques

e.g. density, solubility

LO3 **Determine how to select, modify, compound or adapt polymer material systems for a specific engineering application**

Criteria for material selection

definitions of material properties and characteristics

material selection flow chart

overview of selection methods e.g. structured and unstructured data; material selection charts

Material testing to determine the properties of polymers

mechanical e.g. tensile, flexural, impact

optical (colour)

electrical (conductivity/resistivity)

thermal (melting temperature, glass transition temperature)

rheological

Data sources

published data e.g. British standards, ISO, material's data sheet, IT sources, standard published data sources, manufacturers' literature

assessment of data reliability

Polymer modification

review of polymer additives and their functions

consideration of their cost and quantity in a compound formulation e.g. fillers, plasticisers, stabilisers, flame retardants, blowing agents, colourants, cross-linking and vulcanising agents

LO4 **Recognise the limitations of polymer behaviour and potential solutions to environmental concerns associated with polymers**

Premature failure of polymer products

causes of failure in polymer products e.g. visco-elastic and time-dependent behaviour of polymers, brittle and ductile failure, impact failure, creep rupture and fatigue failure, environmental effects

contributory effects of service conditions to failure e.g. faults in design and manufacture, inappropriate use, changes to service conditions such as load, time, temperature and environment

Solutions to environmental concerns

overview of relevant Government policies and Directives

acceptable waste management and disposal techniques e.g. re-use, mechanical recycling of single and mixed polymers

feedstock recycling to produce monomers, oligomers and chemical raw materials energy recovery

re-processing of polymers and its effect on processing and mechanical properties stabilisation of polymers to prevent weathering, chemical and thermal degradation

Learning Outcomes and Assessment Criteria

<table>
<tr><th>Pass</th><th>Merit</th><th>Distinction</th></tr>
<tr><td colspan="2">LO1 Examine how the fundamental aspects of the molecular structure and morphology of polymers affect their processing and performance properties</td><td rowspan="4">LO1 & LO2

D1 Justify the selection of a polymer material for a given engineering application through critical analysis of its structure and properties</td></tr>
<tr><td>P1 Explain how the structure and morphology of different given polymer materials affect their processing and performance properties</td><td>M1 Calculate the molar mass of a given polymer sample, commenting on the significance of the results to processing and performance properties</td></tr>
<tr><td colspan="2">LO2 Distinguish between the main types of polymer materials to inform the selection of a polymer material for a given application</td></tr>
<tr><td>P2 Use preliminary investigations and simple identification tests to distinguish between different types of polymer materials</td><td>M2 Apply structural considerations to compare and contrast the properties and processability of these polymer materials</td></tr>
<tr><td colspan="2">LO3 Determine how to select, modify, compound or adapt polymer material systems for a specific engineering application</td><td rowspan="2">LO3 & LO4

D2 Critically evaluate test results to justify selection of the most suitable additive or acceptable amount of recycled material in a given product</td></tr>
<tr><td>P3 Identify the required properties for a specified engineering product

P4 Evaluate data sheets to select the most appropriate materials and processing techniques for the engineering product</td><td>M3 Re-examine data sheets to extend the range of selected materials by proposing a suitable modification to the base material</td></tr>
</table>

Pass	Merit	Distinction
LO4 Recognise the limitations of polymer behaviour and potential solutions to environmental concerns associated with polymers		
P5 Explain the common causes of premature failure of polymer products **P6** Explain how polymer materials can be safely disposed or recovered through acceptable waste management techniques	**M4** Give consideration to the contributory effects of service conditions in a given product and make recommendations to prevent failure **M5** For a given product/ evaluate the potential benefit of using recycled material in place of virgin material	

Recommended Resources

Textbooks

ASHBY, M.F. and JONES, D.R.H. (2013) *Engineering Materials 2: An Introduction to Microstructures and Processing*. 4th Ed. Amsterdam: Butterworth-Heinemann.

ASHBY, M.F. and JONES, D.R.H. (2012) *Engineering Materials 1: An Introduction to Properties, Applications, and Design*. 4th Ed. Amsterdam-Boston: Butterworth-Heinemann.

BRAUN, D. (2013) *Simple Methods for Identification of Plastics*. 5th Ed. Munich: Hanser.

CALLISTER, W. and RETHWISCH, D.G. (2015) *Fundamentals of Materials Science and Engineering: An Integrated Approach*. 5th Ed. Hoboken: Wiley.

LA MANTIA, F. (2002) *Handbook of Plastics Recycling*. Shrewsbury: Rapra Technology Limited.

McCRUM, N.G., BUCKLEY, C.P. and BUCKNALL, C.B. (2003*) Principles of Polymer Engineering*. 2nd Ed. Oxford: Oxford. Univ. Press.

OSSWALD, T.A. and MENGES, G. (2012) *Material Science of Polymers for Engineers*. 3rd Ed. Munich: Hanser.

YOUNG, R.J. and LOVELL, P.A. (2011) *Introduction to Polymers*. Boca Raton: CRC Press.

Websites

www.bpf.co.uk	British Plastics Federation (General reference)
www.iom3.org/polymer-society	The Polymer Society (General reference)
www.cia.org.uk	Chemical Industries Association (General reference)
www.cogent-ssc.com	Cogent – Sector Skills Council (General reference)
www.stemnet.org.uk	Network for Science, Technology, Engineering and Maths Network Ambassadors Scheme (General reference)

Essential Resources

Tensometer (to evaluate tensile properties of materials, such as Young's modulus)

Pendulum impact tester

Hardness tester

Controlled laboratory area for flammable tests on polymers