Unit 155: Materials Engineering with Polymers

Unit code F/615/3314

Unit level 4

Credit value 15

Aim

This unit will provide learners 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.

Unit abstract

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. Learners 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 learners 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 learners 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 Understand how the fundamental aspects of the molecular structure and morphology of polymers affect their processing and performance properties

2 Understand the differences between the main types of polymer materials to inform the selection of a polymer material for a given application

3 Understand how to select, modify, compound or adapt polymer material systems for a specified engineering application

4 Understand the limitations of polymer behaviour and potential solutions to environmental concerns associated with polymers.

Unit content

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

Introduction: the polymer concept; definition of the main terms: monomer, repeating units; the classification of polymers (natural, synthetic, organic, inorganic)

Molecular Structure: the 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; the 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, spherulites)

2 **Understand the differences 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 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

3 **Understand how to select, modify, compound or adapt polymer material systems for a specified 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: tests 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, materials 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

4 **Understand 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

Learning outcomes On successful completion of this unit a learner will:		**Assessment criteria for pass** The learner can:	
LO1	Understand how the fundamental aspects of the molecular structure and morphology of polymers affect their processing and performance properties	1.1	explain how the structure and morphology of different given polymer materials affect their processing and performance properties
		1.2	calculate the molar mass of a given polymer sample
		1.3	explain the significance of the calculated results to processing and performance properties
LO2	Understand the differences between the main types of polymer materials to inform the selection of a polymer material for a given application	2.1	use preliminary investigations and simple identification tests to explain the differences between the main polymer material types
		2.2	apply structural considerations to compare and contrast the properties and processability of these polymer materials
		2.3	justify the selection of a polymer material for a given application through critical analysis of its structure and properties
LO3	Understand how to select, modify, compound or adapt polymer material systems for a specified engineering application	3.1	identify the required polymer properties for a specified engineering product
		3.2	evaluate data sheets to select the most appropriate polymer materials and processing techniques for the engineering product
		3.3	re-examine the data sheets to extend the range of selected polymer materials by proposing a suitable modification to the base material
LO4	Understand the limitations of polymer behaviour and potential solutions to environmental concerns associated with polymers	4.1	explain the common causes of premature failure of polymer products
		4.2	explain how polymer materials can be safely disposed of or recovered through acceptable waste management techniques
		4.3	give consideration to the contributory effects of service conditions in a given product, making recommendations to prevent its failure
		4.4	evaluate the potential benefit of using recycled material in place of virgin material for a given product
		4.5	critically evaluate test results to justify selection of the most suitable additive or acceptable amount of recycled material in a given product

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