Unit 156: Polymer Manufacturing Processes

Unit code J/615/3315
Unit level 4
Credit value 15

Aim

This unit is designed to develop students' knowledge and understanding of the main manufacturing processes and techniques that can be applied to a wide range of polymer materials for a variety of manufacturing applications.

Unit abstract

It is essential for a manufacturing engineer who may lead the planning, operation and management of their company's manufacturing systems to have a broad underpinning knowledge of conventional polymer manufacturing processes. Polymer materials have the capacity and potential to be processed into a huge variety of shapes and forms for a wide range of applications.

The first outcome of this unit provides background knowledge of the main principles of polymer flow and heat transfer relevant to processing. The second and third outcomes give a detailed overview of the conventional manufacturing techniques of polymers (extrusion, blow moulding, thermoforming and injection moulding) considering relevant equipment and processing steps. The final outcome provides the context to inform selection of the most suitable method of processing for a given application.

Learning outcomes

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

1 Understand the fundamental principles of polymer flow and heat transfer and their relevance to polymer processing

2 Understand the variety of polymer processing and shaping techniques available to manufacture engineering components and products

3 Understand the main technical components of commonly used polymer processing equipment, their functions and the main operational steps

4 Understand from a design perspective the most suitable manufacturing process for a given engineering component or product.

Unit content

1 **Understand the fundamental principles of polymer flow and heat transfer and their relevance to polymer processing**

Polymer melt behaviour: elongational flow; shear flow; shear stress and shear strain; determination of apparent viscosity; dependence of apparent viscosity on temperature and relative molecular mass; shear thinning behaviour of polymers; viscoelasticity of polymer melt; die swell; flow in a capillary tube; equations for stress and shear rate; melt flow index test (MFI)

Effect of heating and heat transfer in polymers: temperature-dependent behaviour of polymers; conduction; heat conduction equation; thermal conductivity; thermal diffusivity; convection; radiation; comparison of heat transfer properties of polymers to other competitive materials, e.g. metals, ceramics, wood

2 **Understand the variety of polymer processing and shaping techniques available to manufacture engineering components and products**

Overview of processing techniques for thermoplastics: extrusion, e.g. sheet production, pipe production, blown film, wire and cable coating, co-extrusion; injection moulding, injection blow moulding; rotational moulding; thermoforming; consideration of materials and products

Overview of processing techniques for thermosets: e.g. compression moulding and injection moulding; specific requirements to process thermosets; consideration of materials and products

Overview of shaping and processing techniques for rubber and elastomers: e.g. extrusion, compression moulding and injection moulding; compounding principle; consideration of materials and products

3 **Understand the main technical components of commonly used polymer processing equipment, their functions and the main operational steps**

Extrusion: the principle of the extrusion process; extrusion line; main components of extruder and their functions; hopper; screw; motor and gearing; breaker plate and screen pack; die; temperature control system; single and twin-screw extruders; die design and processing faults

Injection moulding: the principle of the injection moulding process; components of injection moulding machine and their functions; clamping unit; injection unit; mould; machine bed and control unit; process sequence; common injection moulding faults and remedies

Thermoforming: the principle of the thermoforming process; process components; clamp frame; heating systems; moulds; selected thermoforming methods, e.g. female mould forming, male mould forming, plug assist forming, pre-stretch forming; wall thickness and molecular orientation in thermoformed products

4 **Understand from a design perspective the most suitable manufacturing process for a given engineering component or product**

Design consideration and application development process: identifying the end-use requirements after considering the product functions; part geometry, e.g. shape, size, tolerances; material selection; flow analysis and the significant implications of process selection stage; prototyping and testing

Design for mouldabilty: e.g. viscosity, melt temperature, shrinkage, cooling requirements, selection of optimum processing conditions

Tooling consideration: design for appearance, e.g. preventing weld lines, gate marks in injection moulded components; design for precision, e.g. gate location, gate type, gate size, die design, cooling lines

Consideration of production volumes and cost of manufacturing: relevant case studies

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 fundamental principles of polymer flow and heat transfer and their relevance to polymer processing	1.1	explain the differences between the types of flow apparent in polymer melt and their relevance to processing
		1.2	analyse the differences in heat transfer between polymers and alternative materials and the effects it has on processing
		1.3	calculate polymer flow and heat transfer parameters for different grades of a thermoplastic material, and give an analysis of the significance of the results for polymer processing
		1.4	critically evaluate the effect of temperature and relative molecular mass on viscosity and processing
LO2	Understand the variety of polymer processing and shaping techniques available to manufacture engineering components and products	2.1	describe a manufacturing set-up for given products and materials
		2.2	compare and contrast a range of alternative processing and shaping manufacturing techniques for a given product or application
LO3	Understand the main technical components of commonly used polymer processing equipment, their functions and the main operational steps	3.1	analyse the main differences between extrusion, injection moulding and thermoforming in terms of their components, functions and process sequence
		3.2	analyse potential process-related faults for a given product or application
		3.3	justify the most suitable manufacturing process for a given engineering product
LO4	Understand from a design perspective the most suitable manufacturing process for a given engineering component or product	4.1	determine functions, shape and material for a given component or product
		4.2	recommend the most appropriate manufacturing process based on the component's or product's functions, shape and material
		4.3	justify specific tooling for a given component or product
		4.4	critically evaluate the cost-effectiveness of the selected manufacturing process

Essential Resources

Laboratory Micro Injection Moulder Filament Extrusion line

Vacuum former

Melt Flow tester

Laboratory balance