Unit 74: Polymer Manufacturing Processes

Unit code M/616/2557
Unit level 4
Credit value 15

Introduction

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.

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. Relate the fundamental principles of polymer flow and heat transfer to polymer processing
2. Illustrate the variety of polymer processing and shaping techniques available to manufacture a wide range of engineering components and products
3. Describe the main technical components of commonly used polymer processing equipment, their functions and the main operational steps
4. Determine from a design perspective the most suitable manufacturing process for a given engineering component or product.
Essential Content

LO1  **Relate the fundamental principles of polymer flow and heat transfer 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

LO2  **Illustrate the variety of polymer processing and shaping techniques available to manufacture a wide range of 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

LO3 Describe 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 e.g. 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 e.g. 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 e.g. Clamp frame, heating systems, moulds
Selected thermoforming methods e.g. Female mould forming, male mould forming, plug assist forming, prestretch forming
Wall thickness and molecular orientation in thermoformed products
LO4 Determine 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 mouldability
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

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<th>Pass</th>
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| **LO1** Relate the fundamental principles of polymer flow and heat transfer to polymer processing | **M1** Calculate polymer flow and heat transfer parameters for different grades of a thermoplastic material, commenting on the significance of the results for polymer processing | **LO1 and LO2**
| **P1** Explain the differences between the types of flow apparent in polymer melt and their relevance to processing | **D1** Critically evaluate the effect of temperature and relative molecular mass on viscosity and hence, processing |  |
| **P2** Explain the difference in heat transfer between polymers and alternative materials and the effect it has on processing | **M2** Compare and contrast a range of alternative processing and shaping techniques for a given product/application |  |
| **LO2** Illustrate the variety of polymer processing and shaping techniques available to manufacture a wide range of engineering components and products | **P3** Describe a manufacturing set-up for given products and materials | **D2** Justify the most suitable manufacturing process for a given engineering product |
| **P4** Define the main differences between extrusion, injection moulding and thermoforming in terms of their components, functions and process sequence | **M3** Analyse potential process-related faults for a given product or application |  |
| **LO3** Describe the main technical components of commonly used polymer processing equipment, their functions and the main operational steps | **D3** Critically evaluate the cost effectiveness of the selected manufacturing process |  |
| **P5** Determine functions, shape and material for a given component/product and recommend the most appropriate manufacturing process based on the component’s or product’s functions, shape and material | **M4** Justify specific tooling for a given component or product |  |
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Recommended Resources

Textbooks


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

Essential Resources

Laboratory Micro Injection Moulder
Filament Extrusion line
Vacuum former
Melt Flow tester
Laboratory balance