

## **Engineering Tripos Part IIA, 3C1: Materials Processing & Design, 2018-19**

### **Module Leader**

[Dr H Shercliff](#) [1]

### **Lecturers**

Dr H Shercliff, Dr C Barlow and Dr G McShane

### **Lab Leader**

Dr J Durrell

### **Timing and Structure**

Michaelmas term. 16 lectures.

### **Aims**

The aims of the course are to:

- Provide an understanding of materials processing technology for the manufacture of products.
- Consider the integrated nature of design, material and processing in the manufacture of products.
- Illustrate the processing factors that influence selection in design.
- Relate processing to microstructure evolution and product failure.

### **Objectives**

As specific objectives, by the end of the course students should be able to:

- Have a broad appreciation of the different materials processing methods used for metals, ceramics, polymers and composites.
- Understand the main interactions between process and material in design and process selection, for each of the main classes of material.
- Understand the factors which control the microstructure of shaped castings, and their consequences for final properties and design for casting.
- Know the main classes of polymers and composites, and understand the processing and design considerations in selecting these for a given component.
- Know the main deformation processes for wrought alloys, and be able to conduct simple upper bound analysis of plastic deformation.
- Know the microstructural characteristics of wrought alloys, and the reasons for alloying and heat treatment, with examples from Al alloys and steels.
- Understand hardenability of steels, using CCT diagrams to select steels and heat treatments for a given component specification.
- Understand the processes and issues in the manufacture of powder metallurgy and ceramic products.
- Understand the importance of surface treatments and joining technologies, and know the main factors to consider in process selection.
- Appreciate the current potential and limitations of additive manufacturing methods.
- Be able to apply their knowledge of materials processing, microstructure evolution, and the mechanisms of

material degradation to analyse and predict failures and to improve product design.

## Content

### Introduction (1L, Dr H Shercliff)

- Classification of manufacturing processes.
- Coupled problems in design and manufacturing: the interaction between material, process and design parameters.

### Metal Casting (2L, Dr HR Shercliff)

- Ingot and shaped casting technology.
- Revision of phase diagrams and transformations applied to solidification: segregation, constitutional supercooling, casting alloys and microstructures.
- Casting defects and design of shaped castings.

### Deformation Processing of Wrought Alloys, Heat treatment (2L, Dr H Shercliff; 2L Dr G McShane)

- Revision of phase transformations and TTT diagrams.
- CCT diagrams and hardenability for steels.
- Wrought alloy processing and microstructure evolution.
- Simple modelling of plastic forming processes (upper bound method).
- Application of plasticity analysis to rolling, forging, extrusion, machining of metals; case studies.

### Powder Processing, Processing of Polymers and Composites (3L, Dr CY Barlow)

- Sintering, HIPing and other processing technologies for powder metals and ceramics.
- Polymer and composite processing technology.
- Design, material and process selection for polymers and composites.

### Surface Engineering, Additive Manufacturing, Joining and Welding (2L, Dr HR Shercliff)

- Surface engineering processes and their applications.
- Welding technology (fusion, friction, laser, ultrasonic), and other joining processes (mechanical, adhesives).
- Additive manufacturing (AM) methods and their current potential.
- Selection of surface engineering, joining and AM processes in design.

### Design against Failure (4L, Dr CY Barlow)

- Processing as the origin of defects and failures (microstructure, damage, residual stress).
- Environmental factors in failure of materials.
- Analysis and case studies of failures.

## Further notes

This module also runs in the MANUFACTURING ENGINEERING TRIPOS PART IIA - Module 3P1: Materials into Products.

Supervisions will be by a combination of conventional groups and larger examples classes.

## Examples papers

0. Revision (Phase Diagrams etc)
1. Metal Casting, Heat Treatment of Steels, Microstructure in Wrought Alloy Processing
2. Modelling of Wrought Alloy Processing

3. Powder Processing, Polymers, Polymer Composites, Surface Engineering, Additive Manufacturing, Joining and Welding, Design against Failure

## Coursework

### Laboratory: Jominy end-quench test for hardenability

#### Learning objectives:

- To understand and conduct a Jominy end quench for steels, measuring and comparing hardness profiles for plain carbon and alloy steels
- To correlate microstructure along the sample with the hardness profiles
- to be able to interpret CCT diagrams for the same steels, and assess their accuracy against experimental data

#### Practical information:

- Sessions will take place in the Materials Lab, during weeks 1-6.
- Students are expected to read the handout in advance of their booked session.
- Practical activity covers a single Jominy end-quench, hardness traverses on two samples (one per pair, pooling the data), observation of microstructures on the two steel samples

### **Full Technical Report:** Weldability of steels, and correlation with hardenability

Students will have the option to submit a Full Technical Report.

A separate document is issued containing:

- 3 point bend test data for welded and unwelded samples of 3 steels
- images of the failed 3 point bend samples
- micrographs from the weld regions in all three steels, with selected hardness data

Students are required to interpret the nature of the failure in each sample (welded and unwelded), relating the hardness, microstructure and failure mechanism (and thus weldability) to the hardenability of the steels, as investigated in the original laboratory.

## Booklists

Please see the [Booklist for Part IIA Courses](#) [2] for references for this module.

## Examination Guidelines

Please refer to [Form & conduct of the examinations](#) [3].

## UK-SPEC

The [UK Standard for Professional Engineering Competence \(UK-SPEC\)](#) [4] describes the requirements that have to be met in order to become a Chartered Engineer, and gives examples of ways of doing this.

UK-SPEC is published by the Engineering Council on behalf of the UK engineering profession. The standard has been developed, and is regularly updated, by panels representing professional engineering institutions, employers and engineering educators. Of particular relevance here is the ['Accreditation of Higher Education Programmes'](#)

[\(AHEP\) document](#) [5] which sets out the standard for degree accreditation.

The [Output Standards Matrices](#) [6] indicate where each of the Output Criteria as specified in the AHEP 3rd edition document is addressed within the Engineering and Manufacturing Engineering Triposes.

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#### **Links**

[1] <mailto:hs10000@eng.cam.ac.uk>

[2] <https://www.vle.cam.ac.uk/mod/book/view.php?id=364091&chapterid=46371>

[3] <http://teaching.eng.cam.ac.uk/content/form-conduct-examinations>

[4] <http://www.engc.org.uk/ukspec.aspx>

[5] <http://www.engc.org.uk/standards-guidance/standards/accreditation-of-higher-education-programmes-ahep/>

[6] <http://teaching.eng.cam.ac.uk/content/output-standards-matrices>