Engineering Tripos Part IIA, 3C1: Materials Processing & Design, 2020-21

Module Leader

Dr H Shercliff [1]

Lecturers

Dr H Shercliff, Dr C Barlow and Dr J Durrell

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 (1L, Dr J Durrell; 3L, Dr H Shercliff)

- 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).
- Selection of surface engineering and joining processes in design.
- Additive manufacturing (AM) methods and their current potential.

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 refer to the Booklist for Part IIA Courses for references to this module, this can be found on the associated Moodle course.

Examination Guidelines

Please refer to Form & conduct of the examinations [2].

UK-SPEC

This syllabus contributes to the following areas of the UK-SPEC [3] standard:

Toggle display of UK-SPEC areas.

GT1

Develop transferable skills that will be of value in a wide range of situations. These are exemplified by the Qualifications and Curriculum Authority Higher Level Key Skills and include problem solving, communication, and working with others, as well as the effective use of general IT facilities and information retrieval skills. They also include planning self-learning and improving performance, as the foundation for lifelong learning/CPD.

IA1

Apply appropriate quantitative science and engineering tools to the analysis of problems.

KU1

Demonstrate knowledge and understanding of essential facts, concepts, theories and principles of their engineering discipline, and its underpinning science and mathematics.

KU2

Have an appreciation of the wider multidisciplinary engineering context and its underlying principles.

D2

Understand customer and user needs and the importance of considerations such as aesthetics.

D3

Identify and manage cost drivers.

S1

The ability to make general evaluations of commercial risks through some understanding of the basis of such risks.

S3

Understanding of the requirement for engineering activities to promote sustainable development.

E1

Ability to use fundamental knowledge to investigate new and emerging technologies.

E2

Ability to extract data pertinent to an unfamiliar problem, and apply its solution using computer based engineering tools when appropriate.

E3

Ability to apply mathematical and computer based models for solving problems in engineering, and the ability to assess the limitations of particular cases.

P1

A thorough understanding of current practice and its limitations and some appreciation of likely new developments.

P3

Understanding of contexts in which engineering knowledge can be applied (e.g. operations and management, technology, development, etc).

P4

Understanding use of technical literature and other information sources.

P7

Awareness of quality issues.

P8

Ability to apply engineering techniques taking account of a range of commercial and industrial constraints.

US1

A comprehensive understanding of the scientific principles of own specialisation and related disciplines.

US2

A comprehensive knowledge and understanding of mathematical and computer models relevant to the engineering discipline, and an appreciation of their limitations.

US3

An understanding of concepts from a range of areas including some outside engineering, and the ability to apply them effectively in engineering projects.

US4

An awareness of developing technologies related to own specialisation.

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