Engineering Tripos Part IA, 1P2: Materials, 2017-18

Lecturers

Dr H Shercliff, Dr A Markaki and Dr A Kabla [1]

Timing and Structure

Lent: 12 lectures (1 or 2 per week); Easter: 8 lectures (2 or 3 per week)

Aims

The aims of the course are to:

- Introduce the material properties and failure mechanisms most relevant to mechanical design and engineering applications.
- Relate properties to atomic, molecular and microstructural features, using appropriate mathematical models.
- Develop systematic strategies for material and process selection for a given component.

Objectives

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

- Describe the atomic and microstructural characteristics which control the important properties of engineering materials, and to interpret material property charts
- Explain briefly the origin of the elastic modulus for each class of engineering materials (metals, ceramics, polymers) and analyse the moduli of composites
- Understand the mechanisms for plastic flow in metals, and the ways in which the strength can be enhanced via the microstructure
- Understand the purpose of modelling the deformation response of materials
- Describe and analyse the stress-strain response of simple geometries under uniform mechanical and thermal loads, distinguishing between true and nominal stress and strain
- Understand a systematic strategy for materials selection for a given component, and use the Cambridge Engineering Selector software to find material data and select materials
- Choose materials from material property charts using simple calculations (e.g. stiffness and strength of beams at minimum weight)
- Choose primary shaping process from process attribute charts, and estimate the cost of manufacture for batch processing
- Understand the environmental impact of materials in the life cycle of products
- Describe the mechanisms of failure in all classes of material
- Apply fracture mechanics analysis to design against fracture in metals, and Weibull failure statistics for design in ceramics
- Describe and model fatigue fracture in design with metals
- Analyse the visco-elastic response of polymers, for both static and cyclic loading
- Briefly describe the mechanisms of wear in engineering

Content

Introduction (1L, Dr H.R. Shercliff)

Classes of engineering materials; materials in design (design-limiting properties); life-cycle of materials. *(1) Chap. 1,2,20; (2) Chap. 1,3; (3) Chap. 30; (4) Chap. 27*

Elastic Properties of Materials (5L, Dr H.R. Shercliff)

- Elastic stiffness in design: analysis of stress and strain, thermal stress. *(1) Chap. 4,12; (3) Chap. 3; (5) Chap. 7*
- Young's modulus and density: measurement, data and materials property charts: introduction to Cambridge Engineering Selector software; stiffness-limited component design. *(1) Chap. 4,5; (2) Chap. 3-6; (3) Chap. 3,7; (5) Chap. 7*
- Microstructure of engineering materials I: Atomic/molecular structure and bonding; physical basis of elastic modulus and density. *(1) Chap. 4; (3) Chap. 4-6; (5) Chap. 2-4*
- Manipulating properties I: Elastic properties in composites and foams. *(1) Chap. 4; (2) Chap. 13; (3) Chap. 6*

Plastic Properties of Materials (4L, Dr H.R. Shercliff)

- Tensile and hardness testing, measurement of strength, data and material property charts: strength-limited component design. *(1) Chap. 6,7; (2) Chap. 3-6; (3) Chap. 8,11,12,31; (4) Chap. 4-6; (5) Chap. 7*
- Microstructure of engineering materials II: Atomic basis of plasticity, dislocations. *(1) Chap. 6; (3) Chap. 9; (5) Chap. 8*
- Manipulating properties II: Strengthening mechanisms in metals. *(1) Chap. 6,14; (3) Chap. 10; (5) Chap. 8,12*

Process Selection and Environmental Impact in Design (2L, Dr H.R. Shercliff)

- Selection of manufacturing process and cost estimation for batch processes. *(1) Chap. 18; (2) Chap. 7,8*
- Environmental impact and life cycle analysis of materials. *(1) Chap. 20; (2) Chap. 16; (5) Chap. 21*

Fracture and Fatigue of Materials (4L, Dr A.E. Markaki)

- Toughness, fracture toughness and fatigue fracture.
- Micromechanisms of fracture and fatigue in metals.
- Analysis of fracture and fatigue in design.
- Weibull statistics for ceramic fracture.
- Polymer failure mechanisms.

(1) Chap. 6,8-10; (3) Chap. 13-19; (4) Chap. 18,23; (5) Chap. 9

Viscoelasticity and Wear of Materials (4L, Dr A Kabla)

- Constitutive modelling of materials deformation.
- Elasticity and viscoelasticity.
- Case studies.
- Micromechanisms of friction and wear in materials.

(1) Chap. 11

REFERENCES

(1) ASHBY, M., SHERCLIFF, H. & CEBON, D. MATERIALS: ENGINEERING, SCIENCE, PROCESSING AND DESIGN
(2) ASHBY, M.F. MATERIALS SELECTION IN MECHANICAL DESIGN
(3) ASHBY, M.F. & JONES, D.R.H ENGINEERING MATERIALS 1
(4) ASHBY, M.F. & JONES, D.R.H ENGINEERING MATERIALS 2
(5) CALLISTER, W.D. MATERIALS SCIENCE & ENGINEERING: AN INTRODUCTION

Booklists

Please see the Booklist for Part IA Courses **[2]** for details of the references for this module.

Examination Guidelines

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

UK-SPEC

This syllabus contributes to the following areas of the UK-SPEC [4] 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.

IA3

Comprehend the broad picture and thus work with an appropriate level of detail.

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.

D1

Wide knowledge and comprehensive understanding of design processes and methodologies and the ability to apply and adapt them in unfamiliar situations.

D3

Identify and manage cost drivers.

D5

Ensure fitness for purpose for all aspects of the problem including production, operation, maintenance and disposal.

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.

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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