Unit 4063: Engineering Mechanics and Materials

Unit Code: F/650/2943

Level: 4

Credits: 15

Introduction

Every aspect of engineering depends upon the use and manipulation of materials. Whether naturally occurring or man-made, it is the properties of these materials that are fundamental to their creation, processing and application.

This unit explores the fundamental structure of common engineering materials, their principal mechanical, chemical and electrical properties, and how these properties affect manufacture, application, service life and end-of-life management and recycling. Systems for categorising and ranking materials are also covered.

Finally, the service life performance of these materials is studied through calculations that measure their performance in static and dynamic applications, building on the work started in the associated level 4 unit, Engineering Science.

On successful completion of this unit, students will be able to identify the underlying structural properties of engineering materials and how these properties relate to their application and performance. They will also be confident in completing calculations relating to the static performance of these materials when in service.

Learning Outcomes

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

LO1 Describe the fundamental structures of common engineering materials

LO2 Determine the most important properties of engineering materials

LO3 Assess the performance of engineering materials using key indicators, including materials constraints and established database resources

LO4 Calculate solutions to problems within static and dynamic mechanical systems, with consideration of constraints on performance.

Essential Content

LO1 Describe the fundamental structures of common engineering materials

Classification of materials:

Metals, polymers, ceramics, composites, semiconductors, biomaterials, smart and nano materials; sub-classification of important materials, for example, ferrous and non-ferrous metals, alloys, thermoplastic and thermosetting polymers.

Structure of materials:

Atomic and molecular bonding; bonding forces; primary atomic bonding; ionic, covalent, hybridisation and metallic bonding

Secondary bonding, van der Waals forces, dipole bonds; mixed bonding and bonding energies

Crystallography of materials, unit cells, crystal systems, cubic and hexagonal; single crystal and polycrystalline materials; defects, dislocations, slip planes and impurities; polymorphism and allotropy, introduction to phase diagrams; non-crystalline (amorphous) materials

Structure and application of specific common materials, including metals, polymers and ceramics; changes to structure and properties due to alloying, doping, heat treatment and processing.

LO2 Determine the most important properties of engineering materials

Types of properties:

Mechanical, electrical, chemical, thermal, magnetic, optical and deteriorative (decay); examples of the importance of listed properties and common values; reasons for variation in a material's properties, for example, processing, heat treatment, operating environment

The importance of these properties in design and operation.

Properties of engineering materials:

Definitions, units, applicability and expected values for common material, for example, density, modulus of elasticity, Poisson's ratio, yield and tensile strength, percentage elongation, strength and fracture toughness, coefficient of thermal expansion and thermal conductivity, specific heat capacity and electrical resistivity; appreciation of quantitative and qualitative aspects of the properties of engineering materials

Examples of the importance of listed properties and common values; use of commercial material properties databases to find these values.

LO3 **Assess the performance of engineering materials using key indicators, including materials constraints and established database resources**

Links between materials properties and structural design:

Design constraints; operating conditions – temperature, loading and environment; cost, availability, processability, appearance and environmental constraints.

Materials selection and the design process:

Analysing the requirements, converting customer's request into a list of constraints for materials selection, creating materials specification parameters; forms of supply of common materials, stock items and special order; research using databases and online sources (e.g. Ansys Granta Selector, Matmatch, Cambridge Engineering Selector, suppliers' catalogues); suggest possible solutions; market analysis (availability, cost and type of supply form); impact on manufacturing/production methods (e.g. single, batch, flow and mass), test and evaluate selection against specification parameters using simulation software; sustainability, end of life and recycling considerations

Report preparation, presentation, feedback, evaluation and modification.

LO4 **Calculate solutions to problems within static and dynamic mechanical systems, with consideration of constraints on performance.**

Shafts and beams:

Revision of basics, Newton's second law, static equilibrium, types of beams and supports, shear force and bending moment calculations; bending in beams, engineers' theory of bending; selection of appropriate beams and columns to meet given specifications.

Torsion:

Revision of shear stress and strain; theory of torsion in solid and hollow circular shafts, engineers' theory of torsion, power transmitted by a shaft; composite shafts.

Introduction to dynamics:

Revision of conservation of energy and work-energy transfer in engineering systems; linear velocity, angular velocity and acceleration; velocity and acceleration diagrams of planar mechanisms; introduction to gyroscopic motion.

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Describe the fundamental structures of common engineering materials		
P1 Describe the crystalline structures of the three most common unit cells found in metals and link these cell types to the metals' engineering properties. **P2** Discuss the different material associated with amorphous and crystalline polymer structures.	**M1** Detail the differences between the effects of impurities, alloying elements and doping processes on the properties of an engineering material.	**D1** Differentiate between polymorphism and allotropy, specifying how the allotropy of iron is employed in the heat treatment of steel to alter its engineering properties.
LO2 Determine the most important properties of engineering materials		
P3 Determine the most important properties, for a given application, of engineering materials. **P4** Explain why the correct assessment of a materials' in-service behaviour is considered so important when selecting a material for a particular application.	**M2** Describe how the properties of metals can be modified by their production processes and how these effects can be subsequently relieved.	**D2** Evaluate Poisson's ratio and Young's modulus to explain their significance in material selection for a specific application.

Pass	Merit	Distinction
LO3 Assess the performance of engineering materials using key indicators, including materials constraints and established database resources		
P5 Use a commercial database to establish values for given material properties. **P6** Assess suitable materials for given products, specifying the normal form of supply for your suggestions.	**M3** Prepare a customer report for a fully costed application using a commercial database, offering at least two alternatives for consideration.	**D3** Explore how metals and polymers are currently recycled and arrangements for end-of-life decisions are made for manufactured products.
LO4 Calculate solutions to problems within static and dynamic mechanical systems, with consideration of constraints on performance.		
P7 Calculate the shear force, bending moment and stress due to bending in given examples of simply supported beams. **P8** Carry out selection exercises for given beams and columns.	**M4** Construct diagrams to find the vector solutions of velocities and accelerations within planar mechanisms.	**D4** Discuss the relationship between the various forms of mechanical energy and their conservation.

Recommended Resources

Note: See HN Global for guidance on additional resources.

Print Resources

Ashby M.F. and Jones D.R.H. (2012) *Engineering Materials 2*. 4th Ed. Butterworth-Heinemann.

Ashby M.F. and Jones D.R.H. (2018) *Engineering Materials 1*. 5th Ed. Butterworth-Heinemann.

Callister W.D. and RETHWISCH D.G. (2020) *Materials Science and Engineering*. 10th Ed. Wiley.

Chehade F.H., Hu C. and Wang K. (Editors) (2022) *Applied Mechanics and Engineering − Applied Mechanics and Materials (Paperback).* Trans Tech Publications Ltd.

Hertzberg R.W., Vinci R.P. and Hertzberg J.L. (2021) *Deformation and Fracture Mechanics of Engineering Materials (Paperback).* John Wiley & Sons Inc.

Hu J.W. (Editor) (2021) *Applied Engineering, Materials and Mechanics IV − Key Engineering Materials (Paperback).* Trans Tech Publications Ltd.

Kalpakjian S. and Schmid S.R. (2013) *Manufacturing Engineering and Technology*. 7th Ed. Pearson.

Mittelstedt C. (2023) *Engineering Mechanics 2: Strength of Materials: An introduction with many examples (Paperback).* Springer Fachmedien Wiesbaden.

Nugroho A.A. and Dahham O.S. (Editors) (2023) *Engineering Materials and Engineering Design − Applied Mechanics and Materials (Paperback).* Trans Tech Publications Ltd.

Tooley M. and Dingle L. (2021) *Engineering Science: For Foundation Degree and Higher National*. 2nd Ed. Routledge.

Journals

Note: Example journals listed below provide a broad range of articles related to unit content and those relevant for the qualification. Staff and students are encouraged to explore these journals and any other suitable journals to support the development of academic study skills, and subject specific knowledge and skills as part of unit level delivery.

ACS Applied Engineering Materials

Advanced Engineering Materials

Composites Part B: Engineering

European Journal of Mechanics

International journal of Refractory Metals and Hard Materials

Journal of Engineering Materials and Technology

Journal of Engineering Mechanics

Journal of Engineering Mechanics and Machinery

Journal of Materials Processing Technology

Material Science: Science Direct

Material Science and Engineering

Materials & Design

Materials Testing

Probabilistic Engineering Mechanics

Links

This unit links to the following related units:

Unit 4003: Engineering Science

Unit 4008: Mechanical Principles

Unit 4009: Materials, Properties and Testing

Unit 5003: Advanced Mechanical Principles.