Course guide
320053 - CEM - Science and Engineering of Materials

Last modified: 30/04/2024

Unit in charge: Terrassa School of Industrial, Aerospace and Audiovisual Engineering
Teaching unit: 712 - EM - Department of Mechanical Engineering.

Degree: BACHELOR'S DEGREE IN MECHANICAL ENGINEERING (Syllabus 2009). (Compulsory subject).

Academic year: 2024 **ECTS Credits:** 6.0 **Languages:** Catalan

LECTURER

Coordinating lecturer: Condal Margarit, Jordi
Alvarez Del Castillo, Javier

Others: Marin Sierra, Jose

PRIOR SKILLS

This subject is related to the subjects Materials Science and Technology, Strength of Materials and Manufacturing Technology.

DEGREE COMPETENCES TO WHICH THE SUBJECT CONTRIBUTES

Specific:
3. MEC: Knowledge and capability for the Implementation of Engineering Materials

Transversal:
1. SELF-DIRECTED LEARNING - Level 3. Applying the knowledge gained in completing a task according to its relevance and importance. Deciding how to carry out a task, the amount of time to be devoted to it and the most suitable information sources.
2. TEAMWORK - Level 3. Managing and making work groups effective. Resolving possible conflicts, valuing working with others, assessing the effectiveness of a team and presenting the final results.

TEACHING METHODOLOGY

-Face-to-face lecture sessions.
-Face-to-face sessions featuring case studies and specific problems.
-Independent study.
-Cooperative work on a project: research and the selection of content, structure, presentation, etc.
- Lecturer-directed activities aimed at developing skills for independent and cooperative work.
- Tutoring sessions, at which students are welcome to share questions that have arisen in the course of studying the material and completing the exercises.
-Oral presentation sessions, which include discussion of the activities and projects.
In the lecture sessions, the lecturer introduces each topic's theoretical foundations, concepts, methods and results, providing illustrative examples to facilitate comprehension. The main objective of the theory-oriented sessions is for students to acquire fundamental knowledge of the subject, which they subsequently use in the problem-solving and laboratory sessions.
There are three types of face-to-face practical work sessions:
a) Sessions in which the lecturer guides students in the search for information, the analysis of data and the application of techniques, concepts and theoretical results to solve problems.
b) Sessions in which students present group projects.
c) Individual and/or group assessment sessions.
The classes featuring application problems complement the lectures and enable students to develop critical-thinking skills and gain experience that will enable them to solve other problems independently. In these sessions, students will carry out projects and solve problems that, to the extent possible, reflect the complexity of the subject and its connection to professional activity. Students will also be encouraged to solve problems cooperatively.
Students are expected to study independently in order to grasp the concepts and solve the assigned exercises, either alone or with the help of a computer.
In 4- or 5-person groups, students will complete group projects and present their work at application sessions using any of various media: PowerPoint presentation, flash presentation, website or a physical medium (e.g. poster). Each group must submit a project report detailing the progress of the group's work, the research carried out and the results obtained.

LEARNING OBJECTIVES OF THE SUBJECT

Upon completion of this subject, students will have acquired:
An in-depth understanding of the structure, properties and transformation methods of the main materials used in industrial applications. An understanding of the technological features and optimisation techniques of the materials, as well as the treatments and processes used to modify their properties.
The ability to select appropriate materials and transformation methods for particular applications. An understanding of the main materials-testing methods and inspection and control techniques, as well as the most common defects in processed components produced and their influence on final properties and in-service performance.
An understanding of the importance of components and the proper use of materials, as well as the ability to recognise their problems and apply the correct treatment. The ability to select the most efficient material-transformation processes from an environmental standpoint.

STUDY LOAD

Type	Hours	Percentage
Hours medium group	15,0	10.00
Hours large group	30,0	20.00
Hours small group	15,0	10.00
Self study	90,0	60.00

Total learning time: 150 h

CONTENTS

TOPIC 1: TECHNOLOGY AND TREATMENT OF FERROUS METALLIC MATERIALS

Description:
1.1. Introduction to metallic materials technology: Historical overview of materials technology; the economic importance of materials and their applications. Classification of ferrous metal alloys: steels. Iron-carbon diagram (Fe-Fe3C). Alloying elements and their effects. Microscopic constituents. Properties.
Heat treatment of ferrous alloys: general classification of heat treatments; heat treatment of steels and cast irons; Quenching and hardenability. Jominy test. Effects of treatments on microstructure. Isothermal and continuous-cooling transformations. Problems. Environmental considerations: waste and recycling.
Surface treatment of metal components: surface cleaning; coating processes; surface treatments. Environmental considerations: waste and recycling.

Related activities:
- Metallography practical (I). Using optical and electron microscopy techniques and other educational resources, we observe the microstructures of various metallic samples consisting of base materials under equilibrium conditions, analyse the most important aspects of their morphology and compare them with the expected properties. We review the main concepts of metallurgy and examine examples of unusual microstructures, which students identify by relating them with the resulting properties.

Full-or-part-time: 20h
Theory classes: 4h
Practical classes: 2h
Laboratory classes: 4h
Self study : 10h

TOPIC 2: TECHNOLOGY AND TREATMENT OF NON-FERROUS METALLIC MATERIALS

Description:
2.1. Aluminium and its alloys: production, properties and characteristics. Main aluminium alloys: heat treatments and applications.
2.2. Titanium and its alloys: production, properties and characteristics. Main titanium alloys: heat treatments and applications.
2.3. Other metal alloys: magnesium, copper, zinc, beryllium, nickel and cobalt. Refractory metals and precious metals: properties and characteristics. Applications.
2.4. Superalloys: microstructure, properties, heat treatments, applications.

Related activities:
Metallography practical (II). Using optical and electron microscopy techniques and other educational resources, we observe the microstructures of metallic samples that have undergone various kinds of processing and analyse the most important aspects of their morphology. Given a particular phase diagram and the resulting microstructures, students infer the process that the alloy has undergone by relating the observed phases with the heat treatment that the element has undergone and deduce its final properties.

Full-or-part-time: 23h
Theory classes: 4h
Practical classes: 2h
Laboratory classes: 3h
Self study : 14h

TOPIC 3: PROCESSING OF MATERIALS AND METAL COMPONENTS: INFLUENCE ON PROPERTIES

Description:
3.1. Melting and casting: stages of the process, solidification of metals and alloys, permanent and non-permanent moulds.
3.2. Formation by plastic deformation. Hardening and softening mechanisms. Effect of temperature. Adequacy of alloys formed by plastic deformation.
3.3. Powder metallurgy: preparation and characterisation of metal powder; compacting and sintering; advanced powder-metallurgy techniques.
3.4. Most common problems in processes of forming metallic materials.
3.5. Environmental considerations: waste and recycling.

Related activities:
Heat treatments. In this practical activity, students become familiar with various simple heat treatments and gain an understanding of how they affect the (mainly mechanical) properties of materials. The activity involves subjecting metallic, plastic and ceramic test pieces to different heat treatments and evaluating and verifying the properties of the parts both before and after the process.

Full-or-part-time: 21h
Theory classes: 3h
Practical classes: 1h
Laboratory classes: 4h
Self study : 13h

TOPIC 4: POLYMERIC MATERIALS: PROPERTIES, MANUFACTURING AND PROCESSING

Description:
4.1 Polymeric materials: general information and classification. Technical and high-performance polymers. Polymer treatments.
4.2 Polymer-forming processes: extrusion parameters and variables, transport processes, plastification, mixture and defects.
4.3 Injection: cycle, parameters and variables of the process; moulds and dies; injection-related processes.
4.4 Other forming processes: thermoforming, rotational moulding. Special processes.

Related activities:
Injection practical. In this practical activity, carried out at the Catalan Plastics Centre, students make plastic parts using the injection method on a commercial machine. They also analyse the effects of the main process variables¿injection pressure, temperature and speed¿on the final quality of the parts.

Full-or-part-time: 28h
Theory classes: 6h
Practical classes: 2h
Laboratory classes: 2h
Self study : 18h

TOPIC 5: CERAMIC AND GLASS MATERIALS: PROPERTIES, MANUFACTURING AND PROCESSING

Description:
5.1 Ceramic materials: traditional ceramics; technical ceramics; forming processes.
5.2 Glasses: general information, raw materials and glass preparation; forming processes; Heat treatments. defects.
5.3 Heat treatments and defects in ceramics and glass.
5.4 Environmental considerations: waste and recycling.

Full-or-part-time: 11h
Theory classes: 3h
Practical classes: 1h
Self study : 7h

TOPIC 6: COMPOSITE MATERIALS: FORMING TECHNIQUES AND THEIR INFLUENCE ON PROPERTIES

Description:
6.1. Components of a composite material. Matrix, reinforcement and interface. Classification of composite materials. Effects of the type, form and content of the reinforcement. Particles and fibres. Matrix/reinforcement adhesives. Thermal and chemical mechanical properties. Nanocomposites. Basics and applications.
6.2. Metal-matrix composites, metal-metal composites and cermets. Ceramic-matrix composites materials. Special forming processes. Applications. Polymer-matrix composites. Forming techniques. Environmental considerations: environmental impact and recycling.

Full-or-part-time: 17h
Theory classes: 4h
Practical classes: 2h
Self study : 11h

TOPIC 7: IN-SERVICE PERFORMANCE AND FRACTURE OF COMPONENTS: TRIBOLOGY AND DEFECT AND CORROSION CONTROL

Description:
7.1. In-service performance: techniques and processes for joining materials.
7.2. Creep and fatigue of in-service materials; mechanical characterisation and microstructural aspects.
7.3. Introduction to fracture mechanics.
7.4. Corrosion of metals; chemical resistance of polymers; SCC; degradation of ceramic materials.
7.5. Introduction to defect analysis: destructive and non-destructive tests; determination of surface and internal defects.
7.6. Tribology: friction and the prevention of wear.

Related activities:
Corrosion (I): Students apply the criteria of brine electrolysis, in which chemical transfers enable the flow of the current. The purpose of this activity is to test how the factors indicated in Faraday's law influence nickel coatings on metal components of different types (i.e. substrates).
Corrosion (II): Students observe the behaviour of different types of materials, or different areas of a single component, in a corrosive environment. They classify metallic materials by chemical nobility on the basis of their behaviour in a saline environment. They also analyse the aging and associated changes in properties of different polymeric samples subjected to environmental and/or accelerated aging.

Full-or-part-time: 30h
Theory classes: 6h
Practical classes: 5h
Laboratory classes: 2h
Self study : 17h

GRADING SYSTEM

- First examination: 45%
- Second examination: 45%
- Presentation- Laboratory practicals: 10%

NOTE:
In this subject, there will be a system for the renewal of unsatisfactory results. Results lower than 5.0 in the first assessment can be taken back to the second assessment. During the second assessment, students with results lower than 5.0 in the first assessment will take a test to be able to repeat the grade obtained from the first assessment. The grade obtained through the retake test cannot be higher than 5.0. The new retake exam grade will replace the old grade only if it is higher. The grade of the subject will be calculated as a weighted average of the partial and final test or as a weighted average of the resit test and the second assessment (in case the first one was lower than 5.0)
The partial test and the final will be scored from 0 to 10, with 10 being 45% of the total value of the subject. The total assessment of the theoretical part will be from 0 to 10, with 10 being equivalent to 90% of the subject.
In the laboratory part, there will be no resumption system. The score will be from 0 to 10, with 10 being equivalent to 10% of the total value of the subject.
Attendance at the laboratory class is mandatory. If you are unable to attend the laboratory class, you must speak to the teacher and present a valid document to excuse attendance. In the event of an unjustified absence from a session, the grade for that session will be graded with a 0.
For those students enrolled in the subject who have obtained a final grade greater than or equal to 2.0 but less than 5.0 during the teaching period, they may take the re-evaluation exam. Students who have obtained the qualification of not presented cannot take part in the re-evaluation.
The grade of the re-assessment exam will replace the grades of all previous assessment instruments.
If the final grade after the re-evaluation is lower than 5.0, it will replace the initial grade only if it is higher. If the final grade after the re-evaluation is greater than or equal to 5.0, the final grade of the subject will be a maximum of 5.0 pass.

BIBLIOGRAPHY

Basic:
- Kalpakjian, Serope. Manufactura, ingeniería y tecnología [on line]. 7a ed. México [etc.]: Pearson Educación, 2014 [Consultation: 20/09/2022]. Available on: https://www-ingebook-com.recursos.biblioteca.upc.edu/ib/NPcd/IB_BooksVis?cod_primaria=1000187&codigo_libro=5323.
- Groover, Mikell P. Fundamentos de manufactura moderna: materiales, procesos y sistemas [on line]. 3ª ed. México: Prentice Hall, 2007 [Consultation: 16/09/2022]. Available on: https://ebookcentral-proquest-com.recursos.biblioteca.upc.edu/lib/upcatalunya-ebooks/detail.action?pq-origsite=primo&docID=4585363. ISBN 9789701062401.
- Apraiz Barreiro, José. Tratamientos térmicos de los aceros. 9a ed. Madrid: Dossat, 1997. ISBN 84896656207.
- Salán, M. N. Tecnología de proceso y transformación de materiales [on line]. Barcelona: Edicions UPC, 2005 [Consultation: 12/05/2020]. Available on: http://hdl.handle.net/2099.3/36673. ISBN 848301789X.

Complementary:
- Gil Mur, Francisco Javier [et al.]. Aleaciones ligeras [on line]. Barcelona: Edicions UPC, 2001 [Consultation: 12/05/2020]. Available on: http://hdl.handle.net/2099.3/36151. ISBN 8483014807.