Course guide
295758 - 295EM113 - Mechanical Behavior of Materials and Their Simulation

Last modified: 27/05/2024

Unit in charge: Barcelona East School of Engineering
Teaching unit: 702 - CEM - Department of Materials Science and Engineering.

Degree: MASTER'S DEGREE IN MATERIALS SCIENCE AND ADVANCED MATERIALS ENGINEERING (Syllabus 2019). (Optional subject).

Academic year: 2024 **ECTS Credits:** 6.0 **Languages:** Spanish, English

LECTURER

Coordinating lecturer: FERHUN CEM CANER BASKURT

Others: NOEL LEÓN ARBITER
FERHUN CEM CANER BASKURT
LUIS LLANES PITARCH

PRIOR SKILLS

Degree in science or engineering. Basic knowledge of the relationship between the microstructure of materials and their mechanical behavior. Basic knowledge of mechanical behavior and strength of materials.

DEGREE COMPETENCES TO WHICH THE SUBJECT CONTRIBUTES

Specific:
CEMCEAM-02. (ENG) Aplicar métodos innovadores para el diseño, simulación, optimización y control de procesos de producción y transformación de materiales
CEMCEAM-04. (ENG) Realizar estudios de caracterización y evaluación de materiales según sus aplicaciones

TEACHING METHODOLOGY

Theoretical and problem classes are taught during the course, along with simulation activities by Abaqus or Matlab or other similar software as well as laboratory activities. Several evaluations are performed, in the form of in-class and take-home exams/projects.

LEARNING OBJECTIVES OF THE SUBJECT

The objective of this course is to combine theoretical and practical knowledge of the mechanical behavior of engineering materials. The course gives special emphasis to elasticity in 3D and plasticity in 3D at the macro scale and the micro and nano scales as well. At the macro scale, the tensor analysis gains importance and therefore an introduction to tensors will be taught as easily as possible. Tensor knowledge will also facilitate the learning of mechanical behavior on the micro scale. The practical applications will be carried out using simulations by Abaqus, Matlab and other software considered appropriate. Unlike tests in a physical laboratory, using different simulation techniques a virtual laboratory will be created where one can experience and visualize a much wider range of material behavior at different scales.

STUDY LOAD

Type	Hours	Percentage
Hours small group	14,0	9.33
Self study	108,0	72.00
Hours large group	28,0	18.67

Total learning time: 150 h

CONTENTS

Tema 1. Configuration of most used mechanical tests and parameters

Description:
Definition of stress and strain. Mechanical response of structural materials: basic concepts of elasticity and plasticity. Types of curves that relate loads to mechanical response of the material: engineering, true and intrinsic. Characteristics that define them. Most used test configurations, mechanical parameters obtained and their physical meaning, practical particularities of each configuration: Tension, bending (at 3 and 4 points), uniaxial compression. Most used constitutive equations.

Full-or-part-time: 9h 20m
Theory classes: 3h
Self study : 6h 20m

Tema 2. Viscoleasticity of materials

Description:
Introduction to linear viscoelasticity of materials. Response in static loads: Creep tests, stress ratio and creep-recovery; parameters that quantify creep recovery response. Boltzman superposition principle. Time-temperature correspondence principle. Micromechanical models: Maxwell, Kelvin-Voigt, Zener, 4 elements.

Full-or-part-time: 18h 40m
Theory classes: 6h
Self study : 12h 40m

Tema 3. Introduction to tensors

Description:
Cartesian tensors. Index notation and Einstein's summation convention. Tensor and matrix notations. Tensor operations. Stress tensor. Strain tensor. Anti-symmetric tensor and energy stored in a material. Transformation of tensors of rank 1 and rank 2. The traction vector. The invariants of tensors of rank 2. Implications in the modeling of the mechanical behavior of the materials. Introduction to Abaqus.

Full-or-part-time: 24h
Theory classes: 7h
Self study : 17h

Tema 4. Elastic behavior and its simulation

Description:
Hooke's Law. Elastic energy stored in the material. Elastic stiffness tensor. Lamé constants. Deviatoric-volumetric split. Voight notation. Stiffness matrix of an elastic material. Elasticity in conditions of plane stress and plane strain. The relationship between elasticity constants and those of bonds between atoms. Effect of distributed microcracking and pores on the elastic behavior of ceramics. Viscoelastic behavior. Simulation of elasticity in 2D and 3D using Abaqus.

Full-or-part-time: 24h
Theory classes: 7h
Self study : 17h

Tema 5. Continuum scale plastic behavior and its simulation

Description:
Additive separation of strains. Work hardening: Ludwik-Hollomon, Johnson-Cook and their calibration. Bridgman correction. Tensile vs. compressive plasticity tests. The effect of Bauschinger. Flow criteria: Rankine, Tresca and von Mises. The plasticity modulus. The second invariant of the deviatoric stress tensor. Calculation algorithms of elastoplasticity in 1D: Isotropic hardening and kinematic hardening.

Full-or-part-time: 25h
Theory classes: 7h
Self study : 18h

Tema 6. Strength and deformation of materials

Description:
Critical parameters for the selection of materials in structural applications: elastic modulus, yield strength, ductility and toughness. Mechanisms of plastic deformation of single- and poly-crystals. Dislocations as deformation agents in crystalline materials. Strengthening mechanisms: solid solution, second-phase precipitation, cold work, microstructural refinement, reinforcement by means of particles and fibers. Optimizing strength-toughness correlation through microstructural design.

Full-or-part-time: 49h
Theory classes: 16h
Self study : 33h

GRADING SYSTEM

The part of Prof. N. León: Mid-term Exam 1: 19%
The part of Prof. F. Caner: Mid-term Exam 2 :24%, Project 1 :24%
The part of Prof. L. Llanes: Mid-term exams :33%

The final exam is obligatory if the weighted average grade from continuing education is less than 5.0. If the final exam is taken, the grade from the final exam becomes the final grade of the course. There is no make-up exam in this course.

BIBLIOGRAPHY

Basic:
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- Owen, D. R. J; Hinton, Ernest. Finite elements in plasticity : theory and practice. Swansea, [U.K.]: Pineridge Press Limited, 1980. ISBN 0906674052.
- Rees, D. W. A. Basic engineering plasticity : an introduction with engineering and manufacturing applications. Oxford [etc.]: Butterworht-Heinemann / Elsevier, 2006. ISBN 0750680253.
- Dunne, Fionn; Petrinic, Nik. Introduction to computational plasticity. Oxford: Oxford University, 2006. ISBN 9780198568261.
- Courtney, Thomas H. Mechanical behavior of materials. 2nd ed. Boston [etc.]: McGraw-Hill, cop. 2000. ISBN 0070285942.
- Khennane, Amar. Introduction to finite element analysis using Matlab and Abaqus. Boca Raton: CRC Press, Taylor & Francis Group, 2013. ISBN 9781466580206.
- Hosford, Williams. Mechanical behavior of materials. Cambridge: Cambridge University Press, 2005. ISBN 0521846706.
- Callister, William D.; Rethwisch, David G. Materials science and engineering: an introduction. 10th. Hoboken: John Wiley & Sons, 2020. ISBN 9781119453918.
- Askeland, Donald R.; Fulay, Pradeep P.; Bhattacharya, D. K. Essentials of materials science and engineering. 2nd ed. Stamford, CT: Cengage Learning, 2010. ISBN 9780495438502.
- Ward, I. M.; Sweeney, J. Mechanical properties of solid polymers [on line]. 3rd ed. Hoboken: John Wiley & Sons, 2013 [Consultation: 15/11/2022]. Available on: https://discovery.upc.edu/permalink/34CSUC_UPC/rdgucl/alma991005065379606711. ISBN 9781444319507.
- Dieter, George Ellwood;. Mechanical metallurgy. SI metric ed. London: McGraw-Hill Book Company, 1988. ISBN 0071004068.
- Hertzberg, Richard W.; Hertzberg, Jason L.; Vinci, Richard P.. Deformation and fracture mechanics of engineering materials. 5th ed. New York: John Wiley & Sons, 2013. ISBN 9780470527801.