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

Last modified: 04/06/2021

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: 2021 **ECTS Credits:** 6.0 **Languages:** Spanish, English

LECTURER

Coordinating lecturer: FERHUN CEM CANER

Others: Primer quadrimestre:
JORGE ALCALA CABRELLES - T10
FERHUN CEM CANER - T10

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 would facilitate the learning experience for the student.

TEACHING METHODOLOGY

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

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
Self study	102,0	68.00
Hours small group	14,0	9.33
Hours medium group	28,0	18.67
Guided activities	6,0	4.00

Total learning time: 150 h

CONTENTS

Tema 2. 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: 27h
Theory classes: 8h
Self study : 19h

Tema 1. 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: 22h 30m
Theory classes: 5h 30m
Self study : 17h

Tema 4. Cristal plastic behavior and its simulation

Description:
The yield strength of a perfect crystal. The edge dislocation. Screw and mixed dislocations. Twinning. Properties of dislocations. Slip systems. Partial dislocations. Intersection of moving dislocations. Dislocation density and macroscopic strain. Initiation of plastic flow in single crystals. Stress-strain behavior of single crystals. Plastic flow in polycrystals. Plastic-flow behavior and material class. General description of strengthening. A summary of different types of hardening in elastoplastic materials: Work hardening, boundary strengthening, solid-solution strengthening, particle hardening and strain-gradient hardening.

Full-or-part-time: 73h
Theory classes: 21h
Self study : 52h

Tema 3. 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: 27h 30m
Theory classes: 8h 30m
Self study : 19h

GRADING SYSTEM

The part of Prof. F. Caner:
Mid-term Exam 1 :20%
Project 1 :15%
Project 2 :15%
The part of Prof. J. Alcalá:
Mid-term Exam 2 :34%
Project 3 : 8%
Project 4 : 8%
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.

BIBLIOGRAPHY

Basic:

- Khennane, Amar. Introduction to finite element analysis using Matlab and Abaqus. Boca Raton: CRC Press, Taylor & Francis Group, 2013. ISBN 9781466580206.
- Malvern, Lawrence E. Introduction to the mechanics of a continuous medium. Englewood Cliffs, NJ: Prentice-Hall, cop. 1969. ISBN 0134876032.
- Dunne, Fionn; Petrinic, Nik. Introduction to computational plasticity. Oxford: Oxford University, 2006. ISBN 9780198568261.
- 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.
- Courtney, Thomas H. Mechanical behavior of materials. 2nd ed. Boston [etc.]: McGraw-Hill, cop. 2000. ISBN 0070285942.