Course guide
240EM146 - 240EM146 - Modelling of Plastic Deformation

Last modified: 26/06/2025

Unit in charge:	Barcelona East School of Engineering
Teaching unit:	702 - CEM - Department of Materials Science and Engineering.
Degree:	ERASMUS MUNDUS MASTER'S DEGREE IN ADVANCED MATERIALS SCIENCE AND ENGINEERING (Syllabus 2014). (Optional subject).

Academic year: 2025 **ECTS Credits:** 4.5 **Languages:** Spanish, English

LECTURER

Coordinating lecturer: Ferhun Cem CANER

Others: Ferhun Cem CANER

PRIOR SKILLS

Having studied the basic subjects of Science and Engineering of Materials: Structure and properties of the materials.

REQUIREMENTS

The structure and mechanical properties of materials

DEGREE COMPETENCES TO WHICH THE SUBJECT CONTRIBUTES

Specific:
CEMAT7. Design, calculation and modeling aspects of materials for mechanical components, structures and equipment.
CEMAT2. Design and develop products, processes, systems and services, as well as the optimization of other already developed, based on the selection of materials for specific applications.

TEACHING METHODOLOGY

The contents of this course, with a strong emphasis on practical application, are developed in classes that combine the theoretical explanation by the professor and its practical application, using a computer (provided by the student) and a commercial FEA program. Many examples illustrating the concepts studied are solved by applying different models of mechanical behavior of the engineering materials of interest.

LEARNING OBJECTIVES OF THE SUBJECT

-To understand the different models of plastic and elasto-plastic behaviour of Engineering Materials.
-To learn strategies of the numerical simulation of forming processes.
-To learn advantages and disadvantages of different formulations of plasticity in the simulation of the plastic behavior of metals.

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STUDY LOAD

Type	Hours	Percentage
Hours large group	27,0	24.00
Hours small group	13,5	12.00
Self study	72,0	64.00

Total learning time: 112.5 h

CONTENTS

1. INTRODUCTION TO THE THEORY OF ELASTOPLASTICITY

Description:
Mechanics of Materials.
Methods for solving plastic deformation problems.

Specific objectives:
Introduction to the physical/mathematical modeling of plasticity and its implementation in commercial numerical simulation programs.

Related activities:
A.1. A numerical simulation exercise of a simple case of elastic and elastoplastic deformation in 1D.

Related competencies :
CEMAT7. Design, calculation and modeling aspects of materials for mechanical components, structures and equipment.

Full-or-part-time: 20h
Practical classes: 7h
Laboratory classes: 3h
Self study : 10h

2. ELEMENTS OF THE THEORY OF PLASTICITY

Description:
2.1. Yield criteria.
2.2. Plastic and elastoplastic stress-strain relationship.
2.3. Non-linear phenomena.

Specific objectives:
To understand the concept of plastic yield and its conditions, as well as stress-strain relationships that represent the plastic deformation behavior of metallic materials.

Related activities:
A.2. Analysis of an isothermal forging / extrusion process by numerical simulation.

Related competencies :
CEMAT7. Design, calculation and modeling aspects of materials for mechanical components, structures and equipment.

Full-or-part-time: 17h
Practical classes: 4h
Laboratory classes: 3h
Self study : 10h

3. ANISOTROPY AND PLASTIC DEFORMATION OF PLANE METALLIC PRODUCTS DURING THEIR COLD WORKING.

Description:
3.1. Anisotropy and microstructure. Coefficients of anisotropy.
3.2. Deep drawing. Effect of the material.
3.3. Theory of anisotropic plasticity: Hill's criterion.

Specific objectives:
To understand the effect of the anisotropy of the structure of the material on its mechanical behavior.

Related activities:
A.3. A numerical simulation exercise of the deep drawing of a metal sheet, assuming: a) isotropy, and b) anisotropy.

Related competencies :
CEMAT2. Design and develop products, processes, systems and services, as well as the optimization of other already developed, based on the selection of materials for specific applications.
CEMAT7. Design, calculation and modeling aspects of materials for mechanical components, structures and equipment.

Full-or-part-time: 16h
Practical classes: 2h
Laboratory classes: 4h
Self study : 10h

4. MODELLING OF THE PLASTIC DEFORMATION USING MULTIPLE YIELD SURFACES

Description:
4.1. Conceptual description and microstructure of the hardening mechanisms in view of families of compact planes.
4.2. Physical / mathematical modelling of the hardening mechanisms by taking into account the families of compact planes.
4.3. Practical applications to the modeling of forming processes and to other plastic deformation processes.

Specific objectives:
To understand the mechanisms of deformation and microstructural changes of metallic materials subjected to plastic deformation taking into account the families of compact planes. Mechanical behavior models and their implementation in FEM calculation programs for this purpose.

Related activities:
A.4. Simulation of the Bauschinger effect.
A.5. Simulation of the Vertex effect.

Related competencies :
CEMAT2. Design and develop products, processes, systems and services, as well as the optimization of other already developed, based on the selection of materials for specific applications.
CEMAT7. Design, calculation and modeling aspects of materials for mechanical components, structures and equipment.

Full-or-part-time: 18h
Practical classes: 4h
Laboratory classes: 4h
Self study : 10h

5. DUCTILE FRACTURE IN METALS

Description:
5.1. Ductile fracture in metals that follows cold work hardening.
5.2. Modeling of ductile fracture in metals using Abaqus.
5.3. Examples of numerical simulation of the process of cracking in ductile metals.

Specific objectives:
To understand the deformation behavior of materials that causes failure due to cracking in ductile metals, the physical / mathematical models that represent it and its implementation in numerical calculation programs.

Related activities:
A.6. Simulation of necking followed by fracture in Mode I.

Related competencies :
CEMAT2. Design and develop products, processes, systems and services, as well as the optimization of other already developed, based on the selection of materials for specific applications.
CEMAT7. Design, calculation and modeling aspects of materials for mechanical components, structures and equipment.

Full-or-part-time: 15h
Practical classes: 2h
Laboratory classes: 3h
Self study : 10h

6. MECHANICAL BEHAVIOUR, MODELLING AND SIMULATION OF ELASTOMERIC MATERIALS.

Description:
6.1. Description and classification of basic elastomers.
6.2. Mechanical behavior of elastomeric materials.
6.3. Modeling and numerical simulation of elastomeric materials.

Specific objectives:
To understand the mechanical, static and dynamic behavior of elastomeric materials, the models that can represent such behavior and the associated simulation strategies.

Related activities:
A.7. Simulation of the mechanical behavior of an elastomeric specimen.

Related competencies :
CEMAT2. Design and develop products, processes, systems and services, as well as the optimization of other already developed, based on the selection of materials for specific applications.
CEMAT7. Design, calculation and modeling aspects of materials for mechanical components, structures and equipment.

Full-or-part-time: 16h
Practical classes: 2h
Laboratory classes: 4h
Self study : 10h

GRADING SYSTEM

The qualification of the subject is constituted by the following contributions:
- 15%: The grade reflecting an active attendance to the classes.
- 35%: The average grade of the reports of the activities presented (from A.1 to A.7).
- 50%: The grade of the final project report (A.8).

EXAMINATION RULES.

Original work developed individually or in groups according to the problem statement.

BIBLIOGRAPHY

Basic:

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- Dieter, George Ellwood. Mechanical metallurgy. SI Metri. Lonoson: McGraw Hill Higher Education, 1988. ISBN 007084187X.
- Hosford, W. F.; Caddell, R. M. Metal forming : mechanics and metallurgy. 4th ed. Cambridge: Cambridge University Press, 2011. ISBN 9781107004528.
- Jonas, J. J.; Sellars, C. M.; Tegart, W. J. McG. "Strength and structure under hot-working conditions". International materials reviews. Volume 14, Issue 1 (01 January 1969), pp. 1-24.
- Bergström, J.S. ; Boyce, M.C.. "Constitutive modeling of the large strain time-dependent behavior of elastomers". Journal of the Mechanics and Physics of Solids [on line]. Volume 46, Issue 5, May 1998, Pages 931¿954 [Consultation: 27/03/2015]. Available on: http://www.sciencedirect.com/science/article/pii/S0022509697000756.- Riera, M.D. ; Prado, J.M.. "Modelización y simulación de la etapa de compactación en pulvimetalurgia". Revista de Metalurgia [on line]. 2006, vol. 42, núm. 6, p. 456-462 [Consultation: 27/03/2015]. Available on: http://revistademetalurgia.revistas.csic.es/index.php/revistademetalurgia/article/view/43/43.- Riera, M.D. ; Coussirat, M. ; Guarmo, A. ; Valls, I.; Casellas, D. "Simulation of hot stamping processes". Proceedings of the 1st International Conference on Hot Sheet Metal Forming of High-Performance Steel : CHS2 : Kassel, Germany, october 22-24, 2008 [on line]. Bad Harzburg: GRIPS Media, 2009. pp. 119-131 [Consultation: 24/03/2015]. Available on: http://upcommons.upc.edu/handle/2117/13974.

Complementary:

- Kobayashi, S.; Oh, S. ; Altan, T. Metal forming and the finite-element method. New York: Oxford University Press, 1989. ISBN 9780195044027.
- Osakada, K.. "History of plasticity and metal forming analysis". Journal of materials processing technology [on line]. Volume 210, Issue 11, 1 Aug. 2010, Pag 1436-1454 [Consultation: 21/05/2020]. Available on: http://www.sciencedirect.com/science/article/pii/S0924013610001111.- Karbasian, H. ; Tekkaya, A. E.. "A review on hot stamping". Journal of materials processing technology [on line]. Volume 210, Issue 15, 19 November 2010, Pages 2103-2118 [Consultation: 21/05/2020]. Available on: http://www.sciencedirect.com/science/article/pii/S092401361000213X.- Estrin, Y. ; Mecking, H. "A unified phenomenological description of work hardening and creep based on one-parameter models". Acta metallurgica. Volume 32, Issue 1, January 1984, Pages 57¿70.
- Baudelet, Bernard. Mise en forme de métaux et alliages. París: CNRS, 1976. ISBN 9782222019176.
- Istúriz, A. ; Riera, M.D. ; Prado, J.M.. "Estudio experimental del llenado de moldes pulvimetalúrgicos". Revista de Metalurgia [on line]. Vol 41, No Extra (2005) pp. 181-186 [Consultation: 27/03/2015]. Available on: http://revistademetalurgia.revistas.csic.es/index.php/revistademetalurgia/article/view/1021/1034.- Riera, M.D. ; Prado, J.M.. "The elastic behaviour of non-sintered metal powder compacts". Proceedings of the IMechE, Part E: J. of Process Mechanical Engineering [on line]. 2010, vol. 224, núm. Special Issue, p. 195-201 [Consultation: 27/03/2015]. Available on: http://search.proquest.com/publication/30473.- Cante, J.C. ; Riera, M.D. ; Oliver, J. ; Prado, J.M. ; Istúriz, A. ; González, C.. "Flow regime analyses during the filling stage in powder metallurgy processes: experimental study and numerical modelling". Granular Matter [on line]. February 2011, Volume 13, Issue 1, pp 79-92 [Consultation: 27/03/2015]. Available on: http://hdl.handle.net/2117/11432.- Gutiérrez, D.; Hernández, R.; Lara, A.; Casellas, D.; Riera, M.D.; Prado, J.M.. "Sheet failure prediction during forming of advanced high strength steels". Forming Technology Forum (5è : 2012 : Zurich). Proceedings of 5th Forming Technology Forum 2012. Advanced Failure Prediction Methods in sheet metal forming [on line]. Zurich: Institute of Virtual Manufacturing, 2012. p. 93-98 [Consultation: 25/03/2015]. Available on: http://upcommons.upc.edu/handle/2117/19598.- Riera, M.D.; Prado, J.M.; Doremus, P. "Model Input Data ¿ Elastic Properties". Brewin, Peter R. Modelling of Powder Die Compaction [on line]. London: Springer-Verlag, 2008. pp 65-76 [Consultation: 24/03/2015]. Available on: http://dx.doi.org/10.1007/978-1-84628-099-3.

RESOURCES

Computer material:

- programa de càlcul FEM ABAQUS-student edition. ABAQUS student edition software