CENTRALE NANTES

ENGINEERING PROGRAMME

2024-2025

Year 2 / Year 3

Specialisation option

Mechanical Engineering for Materials and Manufacturing Processes

OD MATEPRO

PROGRAMME SUPERVISOR

Erwan VERRON

Autumn Semester

Course unit	ECTS Credits	Track	Course code	Title
UE 73	12	Core course	CDMAT EXPER MEF_MATEPRO MPHY	Materials Selection in Mechanical Design Experimental methods in materials science Finite Element Method Multiphysics modelling
UE 74	13	Core course	CONFVE MELAST METAL P1MATEPRO POCOM	Conferences and company visits Mechanics of elastomers Metallurgy Project 1 Polymers and composites

Spring Semester

Course unit	ECTS Credits	Track	Course code	Title
UE 83	14	Core course	FARUP MATSOC MICOM MIMET P2MATEPRO	Fatigue and fracture of materials Materials and Society Composites processing Metal forming and processing Project 2

Materials Selection in Mechanical Design [CDMAT]

LEAD PROFESSOR(S): Guillaume RACINEUX

Requirements

Objectives

Today, there are more than 100,000 materials available for product design, which constitutes a tremendous opportunity for innovation.

In order to choose the proper material, one needs:
- sound knowledge of the different classes of materials
- good understanding of their properties,
- a methodology that best meets the design specifications

At the end of this course, the students will:
- know the different classes of materials
- be able to proceed to a rational choice of materials

Course contents

- Presentation of the different classes of materials (metals, polymers, ceramics, composites and their properties)
- Presentation of the Ashby method for material selection
- Case studies

Course material

- Engineering Materials, I & II, M.F. Ashby and D.R.H. Jones, Elsevier (4th edition), 2012.
- Materials Selection in Mechanical Design, Butterworth-Heinemann (4th edition), 2010.

Assessment

Collective assessment: EVC 1 (coefficient 0.4)

Individual assessment: EVI 1 (coefficient 0.6)

LANGUAGE OF INSTRUCTION	ECTS CREDITS	LECTURES	TUTORIALS	LAB	PROJECT	EXAM
French	3	10 hrs	12 hrs	8 hrs	0 hrs	2 hrs

Experimental methods in materials science [EXPER]

LEAD PROFESSOR(S): Michel CORET

Requirements

Objectives

This course deals with experimental methods that are widely used in mechanics of materials. Most of them focus on the observation the materials or the identification of some physical properties.

Course contents

- Highly instrumented tests using electromechanical and hydraulic machines (with the use of digital image correlation)
- Observation and analysis using scanning electronic microscopes
- tridimensional measurements using tomography

Course material

- ASM Handbook, Vol. 8, Mechanical Testing & Evaluation
- C. Esnouf, 'Caractérisation microstructurale des matériaux' P.P. Romandes, 2011

Assessment

Collective assessment: EVC 1 (coefficient 1.0)

LANGUAGE OF INSTRUCTION	ECTS CREDITS	LECTURES	TUTORIALS	LAB	PROJECT	EXAM
French	3	12 hrs	6 hrs	12 hrs	0 hrs	2 hrs

Finite Element Method [MEF_MATEPRO]

LEAD PROFESSOR(S): Erwan VERRON

Requirements

Continuum Mechanics (MMCe, 1st year), Materials (MATER, 1st year)

Objectives

This course focuses on two important aspects of structural mechanics, that will be used in other courses of the specialty MATEPRO: material strength (bending of beams) and Finite Element Analysis (FEA).

Course contents

This course is made of three distinct parts:
1. In-plane bending of beams
2. Formulation of Finite Element Analysis (one-dimensional)
3. Use of a commercial software for a project (Abaqus)

Course material

1. https://fr.wikipedia.org/wiki/R%C3%A9sistance_des_mat%C3%A9riaux
2. https://www.coursera.org/learn/finite-element-method
3. https://www.3ds.com/fr/produits-et-services/simulia/produits/abaqus/

Assessment

Collective assessment: EVC 1 (coefficient 0.3)

Individual assessment: EVI 1 (coefficient 0.7)

LANGUAGE OF INSTRUCTION	ECTS CREDITS	LECTURES	TUTORIALS	LAB	PROJECT	EXAM
French	3	10 hrs	4 hrs	16 hrs	0 hrs	2 hrs

Multiphysics modelling [MPHY]

LEAD PROFESSOR(S): Sébastien COMAS-CARDONA

Requirements

Objectives

At the end of the 32-hour course the students will be able to:
- Read and explain scientific articles or bibliography related to multi-physics modeling of processes or engineering challenges
- Identify the formulation of proper modelling including domain, physics of interest, boundary and initial conditions, constitutive equations and assumptions
- Generate appropriate modelling for a given process and question to answer

Course contents

1. Basics/Toolbox (6h)
- Operators, Objectivity, Indicial calculus
2. Equations of conservation, behavior's law, consitutive or evolution equations (6h)
- Elasticity, Heat transfer, Fluid dynamics, Electro-Magnetism, Plasticity
- Existence/Unicity : Boundary and initial conditions
3. Coupling (4h)
- Evolution equations, Material parameters, Case studies
4. Résolution (2h)
- Scaling
- Exact and approximated solutions
5. Scientific modeling article analysis(6h, Evaluation 1)
6. Engineering study case (8h, Evaluation 2)

Course material

Assessment

Collective assessment: EVC 1 (coefficient 0.7)

Individual assessment: EVI 1 (coefficient 0.3)

LANGUAGE OF INSTRUCTION	ECTS CREDITS	LECTURES	TUTORIALS	LAB	PROJECT	EXAM
French	3	16 hrs	14 hrs	0 hrs	0 hrs	2 hrs

Conferences and company visits [CONFVE]

LEAD PROFESSOR(S): Bertrand HUNEAU

Requirements

None

Objectives

A series of 10 conferences illustrates the role of a Materials and Processes Engineer through testimony from engineers, mainly former students of the specialisation.

In addition, three visits of local companies are organized.

Course contents

Course material

Assessment

Individual assessment: EVI 1 (coefficient 1.0)

LANGUAGE OF INSTRUCTION	ECTS CREDITS	LECTURES	TUTORIALS	LAB	PROJECT	EXAM
French	3	20 hrs	12 hrs	0 hrs	0 hrs	0 hrs

Mechanics of elastomers [MELAST]

LEAD PROFESSOR(S): Erwan VERRON

Requirements

Continuum Mechanics (MMCe, 1st year), Materials (MATER, 1st year)

Objectives

This course presents the nonlinear elastic constitutive equations classically used for elastomers. More precisely, it focuses on their theoretical derivation and on the fit of the parameters thanks to experimental data.

Course contents

This course adopts a project-based approach. It is divided in three parts:
- part 1 (2h). Conference on hyperelastic models and their applications
- part 2 (8h). Four exercises, covering the four chapters of the course, are solved by the students; video of the solutions can be used for self-study.
- part 3 (20h). Using a scientific article, students discover a given model. They must understand its formulation, then determine its parameters using experimental data from literature. This part is conducted by groups of 3 to 5 students.

Course material

Verron E., Modèles hyperélastiques pour le comportement mécanique des élastomères, Techniques de l'ingénieur, AM8210v1, 2018.
Holzapfel G. A., Nonlinear Solid Mechanics. A Continuum Approach for Engineering, John Wiley & Sons, Chichester, 2000.

Assessment

Collective assessment: EVC 1 (coefficient 0.7)

Individual assessment: EVI 1 (coefficient 0.3)

LANGUAGE OF INSTRUCTION	ECTS CREDITS	LECTURES	TUTORIALS	LAB	PROJECT	EXAM
French	3	10 hrs	0 hrs	20 hrs	0 hrs	2 hrs

Metallurgy [METAL]

LEAD PROFESSOR(S): Bertrand HUNEAU

Requirements

- Physics and Chemistry, bachelor level, the CC-MATER (EI1) course is not a compulsory prerequisite, although it is recommended

Objectives

Industrial products very often contain metallic materials. In this context, it is necessary for an engineer to know the different metals and alloys. Their methods of production from ores will first be studied. Knowing that the whole of the operations of extraction and transformation of the ore into metal represents today approximately 10% of the world emissions of CO2 (source UNEP 2020), one will wonder about the possible reductions of this Carbon footprint. Secondly, the structure of metals and the behaviour of mixtures (alloys) will be considered. Then, the influence of heat treatments during the transformation of these materials into products will be examined. Finally, the mechanical behaviour of metals and alloys and methods to improve their mechanical properties will be described.

Course contents

Part I: Extractive Metallurgy
1. Metal production
2. From ore to metal
3. Steel and aluminium production: towards less polluting processes?

Part II: Physical Metallurgy
1. Cohesion, structure and properties of metals
2. Point, linear, surface and volume defects in metals
3. Thermodynamic equilibria and phase diagrams (Pb-Sn and Fe-C diagrams)
4. Diffusion

Part III: Structural Transformations (= Physical Metallurgy 2)
1. Germination and growth of a new phase / solidification / precipitation
2. Martensitic and bainitic transformations; heat treatment of steels
3. Heat treatments of aluminium alloys

Part IV: Mechanical Metallurgy
1. Plastic deformation of metals
2. Physical mechanisms of plasticity
3. Hardening of metallic materials

Course material

- "Engineering Materials 2", M.F. Ashby and D.R.H. Jones, Elsevier, 2012 (4th edition)
- "Materials Science and Engineering: An Introduction", W.D. Callister, D.G. Rethwisch, Wiley, 2018 (10th edition).

Assessment

Individual assessment: EVI 1 (coefficient 1.0)

LANGUAGE OF INSTRUCTION	ECTS CREDITS	LECTURES	TUTORIALS	LAB	PROJECT	EXAM
French	3	18 hrs	8 hrs	4 hrs	0 hrs	2 hrs

Project 1 [P1MATEPRO]

LEAD PROFESSOR(S): Erwan VERRON

Requirements

All courses from the specialty MATEPRO

Objectives

This course aims to apply the academic lectures of the specialisation to practical cases. Moreover, students are initiated to the management of scientific projects, and also to written and oral presentation of scientific and technical subjects.

Each group of students is supervised by a professor. All subjects are directly related to the scientific activities of the research group.

Course contents

Course material

Assessment

Collective assessment: EVC 1 (coefficient 1.0)

LANGUAGE OF INSTRUCTION	ECTS CREDITS	LECTURES	TUTORIALS	LAB	PROJECT	EXAM
French	1	0 hrs	0 hrs	0 hrs	32 hrs	0 hrs

Polymers and composites [POCOM]

LEAD PROFESSOR(S): Sébastien COMAS-CARDONA

Requirements

Objectives

At the end of the course (32h) the students will be able to:
- Describe the constituents' synthesis & main properties (fibers, reinforcements, matrices)
- Model and simulate behaviors of thermosetting and thermoplastic polymers
- Homogenize thermal and mechanical properties of composites
- Calculate the stiffness matrix of laminates and the stresses and strains in each ply
- List and use laminates' failure criteria
- Use programming software to solve simplified engineering problems involving polymer composites

Course contents

Composites, Fibers and Reinforcements (2h)
Thermoplastic Polymers (3h)
Thermosetting Resins (3h)
Structural Mechanics (3D towards 2D in-plane stress) (2h)
Isotropic multilayered structure (2h)
Anisotropic multilayered structure (Ply behavior, Laminates Theory) (4h)
Homogenization (6h)
Failure criteria (2h)
Final project+Examination (8h)

Course material

1. Traité des matériaux (Editions Ecole Polytechnique Fédérle de Lausane)
2. P. Boisse, Composite Reinforcements for optimum performance , 2011
3. Friedrich Klaus, Fakirov Stoyko, & Zhang Zhong. (2005). Polymer Composites: From Nano- to Macro-Scale. Boston, MA: Springer Science+Business Media, Inc
4. Pascault J.-P. et al. Thermosetting Polymers. New York Basel: M. Dekker, 2002.
5. Bourban Pierre-Etienne, Carlsson Leif A, et Mercier Jean-Pierre, Matériaux Composites à Matrice Organique: Constituants, Procédés, Propriétes. Lausanne: Presses polytechniques et universitaires romandes, 2004
6. Gay Daniel, Matériaux Composites. 6e édition revue et augmentée. Paris: Lavoisier, 2015
7. Mechanics of fibrous composites, C.T. Herakovich, Wiley1998
8. A first course in finite elements, Jacob fish, Ted Belyscho, Wiley 2007
9. Mechanics of solid materials, J. Lemaitre and Chaboche, Cambridge 2000

Assessment

Collective assessment: EVC 1 (coefficient 0.7)

Individual assessment: EVI 1 (coefficient 0.3)

LANGUAGE OF INSTRUCTION	ECTS CREDITS	LECTURES	TUTORIALS	LAB	PROJECT	EXAM
French	3	16 hrs	8 hrs	6 hrs	0 hrs	2 hrs

Fatigue and fracture of materials [FARUP]

LEAD PROFESSOR(S): Erwan VERRON

Requirements

Continuum Mechanics (MMCe, 1st year), Materials (MATER, 1st year)

Objectives

This course aims to introduce the fundamental concepts to handle fracture and fatigue problems. It is divided into two parts:
- Fracture Mechanics to define the physical quantities and the theoretical developments necessary to investigate fracture at the macroscopic scale,
- Fatigue of Materials, which presents this kind of damage and the relationships between microstructure and fatigue resistance.

Course contents

Part 1: Linear Fracture Mechanics
1. Flaws. Stress concentration
2. Local approach: stress intensity factor and toughness
3. Energetic approach: energy release rate and fracture energy

Part 2: Fatigue of Materials
1. Introduction to the fatigue phenomenon. Definitions.
2. Study of fatigue: fatigue life and fatigue crack propagation
3. Physical mechanisms of fatigue
4. Factors that affect the fatigue of materials
5. Case studies

Course material

- E .E. Gdoutos, Fracture Mechanics. An introduction, Kluwer Academic Publishers, 1993.
- A.T. Zehnder, Fracture Mechanics, in Lecture Notes in Applied and Computational Mechanics vol. 62, Springer, 2012.
- J.-L. Engerand, Mécanique de la Rupture, Techniques de l'Ingénieur, pp. B 5 060-1 - B 5 060-12, 1990.
- C. Bathias, J.-P. Baïlon, Fatigue des matériaux et des structures, Hermes, 1997.
- G. Hénaff, F. Morel, Fatigue des structures, Technosup, 2005.
- S. Suresh: Fatigue of Materials, Second Edition, Cambridge University Press, 1998.
- J. Schijve: Fatigue of Structures and Materials, Second Edition, Springer, 2009.

Assessment

Individual assessment: EVI 1 (coefficient 1)

LANGUAGE OF INSTRUCTION	ECTS CREDITS	LECTURES	TUTORIALS	LAB	PROJECT	EXAM
French	3	20 hrs	6 hrs	4 hrs	0 hrs	2 hrs

Materials and Society [MATSOC]

LEAD PROFESSOR(S): Thomas CORRE

Requirements

Energy, Environment and Climate Challenges

Objectives

The aim of the course is to make students aware of the socio-environmental issues related to their training, i.e. the impacts of materials and their use.

Course contents

This course, in which 8 hours are devoted to conferences (given by external experts), allows five groups of students to construct, in a scientific approach, a lecture of around thirty minutes and/or a technical report, intended for Centrale Nantes users, dealing with an issue related to the materials and the societal stakes involved.
Examples of topics covered in 2020 and 2021:
- life cycle assessment of tires;
- comparative environmental impact study
and energy from different cups;
- energy return rate of offshore wind turbines
(offshore and onshore);
- energy balance of a building;
- selective sorting and recycling: from sorting systems to the production of recycled materials.

Course material

Assessment

Collective assessment: EVC 1 (coefficient 1)

LANGUAGE OF INSTRUCTION	ECTS CREDITS	LECTURES	TUTORIALS	LAB	PROJECT	EXAM
French	3	10 hrs	0 hrs	22 hrs	0 hrs	0 hrs

Composites processing [MICOM]

LEAD PROFESSOR(S): Christophe BINETRUY

Requirements

Continuum mechanics
Polymer composites

Objectives

This course has two principal objectives. The first is to present the manufacturing processes of organic composites from a technological and the dominant physical mechanisms perspective. Secondly, process modeling approaches are presented. These include resin flow within rigid and deformable fiber networks, the forming of fiber reinforcements and prepregs, and the flow of fiber suspensions. The course then illustrates these approaches with numerical modeling using academic test cases. Finally, students are given the opportunity to apply their knowledge in practical exercises.

Course contents

1/ Review of Composites Processes

2/ Modeling of LCM processes
Description of fibrous reinforcements
Governing equations for flows in porous media
Macroscopic scale : upscaling
Flow of simple fluids in non-deformable fibrous microstructures
Permeability
Flow in deformable fibrous microstructures
Numerical simulation

3/ Forming
Fishnet algorithm
Methods based on differential geometry
Continuum mechanics based approach

4/ Squeeze flow
Squeeze flow mechanics
Squeeze flow in unidirectional prepregs
Squeeze flow in cross-ply stacks of UD prepregs and woven prepregs
SMC compression

Course material

Assessment

Collective assessment: EVC 1 (coefficient 0.3)

Individual assessment: EVI 1 (coefficient 0.7)

LANGUAGE OF INSTRUCTION	ECTS CREDITS	LECTURES	TUTORIALS	LAB	PROJECT	EXAM
French	3	10 hrs	8 hrs	12 hrs	0 hrs	2 hrs

Metal forming and processing [MIMET]

LEAD PROFESSOR(S): Guillaume RACINEUX

Requirements

Objectives

This course aims to describe the more common processes we can find in industry and the models associated for process modeling. The focus is placed on the mathematical modeling of the processes by order of complexity and the simplified models are given before the generalized standard mechanical behavior. An introduction to non linear finite element modeling for processes is given at the end of the course.

Course contents

- Introduction of metal forming processes
- Bending of sheet metals. Plasticity models
- Forging. Visco-plasticity models
- Stamping. Damage models
- Multi-physics coupling and induced properties
- Numerical simulations

Course material

- Mécanique des matériaux solides, J.Lemaitre & JL. Chaboche
- Mécanique non linéaire des matériaux, S.Forest, JL Chaboche, J Besson G. Cailletaud
- Techniques de l'ingénieur

Assessment

Collective assessment: EVC 1 (coefficient 0.3)

Individual assessment: EVI 1 (coefficient 0.7)

LANGUAGE OF INSTRUCTION	ECTS CREDITS	LECTURES	TUTORIALS	LAB	PROJECT	EXAM
French	3	16 hrs	6 hrs	8 hrs	0 hrs	2 hrs

Project 2 [P2MATEPRO]

LEAD PROFESSOR(S): Erwan VERRON

Requirements

All courses from the specialty MATEPRO

Objectives

This course aims to apply the academic lectures of the specialisation to practical cases. Moreover, students are initiated to the management of scientific projects, and also to written and oral presentation of scientific and technical subjects.

Each group of students is supervised by a professor. All subjects are directly related to the scientific activities of the research group.

Course contents

Course material

Assessment

Collective assessment: EVC 1 (coefficient 0.7)

Individual assessment: EVI 1 (coefficient 0.3)

LANGUAGE OF INSTRUCTION	ECTS CREDITS	LECTURES	TUTORIALS	LAB	PROJECT	EXAM
French	2	0 hrs	0 hrs	0 hrs	48 hrs	0 hrs