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CENTRALE NANTES

# ENGINEERING PROGRAMME

## SPECIALISATION

# MECHANICAL ENGINEERING FOR MATERIALS AND MANUFACTURING PROCESSES

## SPRING SEMESTER

Établissement public sous tutelle du
**ministère de l'Enseignement supérieur, de la Recherche et de l'Innovation**

GROUPE **CENTRALE**

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# FATIGUE AND FRACTURE OF MATERIALS

MECHANICAL ENGINEERING FOR MATERIALS AND MANUFACTURING PROCESSES,
ENGINEERING PROGRAMME SPECIALISATION
SPRING SEMESTER

*Professor: Erwan VERRON*

## 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
6. Fatigue criterion for multiaxial loading

## 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. HÈnaff, 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

## Keywords

Crack, stress intensity factor, thoughness, energy release rate, fracture energy.

Fatigue life, Wˆhler curve, Crack initiation, Crack propagation, Paris law, Microstructure.

## Links with other programmes

First year courses in:

- Continuum Mechanics
- Materials

| LANGUAGE | ECTS CREDITS | LECTURES | TUTORIALS | LABO | PROJECT |
|---|---|---|---|---|---|
| French | 3 | 20 hrs | 10 hrs | 0 hrs | 0 hrs |

# PROJECT 2

## MECHANICAL ENGINEERING FOR MATERIALS AND MANUFACTURING PROCESSES, ENGINEERING PROGRAMME SPECIALISATION
## SPRING SEMESTER

*Professor: Erwan VERRON*

### 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

### Keywords

### Links with other programmes

| LANGUAGE | ECTS CREDITS | LECTURES | TUTORIALS | LABO | PROJECT |
|---|---|---|---|---|---|
| French | 2 | 0 hrs | 0 hrs | 0 hrs | 48 hrs |

# METAL FORMING AND PROCESSING

MECHANICAL ENGINEERING FOR MATERIALS AND MANUFACTURING PROCESSES, ENGINEERING PROGRAMME SPECIALISATION
SPRING SEMESTER

*Professor: Guillaume RACINEUX*

## 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

## Keywords

Process of metal forming and assembly, plasticity, visco-plasticity, damage, multi-physics coupling

## Links with other programmes

Physical and Mechanical Metallurgy, Experimental Methods in Materials Science, Finite Element Method, Non-linear Continuum Mechanics

| LANGUAGE | ECTS CREDITS | LECTURES | TUTORIALS | LABO | PROJECT |
|---|---|---|---|---|---|
| French | 3 | 16 hrs | 6 hrs | 8 hrs | 0 hrs |

# POLYMER PROCESSING

## MECHANICAL ENGINEERING FOR MATERIALS AND MANUFACTURING PROCESSES, ENGINEERING PROGRAMME SPECIALISATION

## SPRING SEMESTER

*Professor: Adrien LEYGUE*

### Objectives

The Polymer Processing course focuses on the modeling of the forming processes of molten polymers.

- Knowledge of polymer families and forming processes
- Modeling of processes
- Choice of a numerical tool/strategy
- Measure, identify and master material properties
- Knowledge of solution methods and tools.

### Course contents

- Introduction to Polymer Processing, Continuum Mechanics basis
- Phenomenology if viscous flows
- Phenomenology if viscoelastic flows
- Polymer Processing
- Simplified solution methods
- Modeling & simulation
- Case study

Lab Practice: Experimental Rheometry
Lab Practice: Numerical modeling

### Course material

Bird, R. B., Stewart, W. E. & Lightfoot, E. N. Transport Phenomena. (John Wiley & Sons, 2007).
Larson, R. G. The structure and rheology of complex fluids. (Oxford University Press, USA, 1999).
Rubinstein, M. & Colby, R. H. Polymer physics. (Oxford University Press, USA, 2003).

### Keywords

Polymer Processing; Extrusion; Viscoelasticity; Rheometry; Rheology; Modeling & Simulation

### Links with other programmes

First Year courses in: Continuum Mechanics, Materials
Other courses of the specialisation: Materials Selection in Mechanical Design, Finite Element Method, Non-linear Continuum Mechanics

| LANGUAGE | ECTS CREDITS | LECTURES | TUTORIALS | LABO | PROJECT |
|---|---|---|---|---|---|
| French | 3 | 8 hrs | 10 hrs | 12 hrs | 0 hrs |

# Composite Processing

Mechanical Engineering for Materials and Manufacturing Processes, Engineering programme specialisation
Spring Semester

*Professor: Christophe BINETRUY*

## Objectives

- Overview of the principal composites processing technologies including the technological and economical aspects, the main physico-chemical mechanisms, constituents, and types of products.
- Processing modeling: fibrous materials descriptors, governing equations in porous and heterogeneous media, multi-physics coupling, constitutive material law, process parameters identification.
- Simplified 1D models
- Numerical simulation for 2D geometries

## Course contents

A. Processing - technological aspects
Notion 1- Constituents: fibrous reinforcements, polymers and prepregs
Notion 2 - Process description: constituents, principle, advantages/drawbacks
Notion 3 - Process classification based on various criteria: main mechanisms, constituents, final products, productivity etc.

B. Processing - physical mechanisms and modeling

Notion 4 - Fibrous reinforcements descriptors, REV, volume average homogenization
Notion 5 - Governing equation (mass, momentum and energy conservation) and adaptation to heterogeneous materials in order to take into account the presence of fibers and in multi-scale material. Notion of permeability.
Notion 6 - Principal multi-physics coupling: flow-deformation, thermo-mechanical
Notion 7 - Constitutive laws: thermo-hydro-chemo-mechanical behavior laws of polymers and fibrous materials. Experimental identification of key parameters such as permeability.

Tutorial: Analytical 1D problem solving representative of processes in order to manipulate the models developed in lectures: non-dimensionalizing, 1D and 2D RTM injection, compression induced flow, prepreg consolidation, heat transfer etc.

Laboratory session on numerical simulation: RTM process and preforming
Laboratory session on processing: Observe and experiment the mecanisms introduced during lectures and numerical sessions.

## Course material

Process Modeling in Composites Manufacturing, Second Edition, 2010 by CRC Press, 630 Pages, Suresh G. Advani, E. Murat Sozer
Pam-RTM (ESI-Group)

## Keywords

Composites processes, governing equations, heat transfer, conservation of mass and energy, fibrous media, modeling and numerical simulation

## Links with other programmes

First Year courses in Materials, Modelling approaches in mechanical engineering
Other courses of the specialisation: Polymers and Composites, Polymer processing, Non-linear Continuum Mechanics

| LANGUAGE | ECTS CREDITS | LECTURES | TUTORIALS | LABO | PROJECT |
|---|---|---|---|---|---|
| **French** | **3** | **10 hrs** | **8 hrs** | **12 hrs** | **0 hrs** |