2EL1830 – Non-linear behavior of materials

Instructors: Véronique Aubin
Department: DÉPARTEMENT MÉCANIQUE ENERGÉTIQUE PROCÉDÉS
Language of instruction: ANGLAIS
Campus: CAMPUS DE PARIS - SACLAY
Workload (HEE): 60
On-site hours (HPE): 35,00
Elective Category : Engineering Sciences
Advanced level : Yes

Description

The design of material structures and their optimization (in terms of service life, performance, cost) requires the ability to predict the response of the materials considered for this application under the stresses imposed during their service life (load, temperature, stress, humidity, etc.).

The objective of this course is to highlight the mechanical behaviour and durability of the main classes of materials under various loading conditions, to understand the physical basis of the micro-mechanisms involved, and to use relevant modelling for design, as part of numerical methods. The concepts are introduced as part of the mechanics of continuous media, and use concepts related to the Materials course.

Applications in transport, energy, electronic systems and civil engineering.

Quarter number

SG6

Prerequisites (in terms of CS courses)

1EL5000 Continuum mechanics
1CC3000 Model representations and analysis

Syllabus

1. Introduction, approach of modelling: Case study on a thermal-elasticity problem (recalls)
2. Anisotropic elasticity of composite materials: Introduction to composite materials (nature, interest using Ashby maps, manufacturing process). Anisotropic linear elasticity. Calculation of the properties of the equivalent homogeneous medium.
3. Homogenization of heterogenous materials: Homogenization scheme.

Voigt and Reuss bounds.
4. Polymer and elastomer viscoelasticity: Introduction to polymers (nature, behavior with respect to temperature). Viscoelasticity. Time dependent behavior.
5. Mechanisms of plasticity in metallic alloys: Structure and defects of crystalline materials. Dislocations and Schmid factor. Hardening of alloys.
6. Elastoplasticity: Description of elastic domain changes. Strain decomposition. Incremental 3D elastoplasticity.
7. Case study: choice of a model. (On 2 given cases, analyze the problem, propose/create a model able to account for the physical mechanisms observed.)
8. Identification of constitutive laws: introduction to optimization (objective function, sensitivity, minimization)
9. Safety of structures - damage and fracture: introduction to concrete (nature and specificities in behavior and damage). Volume damage. Crack sustainability.
10. Case study (use of the various concepts of the course on a given application)
11. Case study(use of the various concepts of the course on a given application)
12. Final examination

Class components (lecture, labs, etc.)

- Sessions 1 to 6: lecture + directed study session
- Session 7: working session
- Sessions 8 and 9: lecture + directed study session
- Sessions 10 and 11: working session
- Session 12: final exam 2H

Grading

The final examination consists in one exam (70% of the grade) and a report on a case study (30% of the grade).
The final case study allows to evaluate learning outcomes #1, 4 and 5, whereas the exam gives the opportunity to evaluate learning outcomes #1, 2, 3 and 4. Every learning outcome is evaluated separately. A feed-back is given to the students on the skills they have developed.
As examination and case study report assess different skills, both will be required for remedial where applicable.

Course support, bibliography

No handout, but a list of books.

Chaboche and Lemaître, Mechanics of Materials, Dunod
Roesler, Harders, Baeker, Mechanical Behaviour of Engineering Materials, Springer, 2007

Besson, Cailletaud, Chaboche, Forest, Non linear Mechanics of Materials, Hermès, 2001

Resources

• Teaching staff (instructor(s) names): Véronique Aubin, Camille Gandiolle, Jan Neggers
• Maximum enrollment (default 35 students): 70
• Software : Matlab

Learning outcomes covered on the course

At the end of this course, students will be able to:

- analyse a material structure, list the loadings applied to it, explain the criteria to which it must respond (performance, economic, etc.).
- interpret the experimental mechanical behaviour of a given material from the physical mechanisms involved, discriminate between several possible interpretations.
- select, use and enrich a constitutive law suitable for the observed experimental behavior
- identify the parameters of this model from the experimental information. Have a critical analysis of the simulation results obtained.
- Persuade at the level of core values; to be clear about objectives and expected results. To apply rigour when it comes to assumptions and structured undertakings, and in doing so structure and problematise the ideas themselves. To make the added value known.

Description of the skills acquired at the end of the course

The first learning outcome allows to reach milestone 1 of skill C1.1. (Examine problems in their entirety and beyond their immediate parameters. Identify, formulate and analyse the scientific, economic and human dimensions of a problem)
Learning outcomes #2 and 3 allow to reach milestones 2 or 3 of skill C1.2. (Develop and use appropriate models, choosing the correct modelling scale and simplifying assumptions when addressing a problem)
Learning outcome #4 allows to reach milestone 2B of skill C1.3 (Solve problems using approximation, simulation and experimentation)
Learning outcome #5 allows to reach milestone 1 of skill C7.1 (Persuade at core value level; to be clear about objectives and expected results. To apply rigour when it comes to assumptions and structured undertakings, and in doing so structure and problematise the ideas themselves. Highlight the added value)
In conclusion, the course allows for progress in the C1 and C7 skills