**The Catholic University of Leuven**

*Module handbook for Semester 2*

| 6 MANDATORY MODULES | | |
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| 1 | Material Selection | 5 ECTS |
| 2 | Mechanics of Materials | 5 ECTS |
| 3 | Mechanics of Composite Materials | 5 ECTS |
| 4 | Durability of Materials | 5 ECTS |
| 5 | Calculation of Planar Structures | 5 ECTS |
| 6 | Rheology | 5 ECTS |

<table>
<tr><td>Module #1</td><td colspan="4">MATERIAL SELECTION</td></tr>
<tr><td>Information</td><td><u>Credit Points :</u><br>5 ECTS</td><td><u>Workload :</u><br>52,5h</td><td><u>Mode :</u><br>Compulsory</td><td><u>Offered :</u><br>2nd semester</td></tr>
<tr><td>Institution in charge</td><td colspan="4">Université Catholique de Louvain</td></tr>
<tr><td>Instructors</td><td colspan="4">Bailly Christian ; Pardoen Thomas</td></tr>
<tr><td>Contents</td><td colspan="4">- The design process<br>- Material properties charts<br>- The basics of materials selection<br>- Over constrained and multiple objectives problems<br>- Influence of shape on material selection<br>- Design of hybrid materials<br>- Process selection</td></tr>
<tr><td>Examination</td><td colspan="4">The students will be individually graded based on the objectives indicated above.<br>More precisely, the evaluation involves the grading of:<br>• the presentation of two case studies already solved in the supporting book by group of two;<br>• the presentation of a new material selection problem by group of two;<br>• a written exam based on a short list of synthetic questions prepared by the teachers and given during the module.</td></tr>
<tr><td>Requirement for examination</td><td colspan="4">No specific requirement</td></tr>
<tr><td>Learning outcomes</td><td colspan="4">Apply the material selection procedure to real problems (case studies) which involve the analysis of the problem (i.e. define the list of requirement by decomposition into the elementary functions in order to define the working conditions and function, main solicitations, objectives and constraints), the derivation of performance indices, the selection of the best solution, the justification of the simplification, the critical assessment of the solution and the formulation of better solution compared to existing solution ' all these steps will require mobilizing all their scientific and technical knowledge gained in earlier training regarding physical phenomena and all the classes of materials.</td></tr>
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| **Module #2** | **MECHANICS OF MATERIALS** | | | |
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| Information | Credit Points :<br>5 ECTS | Workload :<br>60h | Mode :<br>Compulsory | Offered :<br>2nd semester |
| Institution in charge | Université Catholique de Louvain | | | |
| Instructors | Simar Aude ; Delannay Laurent ; | | | |
| Contents | The course will cover the following topics :<br>• Materials selection procedure to achieve desired mechanical properties (material classes, performance indices)<br>• Complements of linear thermo(visco)elasticity : phase partitioning of strain and stress in composite materials (incl. eigenstrains and anisotropy)<br>• Contact stresses<br>• Plasticity and viscoplasticity (yield surface, J2 theory, elastic springback<br>• Linear elastic fracture mechanics + influence of microstructure on toughness<br>• Fatigue | | | |
| Examination | The final exam will asssess both the level of understanding of theoretical concepts and the student's skills to solve practical exercices. Students will be graded while accounting also for the outcome of their project. | | | |
| Requirement for examination | No specific requirement | | | |
| Learning outcomes | At the end of the course, students will be able to:<br>• solve basic problems using models allowing to predict mechanical responses of materials involving (hyper)elasticity and (visco)plasticity under finite strains as well as crack propagations;<br>• explain the physics underlying each model and the link between microstructure and macroscopic mechanical properties;<br>• explain the origin of various phenomena including anisotropy of composite materials, elastic spring back and necking of plastically deformed samples, residual stresses and creep;<br>• select a material with the best combination of mechanical properties based on the definition of performance indices. | | | |

| **Module #3** | **MECHANICS OF COMPOSITE MATERIALS** | | | |
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| Information | Credit Points :<br>5 ECTS | Workload :<br>60h | Mode :<br>Compulsory | Offered :<br>2nd semester |
| Institution in charge | Université Catholique de Louvain | | | |
| Instructors | Doghri Issam | | | |
| Contents | Chap. 1 - Composite materials: types, properties, applications, fibers, matrices, forming processes.<br>Chap. 2 - Anisotropic elasticity.<br>Chap. 3 - Micro-mechanics approaches (homogenization theories).<br>Chap. 4 - Behavior of a single layer (micro- and macro-mechanics).<br>Chap. 5 - Classical laminate theory.<br>Chap. 6 - Damage and failure (I) Classical approach: strength criteria for single plies; first ply approach for laminates.<br>Chap. 7 - Damage and failure (II) More advanced topics: inter-laminar stresses; edge effects; delamination, continuum damage mechanics, micromechanics of damage. | | | |
| Examination | Project (computational, using commercial software and students' own developed module) and written examination.<br>Final grade: 50% project and 50% exam. | | | |
| Requirement for examination | No specific requirement | | | |
| Learning outcomes | Learn the basic concepts and the main models of mechanics of composite materials.<br>Get a good introduction to more advanced topics (e.g., homogenization; multiscale modeling; damage and failure).<br>Use up-to-date software to aid in the design and computation of composite materials, structures and products. | | | |

| **Module #4** | **DURABILITY OF MATERIALS** | | | |
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| Information | Credit Points :<br>5 ECTS | Workload :<br>53h | Mode :<br>Compulsory | Offered :<br>2nd semester |
| Institution in charge | Université Catholique de Louvain | | | |
| Instructors | Laurent DELANNAY, Thomas PARDOEN | | | |
| Contents | All important technological fields are impacted by materials ageing and durability issues. The lifetime assessment of structures and installations is key for a variety of industries involving the aeronautics, nuclear, naval, biomedical, train, microelectronics, automotive, windmills and spatial sectors, and many others. The ageing and durability problems affects both the nominal operation as well as the operation under extreme conditions (such as under earthquakes, flooding, fire, explosion etc). The implications are numerous. It is first a question of human safety to be able to predict when a material will fail to meet the expected performances. Then, it is also an environmental issue – it is essential today to extend the lifetime of all technologies through the use of new advanced materials or coatings. It is also a question of economical cost related to the replacement or repair of the installations. Finally, there is the connection with the ethical problem of programmed obsolescence or of the voluntarily non optimal design of products. The subject is both exciting and complex as it requires taking into account numerous interconnected phenomena, hence convening a number of fundamental engineering disciplines. The objective of the course is to deliver the scientific and technical keys in order to address questions as different as:<br><br>• What are the mechanisms limiting the lifetime of windmills ?<br>• What are the processes leading to the degradation of the performances of Li based batteries?<br>• How to select the best material for the divertor of the futur thermonuclear fusion reactors which must resist intense neutron irradiation fluxes, extreme temperatures and erosion ?<br>• What phenomena governs the ageing of growth rods implanted in the back of children to correct for severe scoliosis?<br>• What are the risks of pollution associated to the storage of high activity nuclear wastes?<br>• What are the factors limiting the lifetime of electronic circuits? Is it possible to do better?<br>• How to design carbon fiber reinforced polymers used for aeronautic applications with respect to ageing due to oils, solvents and water?<br>• What are the phenomena limiting the lifetime of turboengines in the hottest region of the reactors?<br><br>The main topics addressed in the module will involve: | | | |

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| | 1. The overall positioning of the durability issues in the context of sustainable development and safety of people, structures and installations.<br>2. The description of the physical and chemical phenomena affecting the ageing and durability of materials. This includes mechanical loadings (fatigue, plasticity—damage, wear, erosion, internal stress, creep), chemical and physico-chemical phenomena (corrosion-oxydation, chemical reactions, diffusing of embrittlement agents, solvants and others, phase transformations), physical perturbations (radiations of different kinds), and thermal changes while insisting on the couplings between these phenomena. The couplings are of two types: either the kinetics of the damaging/ageing phenomena is modified and/or the properties dictating the resistance to failure are modified.<br>3. The development of tools to predict the failure and lifetime of materials and structures. |
| Examination | The students will be graded both individually and collectively based on the objectives. More precisely, the evaluation involves the grading of:<br>• One group project based on the use of a commercial finite element code. The oral presentation will be supplemented by a written report following provided guidelines. The grading will account also for daily work during the semester. (group evaluation ~30%)<br>• A few homeworks (group and individual evaluations ~30%)<br>• During the exam, students will have to provide answers to a few questions covering the course content, which will be selected in a list provided by the teachers during the year. (individual evaluation ~30%)<br>• The exam will also comprise the mathematical solution of an exercise. Lecture notes will be accessible during this part of the exam (individual evaluation ~25%) |
| Requirement for examination | No specific requirement |
| Learning outcomes | At the end of this course, the student will be able to:<br>• identify and describe the physical, mechanical and chemical phenomena controlling the durability of materials with a clear vision of the spatial and time scales, the intensity of the phenomena, the couplings and measurement methods; the description is formalised in terms of simple mathematical models;<br>• estimate the magnitude of internal stress from different origins;<br>• solve simple problems involving 3D (visco-)plasticity, fracture/fatigue mechanics and tribology;<br>• solve analytically simple coupled problems;<br>• starting from a realistic technological problem, formulate the assumptions and model choices allowing the solution within a reasonable time through a finite element approach;<br>• use a finite element software in order to conduct simulation and analysis about the effect of some parameters in order to evaluate their impact on the lifetime of applications; |

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| | • compare critically the numerical predictions with the results of analytical models and establish the links with technological issues;<br>• communicate in oral and written way the results of the simulations performed with the finite element codes and demonstrating the utility of the mathematical models for the control and the prediction of the durability of materials;<br>• elaborate a global viewpoint regarding the technological issues with respect to sustainable development, to programmed obsolescence, but also with respect to the debate about the acceptable risks and principle of precaution. |

| **Module #5** | **CALCULATION OF PLANAR STRUCTURES** | | | |
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| Information | Credit Points :<br>5 ECTS | Workload :<br>60h | Mode :<br>Compulsory | Offered :<br>2nd semester |
| Institution in charge | Université Catholique de Louvain | | | |
| Instructors | Doghri Issam | | | |
| Contents | Chapitre 1 : Plane strain and plane stress in Cartesian coordinates.<br>Chapitre 2 : Plane strain and plane stress in cylindrical coordinates.<br>Chapitre 3 : Kirchhoff-Love plate theory in Cartesian coordinates.<br>Chapitre 4 : Kirchhoff-Love plate theory in cylindrical coordinates.<br>Chapitre 5 : Reissner-Mindlin plate theory.<br>Chapitre 6 : Finite element formulations of plate theories. | | | |
| Examination | Project (computational, using commercial software and students' own developed module) and written examination.<br>Final grade: 50% project and 50% exam. | | | |
| Requirement for examination | No specific requirement | | | |
| Learning outcomes | After successful completion of the course, students will be able to:<br>• know the main assumptions and some applications of important problems in elasticity (plane problems and plate theories;<br>• solve analytically relatively simple and nevertheless interesting problems (e.g., tube under inner and outer pressures, stress concentration in a plate with a small circular hole, force on the straight edge of a semi-infinite plate, bending of a circular plate under axisymmetric loading, etc.);<br>• solve more complicated, real-life problems with a finite element numerical software, and understand all steps (geometry definition, input of material data and other problem parameters, space and time discretization, solver algorithms, post-processing and visualization of computation results). | | | |

| Module #6 | **RHEOLOGY** | | | |
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| Information | Credit Points :<br>5 ECTS | Workload :<br>60h | Mode :<br>Compulsory | Offered :<br>2nd semester |
| Institution in charge | Université Catholique de Louvain | | | |
| Instructors | Evelyne VAN RUYMBEKE | | | |
| Contents | Main themes:<br>• Physical properties of viscoelastic materials<br>• Polymer flow properties and bonds with their composition<br>• Rheometry and polymers processing<br><br>Chapters:<br>I. Introduction : industrial polymer processing, non Newtonian fluids, continuum mechanics refresher<br>II. Shear viscosity, normal forces and elongational viscosity: observations and phenomenological models<br>III. Flow through a channel<br>IV. Capillary rheometry and extrusion defects<br>V. Origin of viscoelastic effects; notions of rheological models; introduction to processing flow simulation<br>VI. Cone-plate and plate-plate rheometric flow; Elongational flow<br>VII Major industrial polymer processing operations : rheological aspects, technology and applications | | | |
| Examination | • Oral exam (70% of the total mark)<br>• Presentation of a project in groups of two or three on a topic linked to the course content (20%)<br>• A few practical works and lab (10%) | | | |
| Requirement for examination | No specific requirement | | | |
| Learning outcomes | Contribution of the course to the program objectives: | | | |

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| | • Identify and implement the concepts, laws, reasoning applicable to a problem; develop and use the appropriate modeling and calculation tools to solve a problem.<br>• Search in the literature, summarize and present the current state of knowledge on a specific issue related to the rheology of polymer melts. Measuring and modeling the viscoelastic properties of polymer melts.<br>• Write reports on practical works and present a specific topic related to rheology by group of 2 students.<br>• Communicating in a schematic form, Interpreting and presenting in an accurate way a new concept in rheology, based on a scientific publication. |