UCLouvain

lmapr2483

2025

Durability of materials

The version you're consulting is not final. This course description may change. The final version will be published on 1st June.

5.00 credits	30.0 h + 22.5 h	Q2

Language :	English > French-friendly
Place of the course	Louvain-la-Neuve
Prerequisites	The students must be familiar with the basic concepts • of materials science: microstructure, defects, solid state diffusion, phase transformation, basics of electrochemistry, basics of deformation and fracture phenomena; • of continuum mechanics (stress and strain tensors) and mechanics of deformable solids (linear thermoelasticity mainly) that have been covered in the programs of bachelor in engineering sciences.
Main themes	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: • What are the mechanisms limiting the lifetime of windmills ? • What are the processes leading to the degradation of the performances of Li based batteries? • 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 ? • What phenomena governs the ageing of growth rods implanted in the back of children to correct for severe scoliosis? • What are the risks of pollution associated to the storage of high activity nuclear wastes? • What are the factors limiting the lifetime of electronic circuits? Is it possible to do better? • How to design carbon fiber reinforced polymers used for aeronautic applications with respect to ageing due to oils, solvents and water? • What are the phenomena limiting the lifetime of turboengines in the hottest region of the reactors? The main topics addressed in the module will involve 1. The overall positioning of the durability issues in the context of sustainable development and safety of people, structures and installations. 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. 3. The development of tools to predict the failure and lifetime of materials and structures.
Learning outcomes	**At the end of this learning unit, the student is able to :** **Contribution of the course to the program objectives** Having regard to the LO of the programme KIMA, this activity contributes to the development and acquisition of the following LO: LO1 Foundations of scientific and technical knowledge (LO1.1, LO1.2, LO1.3) LO 2 Engineering skills (LO2.1, LO2.2, LO2.5) LO 3 R & D skills (LO3.2) LO 5 Efficient communication (LO5.3, LO5.4, LO5.6) LO 6 Ethics and professionalism (LO6.1, LO6.2, LO6.3) **Specific learning outcomes of the course** At the end of this course, the student will be able to

	• LO1.1 LO6.1 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. • LO1.1 Estimate the magnitude of internal stress from different origins. • LO1.1. Solve simple problems involving 3D (visco-) plasticity, fracture/fatigue mechanics and tribology. • LO1.1 Solve analytically simple coupled problems. • LO2.1 Starting from a realistic technological problem, formulate the assumptions and model choices allowing the solution within a reasonable time through a finite element approach. • LO1.2, 2.1, 2.2, 2.4 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. • AA1.3, 2.2. Compare critically the numerical predictions with the results of analytical models and establish the links with technological issues. • AA5.3, 5.4, 5.6. 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. • AA6.2 6.3 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.
Evaluation methods	The students will be graded both individually and collectively based on the objectives indicated above. More precisely, the evaluation involves the grading of • 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%) • a few homeworks (group and individual evaluations ~30%) • 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%) • 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%) The evaluation will be carried out preferentially in presential mode for the written and oral parts of the exam; TEAMS will be used is needed due to sanitary reasons.
Teaching methods	Face-to-face teaching will be priviledged but some lectures and practical sessions may be organized in distant mode. Co-modal format will be followed if needed due to covid crisis. The course will involve • 13 ex-cathedra lessons, of which some elements will be prepared as "inverted classes" ; • exercises will be supervised by teaching assistants. In some cases, the session may include an experimental demonstration ; • a numerical modeling project will be performed using a commercial finite element code. This will not involve any computer programming, as the focus will be on the formulation modeling hypotheses, selection of constitutive models and decription of the degradation of materials, use of existing computer codes, critical analysis of simulation outcome and comparison to analytical solutions. The project will address a case-study implying several phenomena treated in the course.
Content	**I. Introduction** : context – technological and environmental challenges – global methodology of a life time analysis - novel material solutions **II. Mechanisms and basic models for physico-, electro- chemistry and mechanics, including couplings** : reminders about diffusion, phase transformations, oxydation, electrochemistry, and mechanics related to the course. Formulation of coupled laws (stress assisted diffusion, electromigration, mechanically induced phase transformation, etc) **III. Plasticity-Creep** : basic theories, generation of ageing defects, evolution of the plastic yield strength by solute ageing, etc **IV. Internal stresses** : in the bulk and in coatings, mechanical, chemical, physico-chimichal or other origins, consequences, modeling and solutions to minimize detrimental effects on the life time of components **V. Static fracture and fatigue** : Physical phenomena and micro-mechanical description of fatigue, important technological applications in terms of durability : coatings, thermal fatigue, corrosion cracking, hydrogen embrittlement, and others, and solutions to delay failure **VI. Tribology** : basics of contact mechanics, friction, wear and abrasion phenomena and solutions solutions to extend life time, tribochemistry and other coupled phenomena of wear **VII. Irradiation ageing** : application to neutron irradiation which is crucial for the surity of fission and fusion nuclear power plants as well as the storage of nuclear wastes ; application to polymers under UV ageing **VIII. Other topics of mecano-chemistry :** depending on available time, the course will also cover corrosion cracking and electromigration The course coers both the description and the mathematical modeling of phenomena, available characterization methods and the impact on technology.
Inline resources	https://moodleucl.uclouvain.be/course/view.php?id=14985&lang=en

Bibliography	Lecture notes, prepared by the professors, are written in English. Un syllabus rédigé en anglais par les enseignants.
Other infos	This course requires a solid mechanics background .
Faculty or entity in charge	FYKI

Programmes containing this learning unit (UE)				
Program title	Acronym	Credits	Prerequisite	Learning outcomes
Master [120] in Chemical and Materials Engineering	KIMA2M	5		
Master [120] in Civil Engineering	GCE2M	5		
Master [120] in Biomedical Engineering	GBIO2M	5		
Master [120] in Mechanical Engineering	MECA2M	5		
Master [120] in Physical Engineering	FYAP2M	5		
Master [120] in Electro-mechanical Engineering	ELME2M	5		