INSTITUTO SUPERIOR DE ENGENHARIA DE LISBOA

ISEL ADEM Área Departamental de Engenharia Mecânica

Curricular Unit Form (FUC)

Course:	**FIRST CYCLE IN MECHANICAL ENGINEERING**						
Curricular Unit (UC)	**Composite Materials**					Mandatory	
						Optional	**X**
Scientific Area:	**Mechanical Design, Manufacturing and Industrial Maintenance**						
Year: **3º**	Semester: **2**	ECTS:**4,0**		Total Hours: **3,0**			
Contact Hours:	T:	TP:**30**	PL: **15**	S:	OT:	TT:**45**	
Professor in charge		Academic Degree		Position			
Joaquim Infante Barbosa		**Doctor (PhD)**		**Prof. Coordenador c/Agregação**			

T- Theoretical ; TP – Theory and practice ; PL – Laboratory ; S – Seminar ; OT –Tutorial ; TT – Total of contact hours

Entry into Force	Semester: **Winter**	Academic Year: **2012/2013**

Objectives of the curricular unit and competences

Provide students with basic knowledge about the particular characteristics, that composite materials have, and distinguish them from conventional engineering materials.

Provide a comprehensive knowledge, of the most important aspects, of the manufacture of components and structures in composite materials. Recognize that each manufacturing technique requires different types of material systems, different conditions and different tools; each technique´s advantages and disadvantages in terms of processing, size and shapes of manufactured components, unit cost, etc.

Give competences to the future mechanical engineer, to theoretically characterize any type of stacking sequence; and be able to make its calculation and simulation, in order to design components and structures in composite materials.

The student should be aware of the need to design the composite material, as a function of performance requirements, differences in the project in relation to the isotropic materials, and dimensioning the composite part connections to the global assembly, where it belong.

The student should gain sensitivity to the difficulties encountered in the manufacture and design of composite materials.

Know, understand and produce the technical information necessary for technicians to repair composite components and structures of composite materials in the different application areas.

Syllabus

I – INTRODUCTION TO COMPOSITE MATERIALS AND IT'S APPLICATIONS

Definition of Composite Material; Classification of Composite Materials; fibers and matrices; sandwich-structured composite materials, manufacturing of composite materials; mechanical behavior; applications.

II – MANUFACTURING PROCESSES FOR COMPOSITE MATERIALS

Manufacturing processes selection criteria, manufacturing demands, molds and tools. Hand lay-up process, autoclave and vacuum bag, resin infusion, RTM, SMC, and other processes, for thermoset and thermoplastic matrices.

III – LAMINA BEHAVIOR LAW (Macromechanics)

Elastic materials behavior law (3D). Engineering parameters for isotropic and orthotropic materials. Stress-strain relationship for orthotropic materials (plane stress): main and arbitrary directions of the materials.

IV - LAMINA BEHAVIOR LAW (Macro and micromechanics)

LAMINA STIFFNESS EXPERIMENTAL TESTING (Macromechanics)

Determination of E_{11}, E_{22} , ν_{12} e G_{12}, Off-Axis Tension Test. Testing laminates with $\pm 45^{o}$ plies; Rail Shear Test; Iosipescu testing; tube torsion testing.

LAMINA STRENGTH EXPERIMENTAL TESTING (Macromechanics)

Tensile and compression strength, in the main orthotropic directions; lamina shear strength.

LAMINA BI-AXIAL STRENGTH CRITERIA (Macromechanics)

Max stress, Max strain, Tsai-Hill, Tsai-Wu, Hashin and Puck.

COMPOSITE MATERIALS MICROMECHANICS

Fiber Content and grammage. Stiffness calculation method, based in material mechanics: Determination of E_{11}, E_{22}, ν_{12} e G_{12}, and strength characteristics.

V – LAMINATE MECHANICAL BEHAVIOR (Macromechanics)

Classical Laminated Plate Theory. Particular cases – one layer configuration: isotropic, orthotropic (main axes); orthotropic layer (main axes) and anisotropic layer. Symmetrical configuration with n-layers: n-layer isotropic, special and general orthotropic; anisotropic layers. Antisymmetric n-layer configurations: cross laminates and angled antisymmetric.

Laminate strength, cure temperature effects.

First ply failure analysis. Models of total degradation and progressive damage.

Interlaminar stresses: free edge effect and curved beams.

Demonstration of the syllabus coherence with curricular unit's objectives

The fundamental concepts of the syllabus are introduced in class, giving emphasis to industrial examples, in the case of manufacturing processes and design with composite materials.

The theoretical calculation of laminates is supported by programs of symbolic computation and finite elements, which allow the calculation automation and ease in understanding the various phenomena. Through graphics and 3D models containing these latter stresses and strains arising in the form of color fringes, the student can visualize the result from a given set of loads which were applied to a component or structure.

Predicting the mechanical behavior of the laminate or component, through calculus based on the most relevant failure criteria provides, to the future engineer, means to be able to integrate a design team and project in the field of composite materials.

The sequence of program content leads students to understand the various methods of production, manufacturing and calculation of composite components.

Are shown videos and computational animations that enable better understanding of the essential aspects of the study.

It will always be held, in each semester, a study visit to companies operating in the field of composite materials, such as: OGMA - Indústria Aeronáutica de Portugal, Inapalplásticos, Estaleiros Navais de Peniche, among others.

Teaching methodologies (including evaluation)

The teaching will be done through practical classes and laboratory practices. It is intended that by reading the literature the student is introduced to the fundamental mathematical and physical aspects for each topic to be addressed. The lectures, practical work with brief presentations on each topic, followed by practical examples and exercises, where the student intends to consolidate the concepts studied. In practical lab classes will be made of practical work.

The assessment is carried out in a continuous method.

The final grade (NF) is the result of: NF = TP 1 + TP 2 + TP 3 + E, whose weight percentages are indicated below.

It's mandatory the presence in class and practical examination.

Evaluation elements:

TP 1 – Manufacture of plates by hand lay-up and autoclave with vacuum bag. Calculating the fiber content and calculation of the theoretical weight. Comparison with the real. For the case of autoclave can also produce non-laminated symmetrical and see the effects of distortion upon curing. (15%)

TP 2 – Work on couplings flexion / extension; Extensions / shear and bending / distortion (calculate matrices in Maple software (symbolic calculus) and Ansys (FEM-Finite Element Method) for a given stacking sequence, and comment deformations. (15%)

TP 3 – Main Assignment (45%). Examples of work that may be performed:

TP 3.1 – Prediction of strength and damage of a component by applying failure criteria. Analytical calculations when applicable (slabs, beams etc.). Comparison with FEM and / or experimental testing.

TP 3.2 – FEM Simulation of a complex component: bicycle wheel, footbridge, etc. This work can be done in conjunction with the discipline of Mechanical Design, with prior agreement with the supervisors and teachers of the Mechanical Project curricular unit.

TP 3.3 – Manufacturing of a small structure or component in the laboratory or in a company (with prior agreement). This work should also have some component of the mechanical project, as the TP 3.2.

TP 3.4 – Mechanical tests to standardized components, made of composite materials, with the support of electrical resistance strain gage.

Other defined case by case.

E - Exam (25%).

The minimum in the work and the examination must be of 10 (0 to 20 grade).

Demonstration of the teaching methodologies coherence with the curricular unit's objectives

In teaching methodologies are used different means, which enable the objectives of the course. Depending on the characteristics of concepts to transmit, practical classes and laboratory practice, which are a set that aims to harmoniously, to enable students to understand the fundamental concepts associated with program content. In practical classes and laboratory practices it is explored the potential of new multimedia systems and the use of symbolic computation programs and calculation by Finite Element Method, for the simulation of composite components behavior.

Main Bibliography

- Composite Materials: Design And Applications, Gay, D., Hoa, S. V., Tsai, S. W., CRC Press.
- Mechanics of Composites Materials, Jones, R., Taylor and Francis.
- Laminar Composites, Staab, G., Butterworth-Heineman.
- Materiais Compósitos: Materiais, Fabrico e Comportamento Mecânico, de Moura, M.- Publindústria.
- Papers ISI from Word Wide Failure Exercise.
- Composites Manufacturing: Materials, Product, and Process Engineering, Mazumdar, S. K., CRC Press.
- Care and Repair of Advanced Composites, Armstrong, K., SAE.
- Mechanical Testing of Advanced Fibre Composites, Hodgkinson, J. M., CRC Press.
- ASM Handbook, Volume 21: Composites, ASM International.
- Fundamentals of Composites Manufacturing: Materials, Methods, and Applications, Strong, A. B., SME.
- Lecture notes and visual projection notes (slides) of the curricular unit lecturers