UNIVERSIDAD PONTIFICIA ICAI ICADE COMILLAS MADRID
ESCUELA TÉCNICA SUPERIOR DE INGENIERÍA

COURSE SYLLABUS 2015-2016

GENERAL INFORMATION

Course Information	
Name	Composite Materials
Code	DIM-OPT-620
Degree	Máster en Ingeniería Industrial (MII)
Year	2º
Semester	2º
ECTS credits	6 ECTS
Type	Elective
Department	Mechanical Engineering
Area	Materials
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DETAILED INFORMATION

Contextualization of the course
Contribution to the professional profile of the degree
This subject has been designed to give the students a fundamental understanding of the integrated multidisciplinary nature of Composite Materials. This is an introductory course to deal some of the fundamental principles of composite materials for high performance structures, design, manufacturing and repair, as well as the applications in a range of applications and industries. Composites are used in many industries today to enable high-performance products at economic advantage. These industries range from space to sports and include manufactured products for aircraft, transportation, energy, construction, sports, marine, and medical use. There are many material, economic, and aesthetic advantages to using composites, but a solid knowledge of the physical properties, including the mechanics, tooling, design, inspection and repair, and manufacturing options is required for working in this medium as they are intrinsically linked. This course is designed to address important areas of composites that focus on current and potential applications of composite materials, fibers, matrices, manufacturing methods for composites, review of elasticity of anisotropic solids, methods for determining mechanical properties of heterogeneous materials, micromechanics of continuous and discontinuous fiber systems, laminated plate analysis, static analyses of laminated composites, edge effects in laminates and both macroscopic and microscopic failure analysis of composite materials and laminates. At the end of this course, student should be able to: • Demonstrate understanding of materials. Fibers and matrices. • Describe the characteristics and the manufacturing principles of composite laminates. • Basic understanding of composite micromechanics and classical lamination theory. • Predict the strength of multi-axial laminates. • A knowledge of processing and manufacturing methods of composite materials. Quality inspection and testing. • An ability to design components and composite structures.
Prerequirements
Students are expected to have an understanding of basic materials science and engineering, strength of materials, or an equivalent course or provide evidence of equivalent capabilities. Computer and Technical Requirements. Matlab and Ansys. Microsoft Word and Microsoft PowerPoint are useful for writing reports and presentations.

CONTENTS

Contents
Theory
Chapter 1. Introduction
Introduction to composite materials: classifications, applications, terminology.
Chapter 2. Materials
Characteristics of fibers and matrices. Types and properties of fibers. Types of matrix, prepegs, fillers and other additives. Interface bonding and adhesives.
Chapter 3. Composite micromechanics
Micromechanical analysis of a lamina: prediction of mechanical properties of composites based on properties of fiber and matrix; volume and weight fractions. Longitudinal strength and stiffness. Coefficients of thermal and moisture expansion.
Chapter 4. Analysis of laminated composites
Composite Mechanics Theory. Basic understanding of linear elasticity, isotropic and anisotropic material behavior. Stress-strain relationships. Analysis of fibre composites. Constitutive relationships for orthotropic materials. Laminate theory. Analysis of orthotropic plates and sandwich beams and plates
Chapter 5. Analysis of laminated composites
Failure analysis of laminates: damage mechanisms, progressive failure analysis for a laminate. Failure criteria
Chapter 6. Manufacturing and testing composites
Basic characteristics of manufacturing processes. Hand lay-up, prepreg layup, bag molding, autoclave processing, compression molding, resin transfer molding (RTM), vacuum assisted resin transfer molding (VARTM), pultrusion, and filament winding. Quality control. Standards. Mechanical test. Non destructive testing of composites. Ultrasonic Inspection. Phase array.
Laboratory
Lab. 1 Practice with CAE (ANSYS) system.
Lab. 2 Practice with CAE (ANSYS) system.
Lab. 3 Manufacturing a laminate composite.
Lab. 4 Composite selection and design
Lab. 5 Manufacturing a laminate composite.
Lab. 6 Mechanical testing of laminate composite. Composite bonding and testing

Competences and Learning Outcomes

Competences

General Competences

CG4. Conduct research, development and innovation in products, processes and methods.

CG8. Apply the acquired knowledge to solve problems in new or unfamiliar environments within broader and multidisciplinary contexts.

CG10. Be able to clearly and unambiguously communicate conclusions –and the knowledge and rationale that support them–, to specialist and non-specialist audiences.

CG11. Acquire learning skills that will allow further study in a self-directed or autonomous manner.

Basic Competences

Specific Competences

Learning outcomes

By the end of the course students should be able to:

RA1. Understand the differences between the composites and traditional materials. Know the current and emerging applications of composites in the industry.

RA2. Demonstrate understanding of the different materials (fibres, resins, cores) used in composites.

RA3. Know the different types of matrix and its applications: polymer, metal and ceramic.

RA4. Calculate the elastic and strength properties of unidirectional laminates using micromechanics theory.

RA5. Explain and understanding of linear elasticity, isotropic and anisotropic material behavior.

RA6. Basic understanding of laminate theory. Analysis of orthotropic plates and sandwich beams and plates.

RA7. Select the most appropriate manufacturing process for fabricating composite components.

RA8. Describe the non-destructive inspection (NDE) and structural health monitoring of composites.

RA9. Understand the relation between the design and manufacture of composite parts.

RA10. Develop, implement, and test algorithms in an autonomous manner.

RA11. Provide evidence to assess the validity and performance of the proposed solution.

TEACHING METHODOLOGY

General methodological aspects	
The best way to achieve a fundamental understanding of the basics of mechanics of composite materials, manufacturing processes and applications is a practical approach to this concepts. Both classroom sessions and independent study are developed to imply the students within the learning activities. The contents are developed to keep the student attention and following the competencies acquisition by the students.	
In-class activities	**Competences**
▪ **Lectures and problem-solving sessions (45 hours)**: The lecturer will introduce the fundamental concepts of each chapter, along with some practical recommendations, and will go through worked examples to support the explanation. Active participation will be encouraged by raising open questions to foster discussion and by proposing short application exercises to be solved in class either on paper or using a software package.	CG8, CG11
▪ **Lab sessions (12 hours):** Under the instructor's supervision, students, divided in small groups, will apply the concepts and techniques covered in the lectures to real problems and will become familiar with the most widespread software tools and libraries.	CG4, CG8, CG10, CG11
▪ **Tutoring** for groups or individual students will be organized upon request.	–
Out-of-class activities	**Competences**
▪ Personal study of the course material and resolution of the proposed exercises (60 hours).	CG8, CG11
▪ Lab session preparation to make the most of in-class time (5 hours).	CG8
▪ Lab results analysis and report writing (15 hours).	CG10, CG11
▪ Development of a final project in small groups during the last third of the course (30 hours).	CG4, CG8, CG10, CG11

ASSESSMENT AND GRADING CRITERIA

Assessment activities	Grading criteria	Weight
Mid-term exam	▪ Understanding of the theoretical concepts. ▪ Application of these concepts to problem-solving. ▪ Critical analysis of numerical exercises' results.	20%
Final exam	▪ Understanding of the theoretical concepts. ▪ Application of these concepts to problem-solving. ▪ Critical analysis of numerical exercises' results.	50%
Lab reports	▪ Application of theoretical concepts to real problem-solving. ▪ Ability to use and develop computer vision software. ▪ Written communication skills.	20%
Final project	▪ Problem analysis. ▪ Information search skills. ▪ Quality of the proposed solution. ▪ Teamwork. ▪ Oral presentation and written communication skills. ▪ There will be an intra-group evaluation method to differentiate among team members.	10%

GRADING AND COURSE RULES

Grading

Regular assessment

- **Theory** will account for 70%, of which:
  - Mid-term: 20%
  - Final exam: 50%
- **Lab** will account for the remaining 30%, of which:
  - Lab practices: 20%
  - Final project: 10%

In order to pass the course, the mark of the final exam must be greater or equal to 4 out of 10 points and the mark of the final project must be at least 5 out of 10 points. Otherwise, the final grade will be the lower of the two marks.

Retakes

A new project will have to be developed and handed in. In addition, all students will take a final exam. The resulting grade will be computed as follows:

- Final exam: 70%
- Final project: 30%

As in the regular assessment period, in order to pass the course, the mark of the final exam must be greater or equal to 4 out of 10 points and the mark of the final project must be at least 5 out of 10 points. Otherwise, the final grade will be the lower of the two marks.

Course rules

- Class attendance is mandatory according to Article 93 of the General Regulations (Reglamento General) of Comillas Pontifical University and Article 6 of the Academic Rules (Normas Academicas) of the ICAI School of Engineering. Not complying with this requirement may have the following consequences:
  - Students who fail to attend more than 15% of the lectures may be denied the right to take the final exam during the regular assessment period.
  - Regarding laboratory, absence to more than 15% of the sessions can result in losing the right to take the final exam of the regular assessment period and the retake. Missed sessions must be made up for credit.

Students who commit an irregularity in any graded activity will receive a mark of zero in the activity and disciplinary procedure will follow (cf. Article 168 of the General Regulations (Reglamento General) of Comillas Pontifical University).

WORK PLAN AND SCHEDULE[1]

In and out-of-class activities	Date/Periodicity	Deadline
Mid-term exam	Week 9	
Final exam	May	
Lab sessions	Start at week 5	
Review and self-study of the concepts covered in the lectures	After each lesson	–
Problem-solving	Weekly	–
Lab preparation	Before every session	–
Lab report writing	–	One week after the end of each session
Final project	During the last third of the course	Last week
Final exam preparation	May	–

STUDENT WORK-TIME SUMMARY			
IN-CLASS HOURS			
Lectures	**Problem-solving**	**Lab sessions**	**Assessment**
35	10	12	3
OUT-OF-CLASS HOURS			
Self-study	**Lab preparation**	**Lab report writing**	**Final project**
70	6	18	26
		ECTS credits:	**6 (180 hours)**

[1] A detailed work plan of the subject can be found in the course summary sheet (see following page). Nevertheless, this schedule is tentative and may vary to accommodate the rhythm of the class.

BIBLIOGRAPHY

Basic bibliography

- Notes prepared by the lecturer (available in Moodle).
- Mechanics of Composite Materials, Robert M. Jones, 2nd ed., Taylor and Francis, 1999
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Complementary bibliography

- Fiber-Reinforced Composites: Materials, Manufacturing, and Design, P. K. Mallick, 2nd edition, New York: Marcel Dekker, Inc. (1993).
- Mechanics of Composite Materials, Autar K. Kaw, 2nd ed., CRC Press, 2006
- Engineering Mechanics of Composite Materials, I. M. Daniel, O. Ishai, Oxford University Press, 2006
- Mechanics of Composite Materials with MATLAB, G. Z. Voyiadjis, P. I. Kattan,Springer, 2005.
- Finite Element Analysis of Composite Materials, E. J. Barbero, CRC Press, 2008
- Introduction to Composite Materials Design, 2nd ed., Ever J. Barbero, CRC Press, 2011

	IN-CLASS ACTIVITIES				OUT-OF-CLASS ACTIVITIES				LEARNING OUTCOMES
Week	h/w	LECTURE & PROBLEM SOLVING	LAB	ASSESMENT	h/w	SELF-STUDY	LAB PREPARATION AND REPORTING	OTHER ACTIVITIES	Learning Outcomes
1	2	Composites vs other materials, brief history, general pros/cons, classifications, applications, terminology. Metallic Matrix Composites			8	Review and self-study (8h)			
2	4	Ceramic Matrix Composites, Polymer Matrix Composites, Selection Criteria			4	Review, self-study and problem-solving (4h)			
2	2	Introduction to elasticity. Stress-Strain relationships. Failure criteria for metals			4	Review, self-study and problem-solving (4h)			
3	2	Manufacturing. Single parts. MMC, CMC (1h), PMC (1h)			4	Review, self-study and problem-solving (4h)			
3	2	Linear Elastic Stress-Strain relationships for composite materials. Elastic constants based on micromechanics. Application in Matlab							
4	4	Introduction to stregth of materials. Composite beams.Plane Stress. Theory of plates and shells.			8	Review, self-study and problem-solving (8h)			
5	2	Elastic constans based on global coordinate system.			4	Review, self-study and problem-solving (4h)			
6	2	Manufacturing. PMC (2h)							
6	2	Laminate Analysis. Basic equations. Application in Matlab.			4	Review and self-study (4h)			
7	2	Effective elastic constants of a laminate	Lab 1 (2h) Ansys I		4	Review, self-study and problem-solving (4h)	Lab preparation (1h) and report writing (3h)		
8	2	Manufacturing. PMC (1h); Bonding – Adhesives (1h)	Lab 2 (2h) SW selection		4	Review, self-study and problem-solving (4h)	Lab preparation (1h) and report writing (3h)	Final project proposal (2h)	
9	2	Manufacturing. Joining – Bolts, Machining, Other special issues about CM – Costs, risks, quality.		Mid-term exam (2h)	4	Review, self-study and problem-solving (8h)			
10	2	Failure theories of a lamina: Maximum Stress, Maximum Strain, Tsai-Hill and Tsai-Wu failure theories	Lab 3 (2h) Ansys II		4	Review, self-study and problem-solving (4h)	Lab preparation (1h) and report writing (3h)	Final project development (8h)	
11	4	Tech Visit							
12	2	Testing. Destructive. NDT	Lab 4 (2h) Manufacturing Lab		4	Review, self-study and problem-solving (4h)	Lab preparation (1h) and report writing (3h)	Final project development (8h)	
13	2	Introduction to homogenization. Eshelby Method	Lab 5 (2h) Ansys III		4	Review, self-study and problem-solving (4h)	Lab preparation (1h) and report writing (3h)		
14	2	Introduction to damage mechanics. Overall and local approach	Lab 6 (2h) Testing		4	Review, self-study and problem-solving (4h)	Lab preparation (1h) and report writing (3h)		
15	2	Practical Cases		Final project presentations (2h)				Paper and presentation preparation (8h)	