Course guide
205611 - 205611 - Advanced Structural Analysis

Last modified: 25/10/2023

Unit in charge: Terrassa School of Industrial, Aerospace and Audiovisual Engineering
Teaching unit: 737 - RMEE - Department of Strength of Materials and Structural Engineering.

Degree: MASTER'S DEGREE IN RESEARCH IN MECHANICAL ENGINEERING (Syllabus 2021). (Compulsory subject).

Academic year: 2023 **ECTS Credits:** 4.5 **Languages:** Catalan, Spanish

LECTURER

Coordinating lecturer: Miquel Casafont Ribera

Others: Julián Arnaldo Avila Diaz
Oriol Bové Tous
Miquel Casafont Ribera

PRIOR SKILLS

Knowledge of Continuum Mechanics and Strength of Materials.

TEACHING METHODOLOGY

a) 42 hours of face-to-face sessions, consisting of lectures and sessions to solve practical cases.
b) Autonomous learning based on the resolution of short exercises in the classroom forum.
c) Cooperative learning based on the completion of a project or resolution of a case, in teams of three people.

LEARNING OBJECTIVES OF THE SUBJECT

Learn basic concepts and methodologies commonly applied in research in the field of mechanics of materials and structures:
- Instabilities.
- Geometrically non-linear behaviour.
- Non-linear material behaviour.
- Non-linear analysis using the finite element method.
- Plate and shell theory
- Hyperelastic materials
- Orthotropic and laminated materials
- Fatigue and fracture.
- Failure analysis.
- Experimental structural analysis.

STUDY LOAD

Type	Hours	Percentage
Self study	72,0	64.00
Hours large group	40,5	36.00

Total learning time: 112.5 h

CONTENTS

Review of the Finite Element Method (FEM)

Description:
Elastic problem. Discretisation. Shape functions. Application of the principle of virtual work. Nodal equilibrium. Stiffness matrix, Internal forces. Operational scheme of the method,

Specific objectives:
The student should be able to:
- Identify the basic elements in structural analysis by FEM.
- Explain the different stages in the operation of the method.

Related activities:
Laboratory session 1: Linear and linear buckling analysis of a structure using the FEM.

Full-or-part-time: 8h
Theory classes: 3h
Self study : 5h

Instabilities

Description:
Type of instabilities. Review of Euler critical buckling load. Critical buckling load of columns with different theoretical boundary conditions.

Specific objectives:
The student should be able to:
-For the case of members subjected to compression, determine the flexural buckling critical load.
-Identify the critical buckling lengths for each type of instability considering different supports.

Related activities:
Laboratory session 1: Linear and linear buckling analysis of a structure using the FEM.

Full-or-part-time: 6h 45m
Theory classes: 2h 30m
Self study : 4h 15m

Geometric non-linearity

Description:
Introduction to geometric non-linearity. Incremental analysis method. General stiffness matrix of the beam element. Geometric stiffness matrix of the beam element. Linear buckling analysis of a structure. Tangent stiffness matrix. Internal force. Solution of non-linear systems of equations. Non-linear geometric analysis by means of the co-rotational method. Imperfections.

Specific objectives:
The student should be able to:
- Be able to reason why it is necessary to perform a geometric non-linear analysis on a structure undergoing large displacements.
- Identify the situations in which it is relevant to carry out a geometric non-linear analysis.
- Perform linear buckling analysis of structures.
- Understand the results of a buckling mode analysis.
- Understand the results of a geometrically non-linear analysis.
- Know the basic numerical techniques for solving systems of non-linear equations, and use them in the non-linear analysis of structures using the finite element method.
- Be able to easily understand the implementation algorithm of the finite element co-rotational beam finite element.
- Identify and solve typical non-convergence problems in non-linear analysis of structural systems.
- Use different types of geometric imperfections in the analysis of structures.

Related activities:
Laboratory session 2: Geometrically and material non-linear analysis of a structural component.

Full-or-part-time: 23h 25m
Theory classes: 8h
Self study : 15h 25m

Introduction to theory of plates and shells.

Description:
Plate and shell finite element. Governing equation of plates. Elastic buckling stress of a plate. Post-critical behaviour of plates

Specific objectives:
The student should be able to:
- Perform linear analyses of plates using the finite element method and understand their results.
- Be able to describe the phenomenon of local buckling of plates.
- Calculate the critical local buckling stress of a plate with different support conditions.
- Understand the post-critical capacity of plates.

Related activities:
Laboratory session 2: Geometrically and material non-linear analysis of a structural component.

Full-or-part-time: 9h 30m
Theory classes: 3h 30m
Self study : 6h

Introduction to hyperelasticity

Description:
Common constitutive equations for the simulation of materials working in the elastic zone and large strains (e.g. elastomers), as well as their experimental characterisation.

Specific objectives:
The student should be able to:
Determine the material constants required for simulations using the most common constitutive models. Carry out simulations and understand their results.

Full-or-part-time: 8h 25m
Theory classes: 3h
Self study : 5h 25m

Introduction to plasticity

Description:
Introduction to material non-linearity. Plasticity. Yield surfaces. Hardening models.

Specific objectives:
The student should be able to:
- Know the basic factors involved in the plastic analysis of structures.
- Perform plastic analysis using the finite element method.

Related activities:
Laboratory session 2: Geometrically and material non-linear analysis of a structural component.

Full-or-part-time: 8h 25m
Theory classes: 3h
Self study : 5h 25m

Orthotropic and laminated materials.

Description:
Common constitutive equations used for the simulation of orthotropic anisotropic linear elastic materials in plane strain and their laminates, as well as their experimental characterisation and failure mechanisms and criteria.

Specific objectives:
The student should be able to:
-Model the behaviour of an orthotropic linear elastic laminate material, perform finite element simulations and evaluate their results using appropriate failure criteria.

Full-or-part-time: 12h 35m
Theory classes: 4h 30m
Self study : 8h 05m

Fatigue and fracture.

Description:
Physical phenomenon. Characterisation of materials. Resistance factors. Life prediction, accumulated damage, cycle counting. Numerical methods. Fatigue crack propagation. Fracture mechanics. Fracture toughness.

Specific objectives:
The student should be able to:
Calculate structural elements and components to infinite life. Make fatigue life predictions. Appropriate use of analytical and numerical calculation models. Knowledge of the effect of cracks in structures. Use of technical standards to determine fracture toughness. Make crack propagation rate predictions.

Full-or-part-time: 17h 40m
Theory classes: 6h 30m
Self study : 11h 10m

Fractographic analysis - failures

Description:
The physical phenomenon. Sources of material failure. Characteristic failures according to the type of load. Environmental and temperature effects on failures.

Specific objectives:
The student should be able to:
Understand the macro, meta and micro characteristics of failure mechanisms. Obtain relevant information from observation of fracture surfaces. Discuss the origin of typical failures in the industry.

Full-or-part-time: 9h 45m
Theory classes: 3h 30m
Self study : 6h 15m

Experimental structural analysis

Description:
Presentation of the different types of tests on physical prototypes related to structural analysis. Electrical extensiometry. Digital image correlation. Introduction to experimental modal analysis. Fatigue tests.

Specific objectives:
The student must be able to:
Ensure a holistic view of the structural analysis process that ensures a proper balance between numerical simulation and experimentation. The techniques of extensiometry, digital image correlation, modal analysis and fatigue testing will be presented.

Related activities:
Laboratory session 3: Strain gauges

Full-or-part-time: 8h
Theory classes: 3h
Self study : 5h

GRADING SYSTEM

Final mark = 0.5*NEF+0.35*NTC+0.15*NPL
NEF: Final exam mark.
NTC: Coursework mark.
NPL: Laboratory mark.
For those students who meet the requirements and sit the reassessment exam, the reassessment exam score will replace the marks of all the evaluation tasks that are face-to-face written tests (controls, partial and final exams) and the marks of laboratory, assignments, projects and presentations obtained during the course will be maintained.
If the final mark after the re-evaluation is lower than 5.0, it will replace the initial one only if it is higher.

EXAMINATION RULES.

a) Final exam: eminently theoretical exam. The authorised materials are writing instruments only.
b) Coursework: a project or doctoral thesis in a reduced format must be presented, involving part of the contents covered during the course. A report of the work must be written and must be presented to the lecturers. Work is to be carried out in groups of three people.
c) Laboratory: write a report on each laboratory session.

BIBLIOGRAPHY

Basic:

- Bazant Z.P., Cedolin L. . Stability of structures : elastic, inelastic, fracture and damage theories. Singapore: World Scientific Publishing, 2010.
- Crisfield M.A. . Non-linear Finite Element Analysis of Solids and Structures. John Wiley & Sons, 1998.
- Dowling N.E. . Mechanical Behavior of Materials. Prentice Hall, 2013..