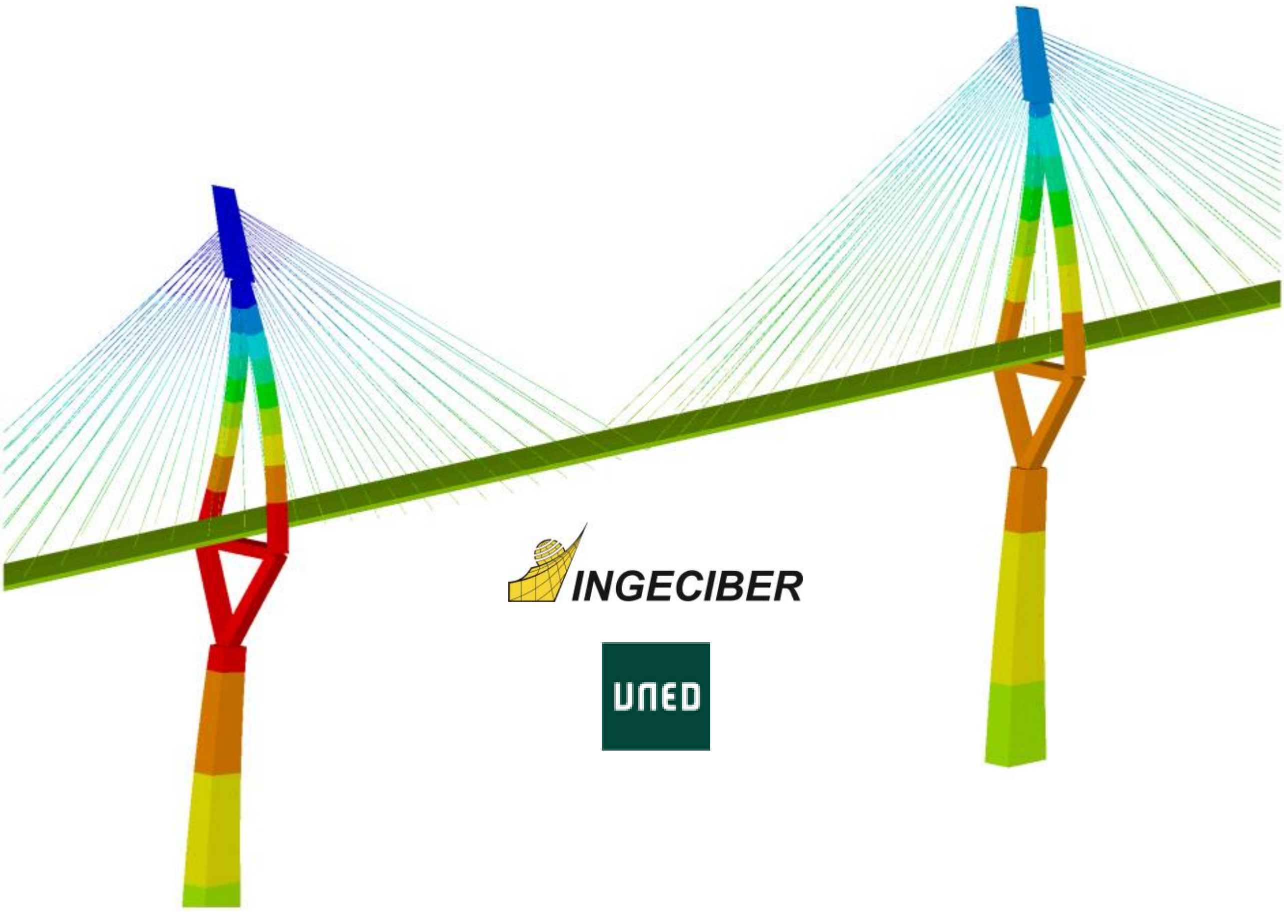
POSTGRADUATE STUDIES

1st Ed. - INTERNATIONAL MASTER'S IN THEORETICAL & PRACTICAL APPLICATION OF FINITE ELEMENT METHOD AND CAE SIMULATION

2024 PROGRAMME

Ansys



INGECIBER

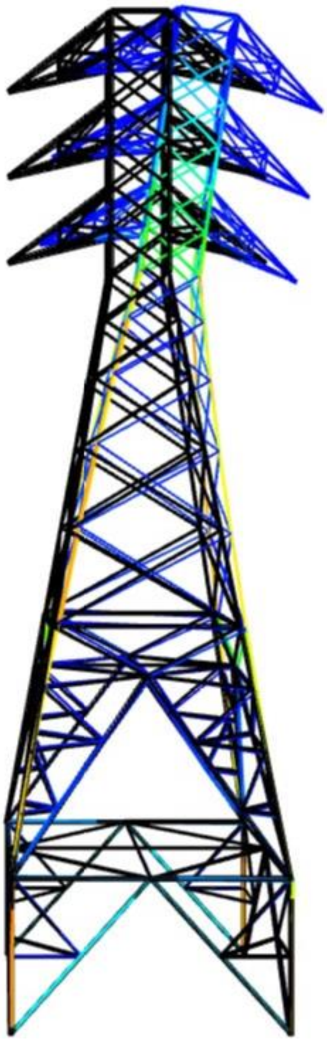
UNED

INTRODUCTION

The principal objective of the Master's is to provide analysts and scientists with training in the Finite Element Method for use in the professional world, as a university-specific Master's should do. With this objective in mind, the Master's is structured into foundation subjects, which give an overview of the Finite Element Method, and application and practical subjects where professional software currently on the market is used.

In 2010, the directors of the Master's decided to make it an international course, and they made it available worldwide.

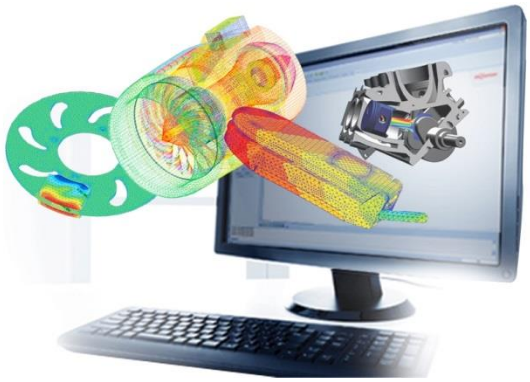
UNED and Ingeciber, their principal partner in the Master's, are investing in a determined internationalization of students and collaborators and want to offer participants the maximum number of options, with the objective of sharing experiences in the world of CAE on a global level.



METHODOLOGICAL GUIDANCE

Due to the heterogeneous knowledge and experiences of the students of a course such as this, the provision of a multidisciplinary approach ranging from the most basic knowledge of certain essential subjects to other more difficult subjects that deepen knowledge in specific areas has been attempted. Furthermore, some freedom has been left to professors so they can approach each subject from their own perspective, losing uniformity but gaining a variety of viewpoints. Nevertheless, the extensiveness of the FEM and virtual simulation makes more teaching hours necessary in order to cover all the specific aspects of the course, therefore every subject has been limited in its length and depth to its credits or corresponding hours. Students interested in deeper understanding of certain aspects of the syllabus may start with the additional bibliography specified in the syllabus of each subject and may consult with the professor/tutor of the subject.

It is very important to highlight that, in a distance learning course, the students must have the self-discipline to follow the timetable of teaching hours for each subject, according to the given guidelines and order of the course (section I from the *General Student Guide*).



During the weeks devoted to each subject in the schedule, and two additional weeks once the subject is finished, there are four hours per week of tutorships or consultation about the subjects taught.

Finally, the continuous assessment exercises must be completed during the term of the corresponding subject and exams must be taken at the end of the term as detailed in section I.8 and I.10 from the *General Student Guide*.

If the students do not take or do not pass their exams, they cannot obtain the corresponding diploma.

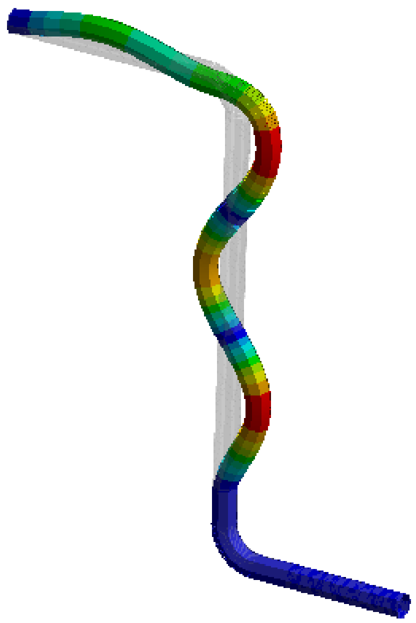
F.E.M GENERAL THEORY

MODULE 1. - F.E.M GENERAL THEORY

TEACHING STAFF

Juan José Benito Muñoz

Jesús Flores Escribano



1. - OBJECTIVES

The aim of this subject is to consolidate the foundations of the Finite Element Method, by thinking mainly about its application in structure analysis, although the basic ideas can be generalized without any difficulty.

Furthermore, it should be pointed out that the subject starts with the most basic concepts, initially treated intuitively in order to allow them to be easily assimilated.

2. - CONTENT

The organization of basic ideas, already known to the student, is the beginning of the subject´s syllabus, which tries to organize them using a matrix approach so that the structural calculation will be more effective. It will immediately set out the heart of the formulation of the direct stiffness method and the problem will be reassessed from a more powerful and general point of view. At the beginning, it will deal with the linear elements, which are easier to handle.

Subsequently, the elastic-linear problems are set out, taking a further step in the generalization of ideas, and the C_0 shape functions are studied in detail.

Finally, the theme of plates is discussed with the aim of laying the foundations for a later study about this important structural type and, above all, of presenting general ideas about the problems raised previously and the solutions adopted in the cases demanding C_1 continuity.

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3.5. - The Boundary Conditions

3.6. - Calculation of Displacements

3.7. - Calculating Reactions and Internal Forces

3.8. - Examples

IV. General Approach for the Finite Element Method Application in Elastic and Steady-State Field Problems.

4.1. - Introduction

4.2. - Differential Approach to the Boundary Value Problem

4.3. - Integral Approach to the Boundary Value Problem

4.4. - Approximation

4.5. - The Finite Element Method

4.6. - Global Features. Application of Essential Boundary Conditions

4.7. - Application of FEM in Solving Linear Elastic Problems

4.8. - Steady-State Field Problems

4.9. - Convergence

V. Shape Functions of Continuity. Isoparametric Elements

5.1. - Introduction

5.2. - Normalized Coordinates

5.3. - Families of Shape Functions of Co Continuity

5.4. - Transformations

5.5. - Isoparametric Elements. Numerical Integration

VI. Thin Plate According To Kirchhoff Theory

6.1. - Introduction. Starting Hypothesis

6.2. - Differential Approach. Field Equations. Definition of Stress

6.3. - Integral Approach. Principle of Virtual Work

6.4. - Finite Element Discretization

6.5. - Requirement for continuity C1

6.6. - Nonconforming Plate Element

6.7. - Conforming Plate Element

6.8. - Conclusions

VII. Thick plates. Reissner-Mindlin Theory

7.1. - Introduction

7.2. - Differential Approach. Stress Definition

7.3. - Integral Approach

7.4. - Finite Element Discretization

7.5. - Shear Locking Solution

7.6. - Triangular Elements

A. - Elementary stiffness matrices

B. - Equivalent Nodal Loads

C. - Rigid Nodes of Finite Size

D. - Plane Stress and Strain

D.1- Plane Stress (XY Plane)

D.2- Plane Strain (XY Plane)

E. - Numerical Integration

E.1- Quadrature Rules

E.2- Gaussian Quadrature

E.3- Multiple Integrals

F. - Historical Reference

3. - BASIC TEXT AND OTHER TEACHING MATERIALS

Course Learning Units

4. - BIBLIOGRAPHICAL REFERENCES

ALARCÓN, A., ALVAREZ, R. & GÓMEZ-LERA, S. *Cálculo Matricial de Estructuras*. Barcelona, Spain: Ed. Reverté, S.A., 1986. ISBN: 84-291-4801-9.

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ZIENKIEWICZ, O.C. & TAYLOR, R.L. *The Finite Element Method: Its Basis and Fundamentals. Sixth edition. Oxford, UK: Ed. Elsevier Butterworth-Heinemann,* 2005. ISBN-10: 0750663219/ ISBN-13: 9780750663212.

Spanish version: ZIENKIEWICZ, O.C., TAYLOR, R.L. *El Método de los Elementos Finitos. Formulación Básica y Problemas Lineales*. Fourth edition. Barcelona, Spain: Ed. CIMNE - McGraw-Hill, 1994. ISBN: 9788495999528.

5. - CONTINUOUS ASSESSMENT EXERCISES

In the distance learning exercises, the exercises and problems given must be directly resolved and delivered on time.

6. - SPECIFIC RECOMMENDATIONS

It is advisable that the problems included in the distance learning exercises are resolved as the student moves forwards in the study of the learning units for sequentially clarifying, as soon as possible, any doubts that may arise.

It is recommended to perform the Self-Assessment Tests, which will help the students know their learning status. Tests results are not taken into account for subject grades, only for student informative purpose.

7. - TUTORSHIPS

Students can contact the tutor using the subject's virtual classroom.

Professor Jesús Flores Escribano

E-mail: jes.flores@invi.uned.es

8. - SENDING THE CONTINUOUS ASSESSMENT EXERCISES

The student will upload the continuous assessment exercises in the virtual classroom.

INTRODUCTION TO F.E.M PROGRAMMING

MODULE 2. - INTRODUCTION TO F.E.M PROGRAMMING

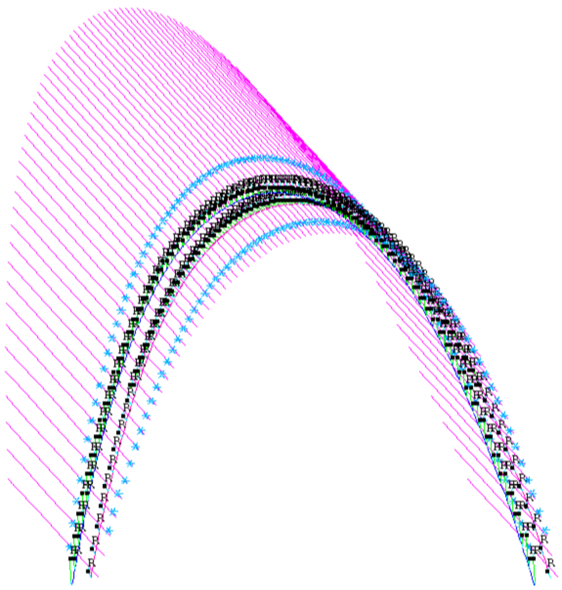
TEACHING STAFF

Luis Gavete Corvinos

1. - OBJECTIVES

The objectives of this course are focused on teaching students to use and introduce desired changes on a small computer program using the Finite Element Method. To that end, the student is provided with solid basis of programming with some basic algorithms related to data structure and numerical calculation. Thus, using this basis and simple programming language the programming of the Finite Element Method is addressed.

We believe, therefore, that the objectives of the course are covered by the information provided, although students can improve the programming themselves so that the programs are more effective. We have opted for clarity over the efficiency of the program. Therefore, we have used the BASIC language because of its ease of use and its wide dissemination.

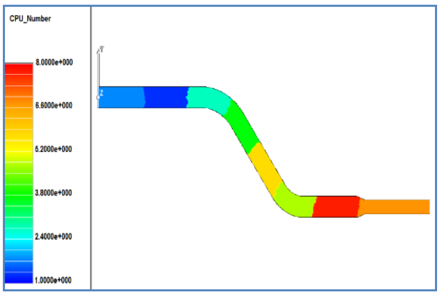


2. - CONTENT

The Introduction to FEM programming course is divided into four sections. The first section, called "Programming introduction" (Warnier Method in a freeware version), is perfectly adapted to solving mathematical problems through numerical methods. This section includes the first chapters and it gives the basis to understand perfectly (starting from scratch) the programming of complex problems. Furthermore, it includes the basic algorithms, which are often used in Finite Element Method programming. Obviously, this could be totally or partially ignored by those students who already have a good knowledge of programming.

The second section constitutes the actual introduction to FEM programming, which is performed for the two dimensional linear elasticity cases using the simplest finite element (three node triangles). This section includes two chapters, the first one addresses the two dimensional elasticity case including a simple graphic processor, which allows the user to see the model and the calculation results; the second one contains a brief introduction to storage improvements.

The third section addresses error estimation in FEM. It includes a simple application example as well as its programming. Finally, the fourth section presents an introduction to parallel computation using finite elements.



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1.6. - Alternative Structure

1.7. - Exercises Resolved

1.7.1. - Exercise 1

1.7.2. - Exercise 2

1.8. - Mix of Repetitive Structures with Alternative Structures (More Complex Programs)

1.9. - Decrease of the Storage Memory Needs

II. Elementary Algorithmic

2.1. - Introduction

2.2. - Sorting Algorithm

2.3. - Search Algorithm

2.4. - Insertion Algorithm

2.5. - Coupled Algorithm (Search + Insertion)

2.6. Elimination Algorithm

2.7. - Merging Algorithm

III. Numeric Algorithmic (I). Interpolation

3.1. - Linear Interpolation

3.2. - One Dimension Lagrange Interpolation

3.3. - Two Dimension Lagrange Interpolation

IV. Numeric Algorithmic (II). Resolution of Linear Equation Systems

4.1. - Introduction: Gauss Method

4.2. - Improvements to Gauss Method

4.2.1. - *PARTIAL PIVOTING METHOD*

4.2.2. - *TOTAL PIVOTING METHOD*

4.3. - Cholesky Method

V. Memory Improvement Algorithms

5.1. - Two Matrices Product

8.2.1. - Obtaining of a Recovered Solution

8.2.2. - Error Estimation in the Energy Norm. Z2Estimator

8.3. - Z2 [11] Estimator Theorem

8.4. - Example 1

8.4.1. - Shape Function for the 3 Nodes Triangular Finite Element

8.4.2. - F.E.M. Process until the Stresses Calculation

8.4.3. - Error Estimation

8.4.4. - Deformation Energy Matrix Norm

8.5. – Computer Program Commented

8.6. - Example 2

8.7. - Conclusions

8.8. - Full Computer Program

8.9. - Chapter 8 references

IX. A Brief Introduction to Parallel Computation in the Finite Element Method

9.1. - Introduction

9.2. - Parallel Computation in the finite element method

9.2.1. - Graph and Laplacian matrix

9.2.2. - Eigenvalues and eigenvectors

9.2.3. - Spectral bisection method

9.2.4. - Application to a simple finite element model in 2D

9.2.5. - Finite elements in 3D

9.2.6. - Example in 3D

X. Bibliography

3. - BASIC TEXT AND OTHER TEACHING MATERIALS

Course Learning Units

4. - BIBLIOGRAPHICAL REFERENCES

ALARCÓN, A., ALVAREZ, R., GÓMEZ-LERA, S. *Cálculo Matricial de Estructuras*. Barcelona, Spain: Ed. Reverté, S.A., 1986. ISBN: 84-291-4801-9.

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5. - CONTINUOUS ASSESSMENT EXERCISES

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6. - SPECIFIC RECOMMENDATIONS

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7. - TUTORSHIPS

Students can contact the tutor using the subject's virtual classroom.

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8. - SENDING THE CONTINUOUS ASSESSMENT EXERCISES

The student will upload the continuous assessment exercises in the virtual classroom.

NUMERICAL CALCULATION

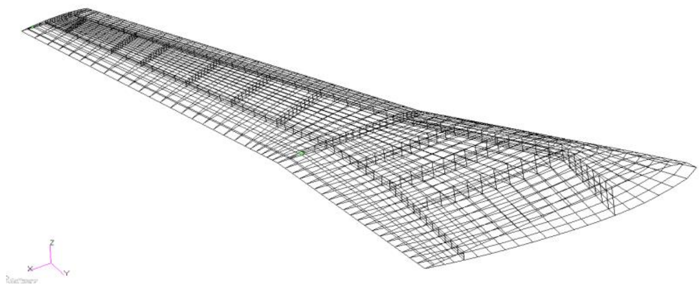
MODULE 3. - NUMERICAL CALCULATION

TEACHING STAFF

Luis Gavete Corvinos

1. - OBJECTIVES

The purpose of this text is to introduce basic numerical calculation techniques employed in the FEM to the student and to serve as the first contact base with the numerical methods.



Thus, all the mathematical concepts have been simplified as much as possible and a series of examples has been provided in order to facilitate the students' work. As it is a "distance learning" course, it is necessary for the text to be accompanied by the required self-taught manual.

Furthermore, the numerical techniques needed in order to do static and dynamic analyses by finite elements in linear and nonlinear cases have been covered.

2. - CONTENT

The text has been structured with two simple introductory chapters containing basic introductory concepts about matrices and numerical calculation followed by a second part about numerical calculation.

This second part has a chapter on interpolation (focused on Lagrange Interpolation) with some "spline" function concepts. Then numerical integration is covered, focusing on Gauss integration.

Three chapters are dedicated to the basic concepts of numerical algebra: a) equation systems; b) nonlinear equation systems; c) eigenvalues and eigenvectors. The intention is to cover the most common algorithm areas in finite element programs.

There is also a chapter based on the resolution of second order differential equation systems, which originate from the dynamic analyses, and there is another chapter that contains an introduction to the equations in partial derivatives and methods of resolving them.

INDEX

4.1. - Introduction

4.2. - Investigation Methods with a Variable

4.2.1. - General Approach. Formulas of Interpolation Type

4.2.2. - Newton-Cotes Formulas

4.2.3. - Gaussian Quadrature Formulas

4.3. - Multiple Integrals

4.4. - Numerical Integration in Triangular or Tetrahedral Regions

4.5. - Needed Numerical Integration Order

VI. Linear Equation Systems

5.1. - Introduction

5.2. - Direct Methods: Gauss Method

5.3. - Special Matrix Types

5.4.-Direct Matrix Factorization

5.5. - Iterative Methods

5.6. - Ill-Conditioned Systems of Equations

5.6.1. - Data Entry Errors

5.6.2. - Rounding Errors

5.6.3. - Conditioning of Non-singular Matrices

5.6.4. – Matrix Norm

5.6.5. - Most Used Matrix Norms

5.6.6. - Property

5.6.7. - Error Calculation

5.7. - Application to the Optimization Techniques to the Linear Equation Systems Resolution

5.7.1. - Introduction

5.7.2. - Methods for the Resolution of Symmetric Systems Defined Positives

5.7.2.1. - Gradient Method (Or the Maximum Decrease)

5.7.2.2. - Conjugated Gradient Method

5.7.2.3. - Pre-conditioning Conjugate Gradient Method

VII. Non-linear Equation Systems

6.1. - Introduction

6.2. - Newton-Raphson Method to Resolve a Non-linear Equation

6.3. - Newton-Raphson Method for Systems (Non-linear)

6.4. - Newton-Raphson Method Applied to the Equations System Originated by the Finite Element Method

6.4.1. - Newton-Raphson Method with Initial Stiffness

6.4.2. - Convergence Control (of the Program)

VIII. Eigenvalues and Eigenvectors

7.1. - Introduction

7.2. - Generalities

7.3. - Eigenvalues and Eigenvectors

7.4. - Determination Methods of the Characteristic Polynomial

7.5. - Transformation Methods

7.6. - Iterative Methods

7.7. - Methods of Values Calculation and Characteristic Vectors in Finite Elements

IX. Differential Equations and Systems

8.1. - Introduction

8.2. - Modal Superposition Method

8.3. - Direct Integration Methods

8.3.1. - Newmark's Direct Integration Method

X. Equations in Partial Derivatives

9.1. - Partial Derivative

9.2. - Mathematical Formulations and Solution of Physical Problems

9.3. - Foundations

9.4. - Some Typical Problems

9.5. - Functionals and Operators

9.6. - Numerical Methods for the Resolution of Equations in Partial Derivatives

9.7. - Application Example

9.7.1. - Variational Method

9.7.2. - Collocation Method

9.7.3. - Subdomain Method

XI. Bibliography

3. - BASIC TEXT AND OTHER TEACHING MATERIALS

Course Learning Units

4. - BIBLIOGRAPHICAL REFERENCES

Software: manuals

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5. - CONTINUOUS ASSESSMENT EXERCISES

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6. - SPECIFIC RECOMMENDATIONS

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7. - TUTORSHIPS

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8. - SENDING THE CONTINUOUS ASSESSMENT EXERCISES

The student will upload the continuous assessment exercises in the virtual classroom.

MATERIAL CONSTITUTIVE LAWS

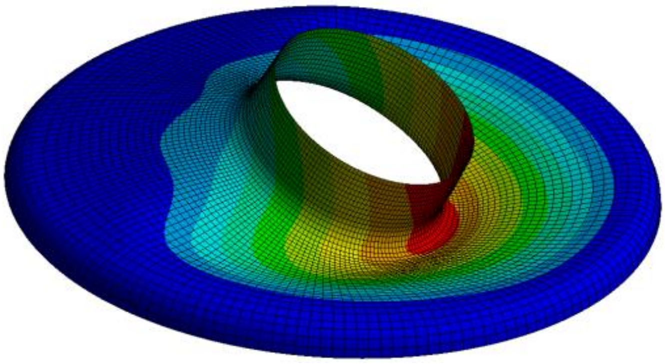
MODULE.4. - MATERIAL CONSTITUTIVE LAWS

TEACHING STAFF

Alberto Fraile de Lerma

1. - OBJECTIVES

The main objective of the subject course is to represent nonlinear behavior of materials through mathematical models.



The mechanical behavior of engineering materials such as metals, polymers, concrete, rocks, wood, etc., is similar even though their physical structures are different. They all sustain deformations at different levels: reversible or irreversible, they are damaged and they fracture. This is the main reason why it is possible to explain material behavior using Continuum Mechanics.

Formulation of constitutive relationships follows two steps: experimental testing and mathematically representing the phenomena observed. The stress states obtained with experimental testing are homogeneous and basic, but mathematically we can extrapolate them to predict the behavior of any stress system. Therefore, the mathematical theories based on experimental observations are, by nature, phenomenological and represent the macroscopic behavior of the matter.

Following the first general considerations chapters, the course is focused in Rheology. The term Rheology means that with sufficient observation time, even the most apparently solid materials will show flow-type behavior. The approach will be purely mechanical introducing the basic concepts with one-dimensional simple mechanical models. These models will be generalized to three-dimensional cases since they are the general methods for solving realistic practical problems. In particular, the use of Prony series to characterize the rheological behaviour will be studied since it is the method used by the computer program associated with this Course.

Plasticity will be introduced in the next section. The mechanical behavior of materials working in the plastic regime will be mathematically described. Its formulation is very useful to model the behavior of ductile materials, such as steel, where the strain is mainly plastic but it is also used for other materials such as concrete, soils and rocks. As in the previous chapter, the one-dimensional models will be studied first and generalized to three dimensions later. Some important concepts as yield surface, loading criterion, flow rule or hardening will be discussed.

Finally, the last section studies Continuum Damage Mechanics. Continuum Damage Mechanics describes the evolution of any material from an initial undamaged state until a macroscopic crack starts to appear. It is, therefore, a state before macroscopic cracking which is studied in "fracture mechanics" and is out of the scope of the present course.

2. - CONTENT

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II. General Considerations

III. Rheological Equations. Mechanical Models

IV. Analysis with Linear Rheological Models. Finite Element Method

3.1.3.5 Laboratory testing in the frequency domain

3.2 Three dimensional generalization of viscoelasticity

3.2.1 General equations of stress analysis

3.2.1.1 (*) Harmonic loading

3.2.1.2 Other methods. Correspondence Principle

3.3 Use of Prony series with 3D Finite Elements

3.3.1 Matrix structural analysis with viscoelastic elements

3.3.2 General Finite elements with Prony series

Self-evaluation exercises

Summary of main ideas

References

Appendix (*)

1. The wave equation in rods

   Axial wave propagation

   The wave equation in a shear beam

2. Harmonic plane waves in an unbounded medium

(*) These sections are only included for informative purposes, they will not be included in the evaluation exams

V. Plasticity

4.1 Uniaxial behavior

4.1.1 Yield stress

4.1.2 Yield Hardening

4.1.3 Loading and unloading criteria

4.1.4 Idealized constitutive equations

4.1.4.1 Elastic-perfectly plastic solid

4.1.4.2 Plastic solid with hardening

4.1.5 Hardening rule

4.2 Plasticity theory. General formulation

4.2.1 Yield surface

4.2.1.1 Von Mises yield surface

4.2.1.2 Tresca's yield surface

4.2.2 Loading criterion

4.2.3 Flow rule

4.2.4 Hardening

4.2.4.1 Isotropic hardening

4.2.4.2 Kinematic hardening

4.2.4.3 Mixed hardening

4.2.4.4 Experimental determination of the hardening parameters

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4.3.1 Newton-Raphson method

4.3.2 Non-linear finite element method: Algorithm

4.3.3 Evaluation of the residual vector: Integration of the elastoplastic constitutive equations

4.3.3.1 Generalized trapezoidal rule

4.3.4 Evaluation of the tangent operator. Consistent tangent modulus

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References

VI. Continuum Damage Mechanics

5.1 Mechanical representation of damage

5.1.1 Damage variable

5.1.2 Effective stress concept

5.1.3 Strain equivalence principle

5.1.4 Damage and the tensile test

5.1.5 Strain energy density release rate Y

5.1.6 Damage evolution law

5.2 Three dimensional generalization

5.2.1 Elastic behavior with damage. Equivalent stress criterion

5.2.2 Plasticity and ductile damage

5.2.3 Pure brittle damage

5.3 Coupling plasticity – damage

5.3.1 Onset of fracture

5.4 Damage mechanics: numerical analysis of fracture prediction in structures

5.4.1 Uncoupled analysis

5.4.2 Locally coupled analysis

5.4.3 Fully coupled analysis

5.5 Recent trends

Self-evaluation exercises

Summary of main ideas

References

3. - BASIC TEXT AND OTHER TEACHING MATERIALS

Course Learning Units

4. - BIBLIOGRAPHICAL REFERENCES

LEMAÎTRE, J. & CHABOCHE, J.L. *Mecanique des Materiaux Solides*. Ed. Dunod, 1988. ISBN: 9782100013975.

LUBLINER, J. *Plasticity Theory*. New York, USA: Ed. Dover Publications, 2008. ISBN: 9780023721618.

MAUGIN, G.A. *The Thermodynamics of Plasticity and Fracture*. New York, USA: Ed. Cambridge University Press, 1992. ISBN: 9780521397803.

5. - CONTINUOUS ASSESSMENT EXERCISES

For the distance learning exercises, the exercises and problems given must be solved and sent on time.

6. - SPECIFIC RECOMMENDATIONS

It is advisable that the distance learning problems/exercises are solved after the student finishes studying a chapter since the later chapters/sections are based on material explained at the beginning. If there are any questions, students can contact the Professor.

7. – HELP WITH THE MATERIAL (OFFICE HOURS)

Students can contact the tutor using UNED's virtual classroom by email and phone (see below).

Associate Professor Alberto Fraile de Lerma: alberto.fraile@upm.es

Mondays, from 4:30 pm to 8:30 pm (UTC/GMT+1).

Phones: (+34) 91-336-53-40

(+34) 91-336-30-21

Dpto. Ingeniería Mecánica (Mechanical Engineering Department)

E.T.S. INGENIEROS INDUSTRIALES. U.P.M.

C/ José Gutiérrez Abascal, 2. 28006 Madrid, Spain

8. - SENDING THE CONTINUOUS ASSESSMENT EXERCISES

The student will upload the continuous assessment exercises in the virtual classroom.

MATERIAL CONSTITUTIVE LAWS

INTRO TO ANSYS FEA SOFTWARE. I.

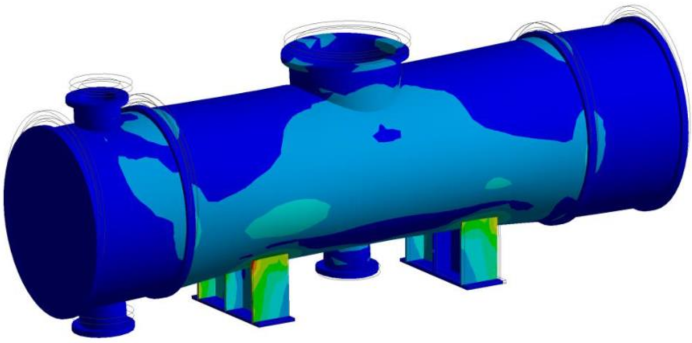
TEACHING STAFF

Responsible

Ronald Siat, Civil Engineer.

Tutors

Alberto Mota, Civil Engineer.



1. - OBJECTIVES

In an engineering project, the Finite Element Method requires the use of algorithms programmed by computer and the basis of calculation is set out, in most cases, using finite element commercial programs. Therefore, it is necessary to supplement the theoretical training in the Finite Element Method with the use of software. To that end, the ANSYS Mechanical program has been chosen since it is a general-purpose program, which in addition allows the use of a specific license for the Master's. A standard of FE programs, it permits the user to put into practice all the knowledge that has been taught on the course and in its specific modules.

The aim of this subject, as its name indicates, is to introduce the student to the use of practical software based on the Finite Element Method and for the student to feel sufficiently at ease from the beginning to acquire knowledge continuously during the course in the rest of the subjects of Theory and Practice.

2.-CONTENT

This subject is eminently practical and both its content and its structuring are focused on the student becoming familiar with the use of the program from the beginning of the course since it will be useful throughout, and will be the means of materializing and applying the knowledge acquired during the study of the other subjects.

ANSYS SpaceClaim as well as ANSYS Mechanical (Meshing Introduction) will be studied in this subject.

AP1. Part 1. ANSYS SpaceClaim (ANSYS Geometry)

SpaceClaim, which is the most advanced ANSYS Geometrical Preprocessor, will be studied. With SpaceClaim, you will be able to create simple and complex geometry as well as modify geometry from standard CAD software.

The study of SpaceClaim has been structured into the following chapters:

- Lecture 1: Core Skills
- Lecture 2: Creating Geometry
- Lecture 3: Repairing Geometry
- Lecture 4: FEA Modeling

  (Module 5 "CFD Modeling" is not included; it is not part of this subject)
- Lecture 6: SpaceClaim to Workbench

The following solved exercises will be provided:

- Workshop 1.1: Basics
- Workshop 1.2: Creating Simple Bracket
- Workshop 2.1: Creating Geometry
- Workshop 3.1: Repairing Geometry
- Workshop 4.1: Preparing for FEA Analysis
- Workshop 6.1: Parameters

AP1. Part 2. ANSYS Mechanical (ANSYS Workbench – Meshing Introduction)

ANSYS Workbench is a project-management tool. It can be considered as the top-level interface linking all our software tools. Workbench handles the passing of data between ANSYS Geometry / Mesh / Solver / Postprocessing tools.

This part of the ANSYS Workbench study is about Meshing. It has been structured into the following chapters:

- Lecture 1: Core Skills
- Lecture 2: Meshing Methods
- Lecture 3: Global Mesh Controls
- Lecture 4: Local Mesh Controls
- Lecture 5: Mesh Quality and Advanced Topics

The next solved exercises will be provided:

- Workshop 1.1: ANSYS Workbench Meshing Basics
- Workshop 2.1: ANSYS Meshing Methods
- Workshop 3.1: Global Mesh Controls
- Workshop 4.1: Local Mesh Controls
- Workshop 5.1: 2D Axisymmetric Plate
- Workshop 5.2: Shell Pressure Vessel

You will continue studying ANSYS Workbench in AP.2 subject

A Course Order Index document has been created to help students follow a proper study order combining the different parts with their documentation (Lectures, Workshops and Assessment Exercises).

3. - BASIC TEXT AND OTHER TEACHING MATERIALS

The teaching material for this subject is composed of:

The Introduction to *ANSYS SpaceClaim 17.0* training material and the related exercises as well as the Introduction to *ANSYS Meshing* and the related exercises.

Both training materials are the original ANSYS base texts for an introductory course of ANSYS SpaceClaim and ANSYS Meshing (ANSYS Mechanical).

Software: ANSYS SpaceClaim and ANSYS Mechanical

4. - BIBLIOGRAPHICAL REFERENCES

The software includes an interactive help section with specific help for each of the different themes dealt with. ANSYS software includes a lot of documentation with many practical examples and technical papers. It is important that the students familiarize themselves with the software help and its documentation.

5. - SPECIFIC RECOMMENDATIONS

Practicing with the computer and consulting the ANSYS Help is recommended.

6. - TUTORSHIPS

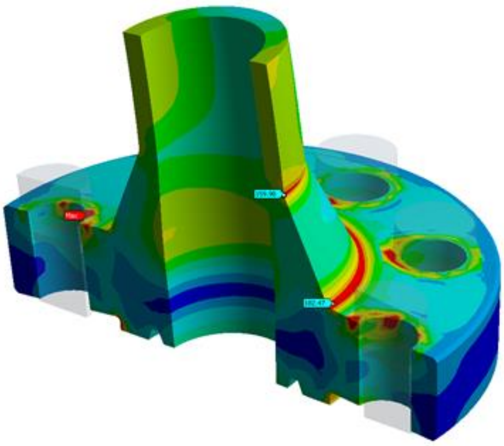
Students can contact tutors using the subject’s virtual classroom.

INTRO TO ANSYS FEA SOFTWARE. II.

TEACHING STAFF

Ronald Siat, Civil Engineer.

Alberto Mota, Civil Engineer



1. - OBJECTIVES AND CONTENT

This subject goes studies ANSYS Mechanical in depth. It’s the continuation of subject AP.1.

The sections of this subject are:

- Lecture 1: Introduction
- Lecture 2: Pre-Processing
- Lecture 3: Structural Analysis
- Lecture 4: Post-Processing
- Lecture 5: Mesh Control
- Lecture 6: Connections and Remote Boundary Conditions

- Lecture 7: Modal, Thermal and Multistep Analyses
- Lecture 8: Eigenvalue Buckling and Submodeling Analyses

The next exercises from ANSYS Mechanical workbook of the introductory course will be also provided in order to complete the practical approach.

- Workshop 1.1: Mechanical Basics
- Workshop 2.1: 2D Gear and Rack
- Workshop 2.2: Named Selections
- Workshop 2.3: Object Generator
- Workshop 2.4: Object Generator with Named Selections
- Workshop 3.1: Linear Structural Analysis
- Workshop 3.2: Beam Connections
- Workshop 4.1: Mesh Evaluation
- Workshop 4.2: Parameter Management
- Workshop 5.1: Mesh Creation
- Workshop 5.2: Mesh Control
- Workshop 6.1: Contact Offset Control
- Workshop 6.2: Joints
- Workshop 6.3: Remote Boundary Conditions
- Workshop 6.4: Constraint Equations
- Workshop 7.1: Modal Analysis
- Workshop 7.2: Thermal Analysis
- Workshop 7.3: Multistep Analysis
- Workshop 8.1: Eigenvalue Buckling
- Workshop 8.2: Submodeling

A Course Order Index document has been created to help students follow a proper study order combining the different parts with their documentation (Lectures, Workshops and Assessment Exercises).

2. – BASIC TEXT AND OTHER TEACHING MATERIAL CONTENT

The teaching material for this subject is Introduction to ANSYS Mechanical 17.0 and the related exercises from the workbook.

Both training materials are the original ANSYS base texts for an introductory course of ANSYS Mechanical.

Software: ANSYS Mechanical

3. – BIBLIOGRAPHICAL REFERENCES

The software includes an interactive help section with specific help for each of the different themes dealt with. ANSYS software includes a lot of documentation with many practical examples and technical papers. It is important that students familiarize themselves with the software help and its documentation

4. - SPECIFIC RECOMMENDATIONS

Practicing with the computer and consulting the ANSYS Help is recommended.

5. - TUTORSHIPS

Students can contact tutors using the subject's virtual classroom.

INTRO TO ANSYS FEA SOFTWARE. EXAMPLES

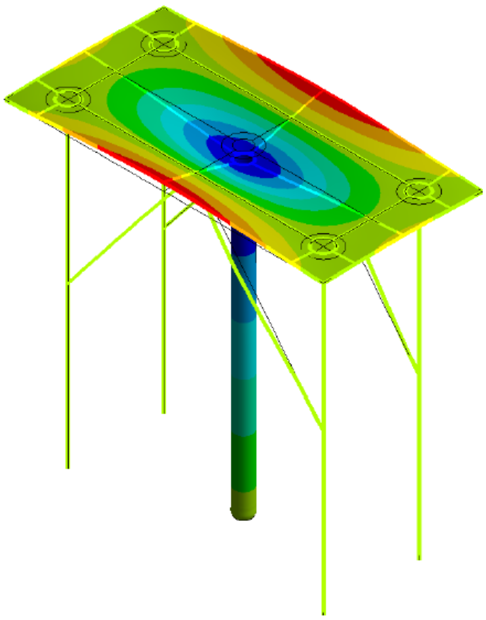
TEACHING STAFF

Ronald Siat, Civil Engineer

Alberto Mota, Civil Engineer

1.-OBJECTIVES

The objective of the course is to complete, with exercises that must be done using SpaceClaim and ANSYS Mechanical, the concepts explained previously in the



theoretical and application subjects of the Expert module.

The exercises of this subject will be done as the chapters of the AP1 and AP2 courses are studied.

The exercises of this subject must be sent to the tutors to be reviewed and graded using the subject's virtual classroom.

Therefore, only the statements will be provided at the beginning. Once the exercises have been sent and graded a complete solution will be provided for checking.

2.-CONTENT

The exercises represent a review of the concepts introduced in the subjects taken up to now, as well as the orderly use of the ANSYS SpaceClaim and ANSYS Mechanical software. The exercises will be similar to the following ones:

- Advanced analysis of a warehouse with temperature jump
- 3D Truss Bridge structural analysis
- Offshore platform design for different structural loads
- Structural analysis and validation of a Space Satellite.
- Structural analysis of a steam condenser
- Pre-stress bolt design of a union.

A Course Order Index document has been created to help students follow a proper study order combining the different parts with their documentation (Lectures, Workshops and Assessment Exercises).

3. - BASIC TEXT AND OTHER TEACHING MATERIALS

The teaching material is given with the resolved exercises proposed.

Software: ANSYS SpaceClaim and ANSYS Mechanical

4. - BIBLIOGRAPHICAL REFERENCES

Subjects of this course:

- AF.1: FEM general theory

- AF.2: FEM Introduction to programming

- AF.3: Numerical calculation

- AF.4: Material laws

5. - CONTINUOUS ASSESSMENT EXERCISES

The student should follow the instructions specified in the virtual classrooms by the professors.

6. - SPECIFIC RECOMMENDATIONS

This subject must be taken following the course order index document indications. The student must use the user's guide, manual of procedures and the online documentation of the corresponding commands, so that the main teachings of the different chapters can be completed and assimilated through practice.

7. - TUTORSHIPS

Students can contact tutors using the subject's virtual classroom.

8. - SENDING THE CONTINUOUS ASSESSMENT EXERCISES

The student will upload the continuous assessment exercises in the virtual classroom.

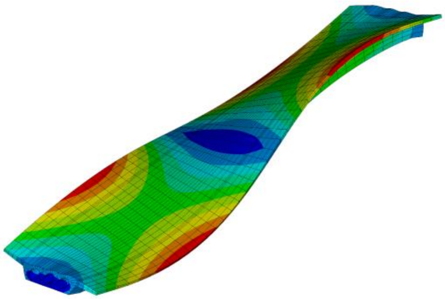
MODULE 6: DYNAMIC ANALYSIS

FEM THEORY APPLIED TO STRUCTURE DYNAMIC ANALYSIS

TEACHING STAFF

Marcos Latorre Ferrús *PhD Aeronautical Eng.*

1. - OBJECTIVES



The initial objectives are to analyze the problems that are presented when a structure calculation is going to be made with a commercial Finite Element program and to provide some criteria to resolve these, and to focus later on some specific structural types such as plates and sheets.

Finally, it is also intended to provide the essential concepts and to identify the fundamental parameters that characterize the dynamic behavior of structural systems.

2. - CONTENT

In the first chapter, we intend to present an overview of the problems and different decisions that a structural designer must take when performing a structural analysis.

The second chapter deals with plate and sheet theories. In addition, the plate theory is established for thin plate cases from the Kirchhoff hypothesis and for thick plates from the Mindlin-Reisner hypothesis. In both cases, the study addresses the case of linear elasticity for homogeneous, isotropic, perpendicular charged to its mid-surface plates of constant thickness.

Both linear theory and the membrane theory are developed for the constant thickness of thin sheets, and for the linear case, making the assumption of supposing homogeneous and isotropic material.

In the last chapters, the structural dynamic analysis is addressed. Thus, after a brief introduction and a review of the essential concepts, the treatment of the systems is studied with a degree of freedom in order to continue, after the mass and consistent damping matrix have been introduced, with the study of structural systems whose dynamic response can be characterized through a number of finite degrees of freedom.

INDEX

2.2.2. - Orthogonality of mode shapes

2.2.3. - Modal matrices

2.2.4. - Normalization of modes

2.2.5. - Response of undamped MDOF systems

2.3- Free damped vibrations of MDOF systems

2.4. - Response of MDOF systems under arbitrary loads

2.5. - Response of MDOF systems under harmonic loads

2.6. - Systems with distributed mass and stiffness

2.6.1. - Vibration of beams

2.6.2. - Vibration of plates

III. Introduction to signal analysis

3.1.-Introduction to signal types

3.1.1 Deterministic signals

3.1.2 Random signals

3.2. - Fourier analysis of signal

3.2.1. - The Fourier series

3.2.2. - The Fourier integral transform

3.2.3. - Digital signals

II. Finite element procedures for the dynamic analysis of structures

IV. Finite element discretization of continuous systems. Stiffness and Mass matrices

4.1. - Stiffness matrix

4.1.1 Beam elements

4.1.2 Continuum elements

4.2. - Mass matrices

4.2.1 Consistent mass matrix

4.2.2 Lumped mass matrix

V. Computational procedures for eigenvalue and eigenvector analysis.

5.1. - The modal decomposition revisited. Mode superposition analysis

5.2. - Other eigenvalue and eigenvector problems

5.3. - Computation of modes and frequencies

5.4. - Reduction of the general eigenvalue problem to the standard Eigen Value problem.

5.5. - Static condensation.

5.6. - Model order reduction techniques: the Guyan reduction

5.7. - Inclusion of damping matrices

5.8. - Complex eigenvalue problem: complex modes

VI. Computational algorithms for eigenvalue and eigenvector extraction

6.1. - Some previous concepts

6.1.1. - Matrix deflation

6.1.2. - Rayleigh quotient

6.1.3. - Courant minimax characterization of eigenvalues and Sturm sequence

6.1.4. - Shifting

6.1.5. - Krylov subspaces and Power

6.2. - Determinant search method

6.3. - Inverse iteration method

6.4. - Forward iteration method

6.5. - Jacobi method for the standard eigenvalue

6.6. - The QR decomposition and algorithm

6.7. - Jacobi method for the generalized eigenvalue

6.8. - Bathe's subspace iteration method and Ritz

6.9. - Lanczos method

VII. Transient analyses in linear elastodynamics

7.1.-Introduction

7.2. - Structural dynamics and wave propagation analyses. The Courant condition

7.3. - Linear multistep methods. Explicit and implicit algorithms. Dahlquist theorem

7.4. - Explicit algorithms: central difference method

7.5. - Implicit algorithms

7.5.1 Houbolt method

7.5.2 Newmark-β method

7.5.3 Collocation Wilson-θ methods

7.5.4 Hilbert-Hughes-Taylor (HHT) α−method

7.5.5 Bathe-Baig composite (substep) method

7.6. - Stability and accuracy analysis

VIII. Transient analysis in nonlinear dynamics

8.1. - The nonlinear dynamics equation

8.2. - Time discretization of the nonlinear dynamics equation

8.3.-Example: The nonlinear Newmark- β algorithm in predictor-d-form

IX. Harmonic analyses

9.1. - Discrete Fourier Transform revisited

9.2. - Harmonic analysis using the full space

9.3. - Harmonic analysis using mode

X. Spectral and seismic analyses

10.1. - Accelerograms and ground excitation

10.2. - The equation of motion for ground excitation. Accelerometers and vibrometers

10.3. - Elastic Response Spectra: SD, SV, SA, PSV, and PSA

10.4. - Modal superposition methods for spectral analysis. Modal

10.5. - Static correction or mode acceleration method

XI. Bibliography

3. - BASIC TEXT AND OTHER TEACHING MATERIALS

Course Learning Units

4. - BIBLIOGRAPHICAL REFERENCES

ALARCÓN, A., ALVAREZ, R. & GÓMEZ-LERA, S. *Cálculo Matricial de Estructuras*. Barcelona, Spain: Ed. Reverté, S.A., 1986. ISBN: 84-291-4801-9.

CLOUGH R.W. & PENZIEN J. *Dynamics of Structures.* 2nd edition. London, UK: Ed. McGraw-Hill, 1993. ISBN-10: 0071132414 / ISBN-13: 9780071332411.

HOU-CHENG HUANG. *Static and Dynamic Analysis of Plates and Shells.* Berlin, Germany: Ed. Springer-Verlag, 1989. ISBN-10: 0387195386 / ISBN-13: 9780387195384.

LAROZE S. & BARRAN, J.V. *Mécanique des Structures. Solides Èlastiques, Plasques et Coques. Vol. 1. Paris, France: Ed. Eyrrolles-Masson.*

PRZEMIENIECKI J.S. *Theory of Matrix Structural Analysis.* New York, USA: Ed. Dover Publications, 1986. ISBN-10: 0486649482 / ISBN-13: 9780486649481.

RAO S.S. *Mechanical Vibrations.* 5th edition. Singapore: Ed. Pearson Education Center, 2011. ISBN: 9788177588743.

TIMOSHENKO, S. & WOINOWSKY-FRIEGER, S. *Theory of Plates and Shells*. New York, USA: Mc Graw Hill, 1989. ISBN: 9780000858206.

Spanish version: TIMOSHENKO, S. & WOINOWSKY-FRIEGER, S. *Teoría de Placas y Láminas.* Bilbao, Spain: Ed. Urmo, 2005. ISBN: 9788431401160.

ZIENKIEWICZ, O.C. *Finite Element Method*. 5th edition. Oxford, UK: Ed. Butterworth-Heinemann, 2005.

Spanish version: ZIENKIEWICZ, O.C. *El Método de los Elementos Finitos.* Barcelona, Spain: Ed. Reverté, S.A., 2004.

5. - SPECIFIC RECOMMENDATIONS

It is generally advisable to resolve the simple exercises by analyzing the results obtained with different meshes and to verify to what extent the hypotheses made are fulfilled in the theoretical approaches.

On the other hand, it should not be forgotten that only with training in calculus could clear criteria be acquired. Therefore, it is recommended that students try to do similar exercises to the ones proposed for continuous assessment, but using problems from their professional activity as a base.

It is recommended to perform the Self-Assessment Tests, which will help the students know their learning status. Tests results are not taken into account for subject grades, only for student informative purpose.

6. - TUTORSHIPS

Students can contact the tutor using the subject’s virtual classroom.

Dr. Marcos Latorre Ferrús

E-mail: marcos.latorre@yale.edu

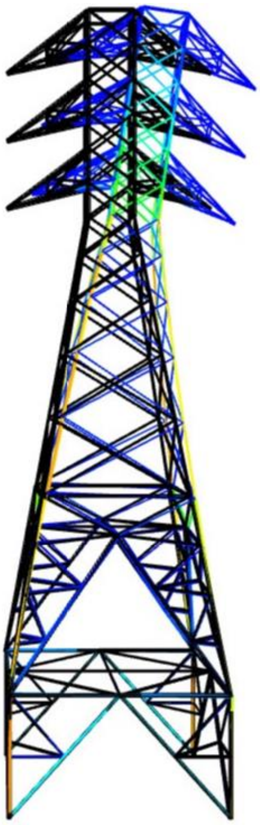
7. - SENDING THE CONTINUOUS ASSESSMENT EXERCISES

The student will upload the continuous assessment exercises in the virtual classroom.

DYNAMIC ANALYSIS WITH ANSYS FEA SOFTWARE

TEACHING STAFF

Ambrosio Baños, *MSc* Science.



1. - OBJECTIVES

The purpose of the subject is to introduce the student to the basic concepts of dynamic analysis of structures by using the practice program to resolve different types of dynamic analyses, so that theoretical concepts studied in previous chapters can be assimilated. Real problems will be studied with a Finite Element program (ANSYS Mechanical).

2. - CONTENT

The following analyses will be studied:

Type	Input	Output	Nonlinearity
Modal	○ none	○ natural frequencies and corresponding mode shapes ○ stress/strain profile	○ No
Harmonic	○ sinusoidally-varying excitations across a range of frequencies	○ sinusoidally-varying response at each frequency ○ min/max response over frequency range	○ No
Spectrum	○ spectrum representing the response to a specific time history	○ maximum response if the model were subjected to the time history	○ No
Random	○ spectrum representing probability distribution of excitation	○ response within specified range of probabilities	○ No
Transient	○ time-varying loads	○ time-varying response	○ Yes

The content of this subject is presented in two parts: software training notes and application exercises from the workbook.

The ANSYS Mechanical training notes are structured into the following chapters:

- Lecture 1: Introduction
- Lecture 2: Mechanical Basics
- Lecture 3: Damping
- Lecture 4: Modal Analysis
- Lecture 5: Harmonic Analysis
- Lecture 6: Linear Perturbation Analysis
- Lecture 7: Response Spectrum Analysis
- Lecture 8: Random Vibration
- Lecture 9: Transient Analysis

Various exercises are also proposed, involving the following topics: Modal Analysis, Transitory Analysis, Analysis of Harmonic Response, Spectral Analysis and PSD Analysis.

- Workshop 1: Intro. (Fly Wheel)
- Workshop 2: Mechanical Basics
- Workshop 3: Damping in Mechanical Workbench
- Workshop 4A: Modal Analysis (Plate with a Hole)
- Workshop 4B: Modal Analysis (Model Airplane Wing)
- Workshop 5: Harmonic Response (Fixed-Fixed Beam)
- Workshop 7: Response Spectrum (Suspension Bridge)
- Workshop 8: Random Vibration (Girder Assembly)
- Workshop 9A: Transient Analysis (Caster Wheel Test)
- Workshop 9B: Transient Analysis of a Gantry Crane
- Workshop 9C: Applying Initial Rotational Velocity

A Course Order Index document has been created to help students follow a proper study order combining the different parts with their documentation (Lectures, Workshops and Assessment Exercises).

3. - BASIC TEXT AND OTHER TEACHING MATERIALS

ANSYS Mechanical Linear and Nonlinear Dynamics 17.0

Software: ANSYS Mechanical

ANSYS Help

4. - BIBLIOGRAPHICAL REFERENCES

For bibliographical references, it is useful to use the ANSYS Help

5. - SPECIFIC RECOMMENDATIONS

This subject is very large and interesting; it offers a complete and exhaustive treatment of the different types of dynamic analyses that are made today using Finite Element software.

6. - TUTORSHIPS

Students can contact tutors using the subject's virtual classroom.

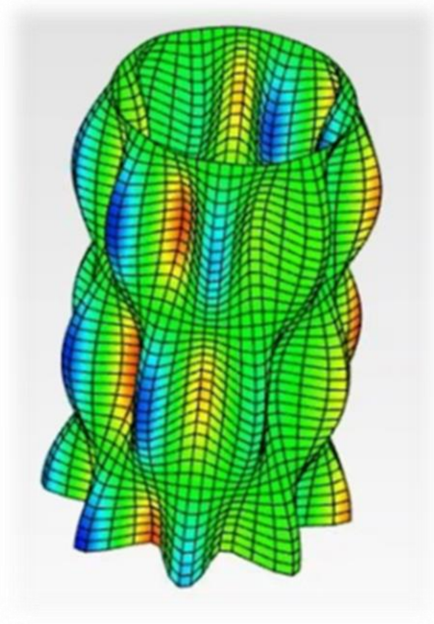
Email: ambrosio@invi.uned.es

Skype meetings can be scheduled with the tutor if necessary.

DYNAMIC ANALYSIS WITH ANSYS FEA SOFTWARE. EXAMPLES

TEACHING STAFF

Ambrosio Baños, *MSc* Science.



1. - OBJECTIVES

The exercises of this subject must be sent to the tutors to be reviewed and graded using the subject's virtual classroom.

Therefore, only the statements will be provided at the beginning. Once the exercises have been sent and graded a complete solution will be provided for checking.

The solutions provided will include the meshing, setup and post-processing stages of the analysis.

2. - CONTENT

The exercises provided are similar to the ones shown below:

- Frequency response of a bedplate.
- Transient response of a bedplate.
- Harmonic analysis of the behavior of a chimney subjected to wind loads (Vortex Shedding)
- Response spectrum analysis of a workbench
- Airbus A-320 Aircraft Wing Random Analysis (PSD analysis).

A Course Order Index document has been created to help students follow a proper study order combining the different parts with their documentation (Lectures, Workshops and Assessment Exercises).

3. - BASIC TEXT AND OTHER TEACHING MATERIALS

The documentation provided with the resolved exercises given pertaining to the dynamic analysis of ANSYS Mechanical composes the teaching material.

Software: ANSYS Mechanical. ANSYS SpaceClaim

4. - BIBLIOGRAPHICAL REFERENCES

Subjects of this course:

A.1. - Static and Dynamic Structural Analysis Foundations

A.2. - Dynamic Analysis Course. Application with the Practice Program

ANSYS Help

5. - CONTINUOUS ASSESSMENT BOOKLETS

The student must follow the instructions given in the virtual classroom by the professor.

6. - SPECIFIC RECOMMENDATIONS

This subject must be taken at the same time that the subject A.2 using the online documentation of the corresponding commands and onscreen menus, so that the other chapter's main teachings can be completed and assimilated through practice.

7. - TUTORSHIPS

Students can contact tutors using the subject's virtual classroom.

Email: ambrosio@invi.uned.es

Skype meetings can be scheduled with the tutor if necessary.

8. - ADDRESS FOR SENDING THE CONTINUOUS ASSESSMENT EXERCISES

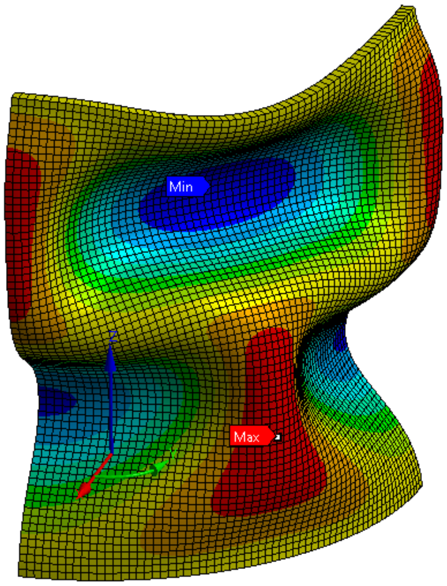
The student will upload the continuous assessment exercises in the virtual classroom.

MODULE 7: NON LINEAR ANALYSIS

F.E.M THEORY APPLIED TO NON-LINEAR STRUCTURES CALCULATION

TEACHING STAFF

José Mª Sancho Aznal



1. - OBJECTIVES

The purposes of this subject are get to know and understand the formulation using the Finite Element Method for nonlinear problems in structures from an engineering perspective, the application to large displacements, large deformations and stiffening by stress problems; as well as being an introduction to nonlinear mechanics of solids, and in addition to beam element formulation and their solution methods.

2. - CONTENT

INDEX

III. Matrix Formulation of Elements

3.1. - Incremental Equilibrium Equations

3.2. - Stiffness Matrix of a Hinged Bar

3.3. – Stiffness Matrix of a Bar Subjected to Flexure

IV. Solution Methods

4.1. - Loads Increment

4.2. - Critical Steps

4.3. - Arc-length Methods

4.4. - Instability Points Calculation. Linearized Buckling

3. - BASIC TEXT AND OTHER TEACHING MATERIALS

Teaching Units

4. - BIBLIOGRAPHICAL REFERENCES

Teaching units and references are in the same unit.

5. - TUTORSHIPS

Students can contact the tutor using the subject's virtual classroom.

Professor José Mª Sancho Aznal

E-mail: jmsancho@invi.uned.es

6. - SENDING THE CONTINUOUS ASSESSMENT EXERCISES

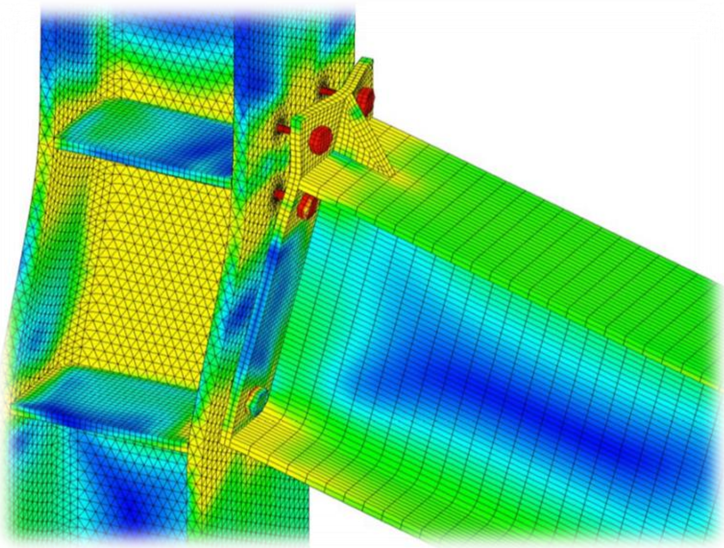
The student will upload the continuous assessment exercises in the virtual classroom.

NONLINEAR ANALYSIS WITH ANSYS FEA SOFTWARE

TEACHING STAFF

Ambrosio Baños, *MSc* Science.

1. - OBJECTIVES



The first objective of the course is to find answers to some basic questions of nonlinear structural calculation such as the following: What is a nonlinear structure? What kind of problem requires a nonlinear analysis? What are the causes of nonlinear behavior? What is different in a nonlinear analysis? What is different in a nonlinear analysis by finite elements? What are the essential peculiarities of a nonlinear analysis by finite elements? The second objective is to learn how to solve the questions using a Finite Elements program like ANSYS Mechanical.

2. - CONTENT

The content of this subject is structured into different chapters in which the different nonlinearities are described, the proceedings to address them, examples of each one and recommendations for their treatment.

In this, subject the various types of non-linear behavior, which can be grouped in three main groups, are studied with ANSYS Mechanical:

1. Geometric nonlinearities
2. Material nonlinearities
3. "Status" change nonlinearities (Contacts)

These topics will be seen in the following chapters:

- Overview
- General Procedures
- Introduction to Contact
- Introduction to Metal Plasticity
- Buckling
- Nonlinear Diagnostics

Furthermore, some examples of the application of the different types of nonlinear behavior are presented in the workbook:

- Workshop 2A: Small vs Large Deflection
- Workshop 2B: Performing a Restart
- Workshop 3A: Contact Stiffness Study
- Workshop 3B: Symmetric vs. Asymmetric
- Workshop 4A: Metal Plasticity
- Workshop 5A: Linear Eigenvalue Buckling Analysis
- Workshop 5B: Post Buckling Analysis
- Workshop 6A: Contact Diagnostics

A Course Order Index document has been created to help students follow a proper study order combining the different parts with their documentation (Lectures, Workshops and Assessment Exercises).

3. - BASIC TEXT AND OTHER TEACHING MATERIALS

The basic text for the course is the *ANSYS Mechanical Introduction to Structural Nonlinearities.*

Software: ANSYS Mechanical

4. - BIBLIOGRAPHICAL REFERENCES

From the aforementioned references, the following have been chosen:

- *ANSYS Help* (installed with the software)

5. - SPECIFIC RECOMMENDATIONS

This subject is very large as nonlinear problems are found in a wide range of technical applications. It is a good idea to study subject B.1 first.

It is advisable for students to follow the resolution of the exercises after studying each chapter and to resolve the problems highlighted in the text of the subject as well as the exercises of subject B.3 in the continuous assessment booklet.

6. - TUTORSHIPS

Students can contact tutors using the subject's virtual classroom.

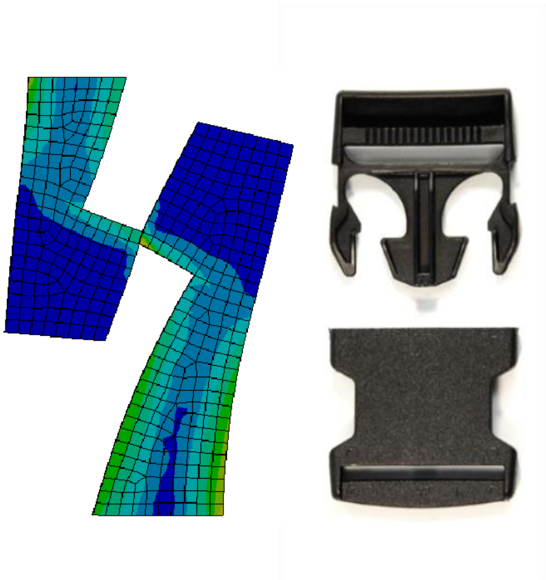
Email: ambrosio@invi.uned.es

NONLINEAR ANALYSIS WITH ANSYS FEA SOFTWARE. EXAMPLES

TEACHING STAFF

Ambrosio Baños, *MSc* Science.

1. - OBJECTIVES



The main goal of this subject is to complete, with exercises that have to be done using ANSYS, the concepts explained in the Theoretical and Application subjects of module B.

2. - CONTENT

The exercises provided are similar to the ones shown below:

1. Large Displacements: arc with concentrated load
2. Buckling: Linear and nonlinear buckling analysis of a pile
3. Large Strains: Compression of an axisymmetric disc

4. Plasticity: Disc under cyclic load
5. Contact exercise: locking tab

A Course Order Index document has been created to help students follow a proper study order combining the different parts with their documentation (Lectures, Workshops and Assessment Exercises).

3. - BASIC TEXT AND OTHER TEACHING MATERIALS

The basic documentation of the subject is provided with the resolved exercises given.

Software: ANSYS Mechanical

4. - BIBLIOGRAPHICAL REFERENCES

The references are the same as in the application subject.

5. - CONTINUOUS ASSESSMENT EXERCISES

The student must follow the instructions given in the virtual classroom

6. - SPECIFIC RECOMMENDATIONS

This subject must be studied at the same time as subjects B.1 and B.2. At some points of B.2, students are asked to do B.3 exercises. The additional exercises can be completed after B.1 and B.2.

7. - TUTORSHIPS

Students can contact tutors using the subject's virtual classroom.

Email: ambrosio@invi.uned.es

8. - SENDING THE CONTINUOUS ASSESSMENT EXERCISES

The student will upload the continuous assessment exercises in the virtual classroom.

MODULE 8: HEAT TRANSFER ANALYSIS

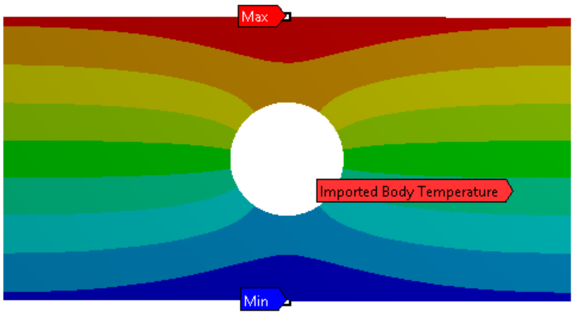
F.E.M THEORY APPLIED TO HEAT TRANSFER

TEACHING STAFF

Julio Hernández Rodríguez. Mechanical Engineer PhD, UNED.

Claudio Zanzi. Mechanical Engineer PhD, UNED.

1. - OBJECTIVES



This course aims to provide the theoretical knowledge about heat transfer and the finite element method necessary for its specific application in the resolution of heat transfer problems, as well as in stationary or non-stationary systems.

2. – CONTENT

INDEX

FIRST PART: HEAT TRANSMISSION BASIS

I. Basic Heat Transmission Mechanisms

1.1. - General considerations

1.2. - Heat Flow. Gauss Theorem

1.3. - Heat Conduction

1.4. - Convection

1.5. - Thermal Radiation

1.6. - Combined Convection and Radiation

II. Heat Transfer by Conduction

2.1. - Introduction

2.2. - Temperature Field in a Solid

2.3. - Contour Conditions

2.4. -2D Planar Wall in Steady State

SECOND PART: FINITE ELEMENT METHOD IN FLUID DYNAMICS AND HEAT TRANSMISSION PROBLEMS

5.3.4. - Galerkin FEM Application to a Non Stationary Problem of Heat Transfer with Convection Effects

VI. Exercises

3. - BASIC TEXT AND OTHER TEACHING MATERIALS

Teaching Units

4. - BIBLIOGRAPHICAL REFERENCES

CHAPMAN, A.J. *Heat Transfer.* 4th edition. New York, USA: Ed. Collier-McMillan, 1984. ISBN-10: 0023214708 / ISBN-13: 978-0023214707.

CUVELIER, C., SEGAL, A. & VAN STEENHOVEN, A.A. *Finite Element Methods and Navier-Stokes Equations*. Dordrecht, NL: Ed. Springer, 1986. ISBN-10: 90277221483/ ISBN-13: 978-9027721488.

FLETCHER, C.A.J. *Computational Techniques for Fluid Dynamics.* 2nd edition, vols. I and II. Sydney, Australia: Ed. Springer-Verlag, 1991. ISBN-10: 3540530584/ISBN-13: 978-3540530589.

LEWIS, R.W., ET AL. *The Finite Element Method in Heat Transfer Analysis*. West Sussex, UK: Ed. Wiley, 1996. ISBN-10: 0471943622/ ISBN-13: 9780471943624.

MCADAMS, W.H. *Heat Transmission*. 3rd edition. New York, USA: Ed McGraw-Hill, 1954. ISBN-10: 0070447993/ISBN-13: 9780070447998.

PEYRET, R. & TAYLOR, T.D. *Computational Methods for Fluid Flow.* USA: Ed. Springer-Verlag, 1983. ISBN-10: 3540111476/ISBN-13: 9783540111474.

TANNEHILL, J.C., ANDERSON, D.A., & PLETCHER, R.H. *Computational Fluid Mechanics and Heat Transfer*.2nd edition. Philadelphia, USA: Ed. Taylor & Francis, 1997. ISBN: 9781591690375.

WENDT, J.F. *Computational Fluid Dynamics: An Introduction*. 3rd edition. Belgium: Springer-Verlag, 2009. ISBN: 9783540850557.

ZIENKIEWICZ, O.C. *Finite Element Method*. 5th edition. Oxford, UK: Ed. Butterworth-Heinemann, 2005.

5. - TUTORSHIPS: OFFICE HOURS

Students can contact tutors using the subject's virtual classroom.

Professors: Dr. Julio Hernández Rodríguez and Claudio Zanzi

Mondays, from 4:00 pm to 8:00pm

Telephone: (+34) 91-398-64-24

E-mails: jhernandez@ind.uned.es, czanzi@ind.uned.es

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6. - SENDING THE CONTINUOUS ASSESSMENT EXERCISES

The student will upload the continuous assessment exercises in the virtual classroom.

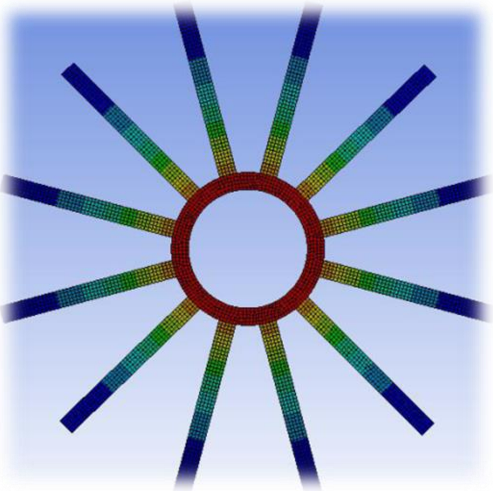
HEAT TRANSFER WITH ANSYS FEA SOFTWARE

TEACHING STAFF

Mr. Ambrosio Baños, *MSc* Science.

1. - OBJECTIVES

In this course, students come into contact with and manage, from an analysis by finite elements perspective, the basic concepts of heat transfer such as conduction and convection, at the same time as resolving stationary or transient heat transfer problems and other peculiarities of the thermal processes, which can be treated like nonlinearities.



The software, which allows the numerical treatment of problems, is ANSYS Mechanical.

2. - CONTENT

The content of this subject is presented in two parts: software training notes and application exercises from the workbook:

The ANSYS Mechanical training notes are structured in the following chapters:

- Lecture 1: Introduction
- Lecture 2: Heat Transfer Fundamentals
- Lecture 3: Preprocessing
- Lecture 4: Boundary Conditions
- Lecture 5: Steady-State Heat Transfer
- Lecture 6: Nonlinear Thermal Analysis
- Lecture 7: Transient Thermal Analysis
- Lecture 8: APDL and Command Objects

- Lecture 9: Thermal-Structural Coupled Analysis

The exercises from the workbook represent a review of the concepts related to heat transmission. A series of exercises containing the physics of thermal analysis will be proposed throughout the course:

- Workshop 1: Thermal Conduction Bar
- Workshop 2: Heating Coil
- Workshop 3: Thermal Contact
- Workshop 4: Radiating System
- Workshop 5: Solenoid
- Workshop 6: Fin Tube Heat Exchanger
- Workshop 7: Soldering Iron
- Workshop 8: Phase Change

A Course Order Index document has been created to help students follow a proper study order combining the different parts with their documentation (Lectures, Workshops and Assessment Exercises).

3. - BASIC TEXT AND OTHER TEACHING MATERIALS

The basic text is ANSYS Mechanical Heat Transfer 17.0.

Software: ANSYS Mechanical

4. - BIBLIOGRAPHICAL REFERENCES

Expanding the aforementioned references, the following have been chosen:

- ANSYS Help available at ANSYS installation directory

5. - SPECIFIC RECOMMENDATIONS

Even though the subject is short in length, it has its own peculiarities, so the student must handle the heat transmission concepts very well and must apply them to each case. Before starting, the student must manage the concepts of conduction and convection, and know what kinds of elements are useful to simulate these phenomena. At the same time, the student must know how to distinguish whether the problem is stationary or transitory.

6. - TUTORSHIPS

Students can contact tutors using the subject's virtual classroom.

Professors: Dr. Julio Hernández Rodríguez and Claudio Zanzi

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Telephone: (+34) 91-398-64-24

E-mails: jhernandez@ind.uned.es, czanzi@ind.uned.es

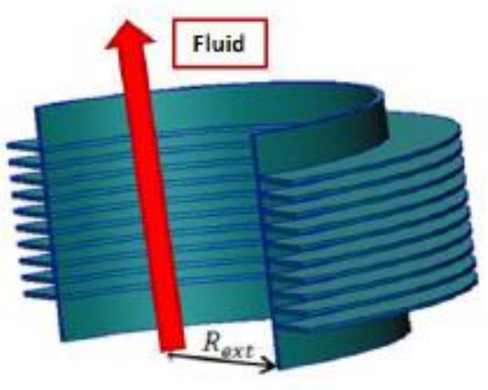
HEAT TRANSFER WITH ANSYS FEA SOFTWARE. EXAMPLES

TEACHING STAFF

Mr. Ambrosio Baños, *MSc* Science.

1. - OBJECTIVES

The main objective of this subject is to complete, with exercises that have to be done using ANSYS Mechanical, the concepts explained in the Theoretical and Application subjects of module C.



2. - CONTENT

The exercises of this subject must be sent to the tutors to be reviewed and graded using the subject's virtual classroom.

Therefore, only the statements will be provided at the beginning. Once the exercises have been sent and graded a complete solution will be provided for checking.

The solutions provided will include the meshing, setup and post-processing stages of the analysis.

The exercises provided are similar to the ones shown below:

- Thermal analysis of an igloo.
- Cryogenic tank thermal analysis.
- Thermal analysis of a finned tube.
- Concrete wall thermal analysis.

A Course Order Index document has been created to help students follow a proper study order combining the different parts with their documentation (Lectures, Workshops and Assessment Exercises).

3. - BASIC TEXT AND OTHER TEACHING MATERIALS

The basic documentation of the subject is provided with the proposed and resolved exercises.

Software: ANSYS Mechanical and ANSYS SpaceClaim

4. - BIBLIOGRAPHICAL REFERENCES

Subjects of this course:

C.1. - FEM Theory Applied to Heat Transfer

C.2. - Heat Transfer Course. Application with the Practice Program

In addition to the accompanying documentation specified in C.1 and C.2, the use of ANSYS Help is recommended.

5. - CONTINUOUS ASSESSMENT EXERCISES

The student must follow the instructions given in the virtual classroom.

Each exercise should not take more than three hours, although it is recommended that the student practices as much as possible with the menu in the post-process phase, analyzes, and interprets the physical sense of the results obtained.

6. - TUTORSHIPS

Students can contact tutors using the subject's virtual classroom.

Email: ambrosio@invi.uned.es

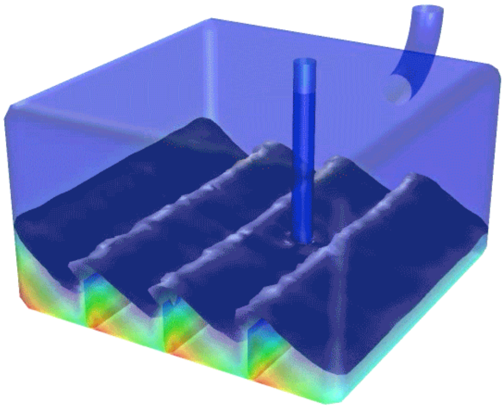
7. - ADDRESS FOR SENDING THE CONTINUOUS ASSESSMENT EXERCISES

The student will upload the continuous assessment exercises in the virtual classroom.

MODULE 9: FLUID MECHANICS

FEM THEORY APPLIED TO FLUID MECHANICS

TEACHING STAFF



Julio Hernández Rodríguez. Mechanical Engineer PhD, UNED.

Claudio Zanzi. Mechanical Engineer PhD, UNED.

1. - OBJECTIVES

In the first section of this subject, fluid mechanics foundations are studied with a particular emphasis on deduction and analysis of mass conservation equations, movement quantity and energy. Furthermore, the characteristics of different flow types are described and the conditions in which the different simplified shapes of general equations can be applied are discussed.

The comparative study of the different treatments, equations and contour conditions used will allow the student a better all-round understanding of the subject and the acquisition of indispensable knowledge in order to set out and carry out the numeric resolution of fluid mechanics problems of interest in engineering.

In the second part of the subject, an introduction to the finite element method application to some of the flow types studied in the first part is made.

2.-CONTENT

I. Introduction
   - 1.1. - Basic characteristics of fluids
   - 1.2. - Continuum hypothesis
   - 1.3. - Forces in fluids
   - 1.4. - Thermodynamic concepts
   - 1.5. - Transport Phenomena

II. Fluid Kinematics

2.1. - Description of the flow field. Substantial derivative. Acceleration of a fluid particle

2.2. - Concepts of pathline, streakline and streamline

2.3. - Some particular types of flow

2.4. - Analysis of relative motion near a point

2.5. - Circulation. Irrotational flow

III. General equations of Fluid Mechanics

3.1. - Time derivatives of integrals extended to fluid volumes

3.2. - Mass-conservation equation

3.3. - Momentum-conservation equation

3.4. - Energy conservation equation

3.5. - Summary of Fluid Mechanics equations

IV. Dimensional analysis and physical similarity

V. Approximate forms of the conservation equations

5.1. - Introduction

5.2. - Kinematic simplifications

5.3. - Simplifications of the constitutive laws or of the state equations

5.4. - Approximations based on considerations about the dynamics of the problem.

3. - BASIC TEXT AND OTHER TEACHING MATERIALS

Teaching Units

4. - BIBLIOGRAPHICAL REFERENCES

ARIS, R. *Vectors, Tensors, and the Basic Equations of Fluid Mechanics*. New York, USA: Ed. Dover Publication, Inc., 1990. ISBN-13: 9780486661100 / ISBN-10: 0486661105

BAKER, A.J. *Finite Element Computational Fluid Dynamics*. USA: Ed. Hemisphere, 1983. ISBN-10: 0070034656/ ISBN-13: 978-0070034655.

BATCHELOR, G.K. *An Introduction to Fluid Dynamics*. USA: Ed. Cambridge University Press, 2000. ISBN-10: 0521663962 / ISBN-13: 978-0521663960.

CRESPO, A. *Mecánica de fluidos*. Madrid, Spain: Ed. Paraninfo, 1997. ISBN: 9788497322928.

CUVELIER, C., SEGAL, A. & VAN STEENHOVEN, A.A. *Finite Element Methods and Navier-Stokes Equations*. Dordrecht, NL: Ed. Springer, 1986. ISBN-10: 90277221483/ ISBN-13: 978-9027721488.

FLETCHER, C.A.J. *Computational Techniques for Fluid Dynamics.* 2nd edition, vols. I and II. Sydney, Australia: Ed. Springer-Verlag, 1991. ISBN-10: 3540530584/ISBN-13: 978-3540530589.

GRESHO, Ph.M. (1989). *The Finite Element Method in Viscous Incompressible Flows*, Lecture Notes in Engineering, Vol. 43, pp. 148-190, Springer.

HIRSCH, C. *Numerical Computation of Internal and External Flows*. 2nd edition, vols. 1 and 2. Oxford, USA: Ed. John Wiley and Sons, 2007. ISBN-13: 9780750665940/ ISBN-10: 0750665947. LIÑÁN, A. *Mecánica de Fluidos*. Spain: Ed. Publicaciones de la ETS de Ingenieros Aeronáuticos, 1967.

PEYRET, R. & TAYLOR, T.D. *Computational Methods for Fluid Flow.* USA: Ed. Springer-Verlag, 1983. ISBN-10: 3540111476/ISBN-13: 9783540111474.

PIRONNEAU, O. *Finite Element Methods for Fluids*. Chichester, UK: Ed. John Wiley and Sons, 1989. ISBN-13: 9780471922551 /ISBN-10: 0471922552.

WENDT, J.F. *Computational Fluid Dynamics: An Introduction*. 3rd edition. Belgium: Springer-Verlag, 2009. ISBN: 9783540850557.

WILCOX, D.C. *Turbulence Modeling for CFD*. USA: DCW Industries, 2006. ISBN-13: 9781928729099.

5. - TUTORSHIPS: OFFICE HOURS

Students can contact tutors using the subject's virtual classroom.

Professor: Dr. Julio Hernández Rodríguez and Claudio Zanzi

Mondays, from 4:00 pm to 8:00pm

Telephone: (+34) 91-398-64-24

E-mails: jhernandez@ind.uned.es, czanzi@ind.uned.es

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6. - SENDING THE CONTINUOUS ASSESSMENT EXERCISES

The student will upload the continuous assessment exercises in the virtual classroom.

FLUID MECHANICS WITH ANSYS FEA SOFTWARE

TEACHING STAFF

Julio Hernández Rodríguez. Mechanical Engineer PhD, UNED.

Claudio Zanzi. Mechanical Engineer PhD, UNED.

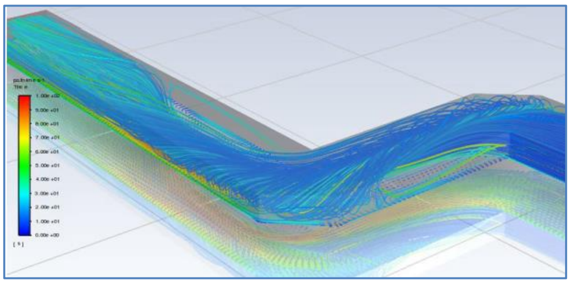
1. - OBJECTIVES AND CONTENT

The objective of this subject of Module F is to introduce the students to the field of CFD techniques, and in particular to familiarize them with ANSYS Fluent software for fluid mechanics.

This subject is divided into two parts: first of all the application texts and then the application exercises.

The subject has the following chapters about the ANSYS Fluent software:

- Lecture 01: SpaceClaim
- Lecture 02: CFD Overview and Demo
- Lecture 03: Fluent Meshing Overview and Surface Meshing



- Lecture 04: Regions and Volume Mesh
- Lecture 05: Fluent Workspace
- Lecture 06: Physics
- Lecture 07: Parametric Workflow
- Lecture 08: Solution Tab
- Lecture 09: Best Practice Guidelines
- Lecture 10: Turbulence
- Lecture 11: Heat Transfer
- Lecture 12: Transient Flows

To put into practice the knowledge acquired, some training examples are proposed with their respective geometry files in the part corresponding to application exercises. The ANSYS Fluent training examples illustrate a variety of flow scenarios with each case highlighting a particular feature of the code or the graphic interface.

A Course Order Index document has been created to help students follow a proper study order combining the different parts with their documentation (Lectures, Workshops and Assessment Exercises).

2. - BASIC TEXT AND OTHER TEACHING MATERIALS

Introduction to ANSYS Fluent

Software: ANSYS Fluent and ANSYS SpaceClaim

3. - BIBLIOGRAPHICAL REFERENCES

WHITE, F. M. *Fluid Mechanics*. Seventh edition. New York, USA: Ed. McGraw Hill, 1979. ISBN: 9780073529349.

JOHNSON, R. W. *The handbook of Fluid Mechanics.* Heidelberg, Germany: Ed. Springer, 1998. ISBN-10: 3540646124 /ISBN-13: 978-3540646129.

DAUGHERTY, R. L. *Fluid Mechanics with Engineering Applications.* 7^{th} edition. Ed. McGraw Hill, 1985. ISBN-10: 0070154279 /ISBN-13: 978-0070154278.

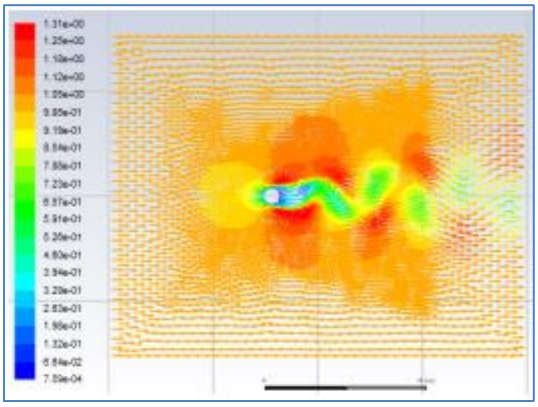
SAAD, M.A. *Compressible Fluid Flow.* Upper Saddle River, US: Prentice Hall, 1985. ISBN-13: 9780131613737 /ISBN-10: 0131613731.

4. - TUTORSHIPS

Students can contact tutors using the subject's virtual classroom.

FLUID MECHANICS WITH ANSYS FEA SOFTWARE. EXAMPLES

TEACHING STAFF



Julio Hernández Rodríguez. Mechanical Engineer PhD, UNED.

Claudio Zanzi. Mechanical Engineer PhD, UNED.

1. - OBJECTIVES AND CONTENT

The objective of this subject is to assimilate the concepts taught in subject F.1 and the use of the ANSYS Fluent program as a calculation tool (which has been developed intensively in subject F.2), in order to enter the fluid mechanics field with clear concepts and with a calculation tool. For this purpose, some exercises of progressive difficulty have to be resolved. At the same time, the student will verify the evolution of different magnitudes related to the fluid that is being studied, as well as the nature of the type of flow, which corresponds to the physical phenomenon studied.

The exercises of this subject must be sent to the tutors to be reviewed and graded using the subject's virtual classroom.

Therefore, only the statements will be provided at the beginning. Once the exercises have been sent and graded a complete solution will be provided for checking.

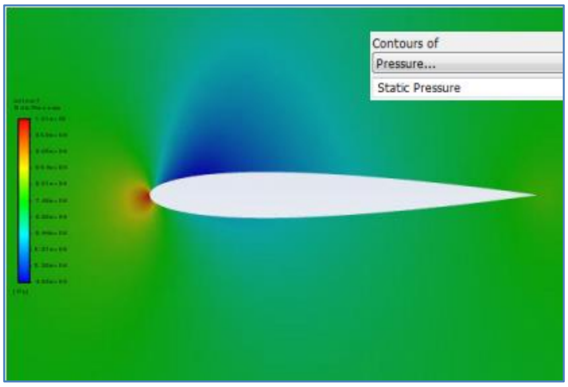
The solutions provided will include the meshing, setup and post-processing stages of the analysis.

A Course Order Index document has been created to help students follow a proper study order combining the different parts with their documentation (Lectures, Workshops and Assessment Exercises).

2. - BASIC TEXT AND OTHER TEACHING MATERIALS

The exercises provided are similar to the ones shown below:

- Workshop 01: Mixing Tee
- Workshop 02: Mixer
- Workshop 03: Heat Sink
- Workshop 04: Arcjet
- Workshop 05: Manifold
- Workshop 06: Duct Vanes
- Workshop 07: Obstacles
- Workshop 08: Valve
- Workshop 09: Airfoil
- Workshop 10: Electronics Cooling
- Workshop 11: Vortex Shedding



3. - BIBLIOGRAPHICAL REFERENCES

WHITE, F. M. *Fluid Mechanics*. Seventh edition. New York, USA: Ed. McGraw Hill, 1979. ISBN: 9780073529349.

JOHNSON, R. W. *The handbook of Fluid Mechanics.* Heidelberg, Germany: Ed. Springer, 1998. ISBN-10: 3540646124 /ISBN-13: 978-3540646129.

DAUGHERTY, R. L. *Fluid Mechanics with Engineering Applications.* Seventh edition. Ed. McGraw Hill, 1985. ISBN-10: 0070154279 /ISBN-13: 978-0070154278.

SAAD, M.A. *Compressible Fluid Flow.* Upper Saddle River, US: Prentice Hall, 1985. ISBN 13: 9780131613737 /ISBN 10: 0131613731.

4. - TUTORSHIPS

Students can contact tutors using the subject's virtual classroom.

Professor: Dr. Julio Hernández Rodríguez and Claudio Zanzi

Mondays, from 4:00 pm to 8:00pm

Telephone: (+34) 91-398-64-24

E-mails: jhernandez@ind.uned.es, czanzi@ind.uned.es

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5. - SENDING THE CONTINUOUS ASSESSMENT EXERCISES

The student will upload the continuous assessment exercises in the virtual classroom.

MODULE 10: COMPOSITE ANALYSIS OF STRUCTURES

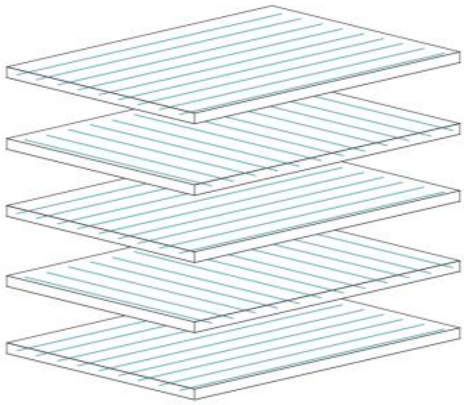
FINITE ELEMENT ANALYSIS OF COMPOSITE STRUCTURES

TEACHING STAFF

Professor Francisco Montans Leal *Mech. Engineer PhD*

Mr. Marcos Latorre Ferrús *MSc Aeronautical Eng.*

1. - OBJECTIVES



The objective of this module is to introduce the student to the basic concepts of the mechanical behavior of composite structures.

In the first part of the module, these materials are studied from an analytical point of view, analyzing first the mechanical response of single laminas and then the more complex behavior of laminates. Common failure criteria and general design concepts are presented. The comparison with experimental data will provide the required foundation to the derived theories.

In the second part of the subject, the basic formulations for the treatment of this type of material in a Finite Element code are introduced. A good understanding of all the concepts explained in the first part of the module is essential to successfully follow this computational approach. The content of this second part will be complemented with the practical sessions for Composite Structures.

The background of the student should include a mechanics of materials course, in which the fundamentals of tensor analysis, elasticity theory and the strength of materials are treated. A basic knowledge on finite element procedures would be desirable. A brief review of the basics needed for each Chapter is given throughout the text.

2. - CONTENT

1. Introduction to Composite Materials

a. What is a Composite Material?
b. Types of Composite Materials.
c. Advantages and disadvantages of composites.
d. Use of composite materials in industry.

2. Mechanical Analysis of a Lamina

a. Stress and strain tensors.
b. Constitutive equations for isotropic solids.
c. The linearized stress-strain behavior for transversely isotropic and orthotropic materials.
d. Apparent material constants. Coupling coefficients.
e. Failure criteria for composite laminas.
f. Determination of the overall behavior of a lamina through the behavior of its constituents. Strength of materials approach.
g. Determination of the overall behavior of a lamina through the behavior of its constituents. Theory of elasticity approach.
h. Determination of the strength properties of a lamina from its constituents.

3. Mechanical Analysis of Composites

a. Review of the theory of beams and plates.
b. In-plane and out-of-plane analysis of the behavior of a layered material.
c. Coupling coefficients.
d. Symmetric and unsymmetrical laminates.
e. Examples.

4. Failure and Design of Fiber-Reinforced Composites

a. Types of mechanical failure in composite materials.
b. Types of mechanisms that yield to failure in composite materials.
c. Strength of laminates.
d. Interlaminar stresses. Delamination.
e. Buckling of composite materials.

f. Resonance in composite materials.
g. Fatigue in composite materials.
h. Fracture in composite materials.
i. Considerations about a good design. Design requirements. Some basic optimization concepts.
j. Design of structural members made of composite materials.
k. Joints in composite materials.

5. Finite Element Formulations for Composites

a. Finite element formulation for isotropic, transversely isotropic and orthotropic solids.
b. Finite element formulation of plates. Approaches to the finite element formulation of a laminate. Recovery of strains and stresses.
c. Modelling delamination in finite elements.
d. A brief on finite element formulation of shells. Layout of fibers in a composite shell.
e. Linear and nonlinear analysis of composite structures.

3. - BASIC TEXT AND OTHER TEACHING MATERIALS

Course Learning Units.

It is recommended to perform the Self-Assessment Tests which will help the students know their learning status. Tests results are not taken into account for subject grades, only for student informative purpose.

4. - BIBLIOGRAPHICAL REFERENCES

JONES, R.M. *Mechanics of Composite Materials*. Taylor and Francis, 1999.

GIBSON, R.F. Principles of Composite Material Mechanics. CRC Press, 2012.

HALPIN, J.C. *Primer on Composite Materials: Analysis.* Technomic Publishing Company, 1992.

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BARBERO, E.J. Introduction to Composite Materials Design. CRC Press, 2011.

BARBERO, E.J. Finite Element Analysis of Composite Materials. CRC Press, 2008.

5. - TUTORSHIPS: OFFICE HOURS

Students can contact tutors using the subject's virtual classroom.

Professor Francisco Montans

E-mail: Fco.Montans@upm.es

Tutor: Mr. Marcos Latorre

E-mail: marcos.latorre@yale.edu

Tuesday and Thursday, from 16.00 to 18.00

6. - SENDING THE CONTINUOUS ASSESSMENT EXERCISES

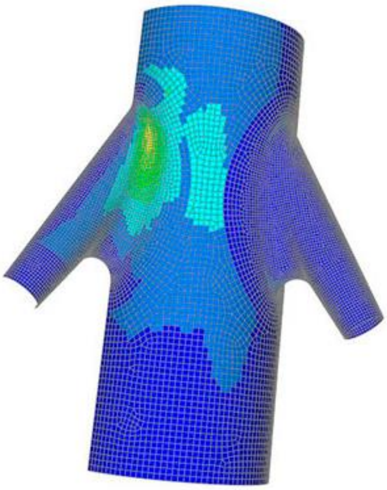
The student will upload the continuous assessment exercises in the virtual classroom.

COMPOSITE STRUCTURES WITH ANSYS FEA SOFTWARE

TEACHING STAFF

Ronald Siat *MSc Civil Eng.*

1. - OBJECTIVES



The purpose of the subject is to introduce the student to the basic concepts on composite materials and finite element procedures. The main aspects about this subject will be exposed by the way of elementary problems in composite materials, and will be studied with the finite element program provided (ANSYS Mechanical and ANSYS Composite Prep-post), taking into account the theoretical knowledge related in the previous subject.

2. - CONTENT

The content is presented in two parts: software training notes and application exercises from the workbook. The subject is structured into the following main topics:

- ANSYS Composite Prep Post Demonstration
- Composite Introduction
- ANSYS Composite Prep Post Introduction
- Rosettes
- The Oriented Element Sets
- Rules and Edge Sets
- Draping
- Solid Modeling
- Parameters in ANSYS Composite Prep Post
- Failure Criteria
- Progressive Failure and Crack Growth Analyses
- Tips and Tricks

Exercises available:

- Workshop 1: Introduction to ANSYS Composite Prep Post
- Workshop 2: Kiteboard
- Workshop 3: Helix
- Workshop 4: T-Joint
- Workshop 5: Rules
- Workshop 6: Basic/Advanced Sandwich Panel
- Workshop 7: Solid Modeling
- Workshop 8: Solid Modeling and Ply Drop Offs
- Workshop 9: Parameters in ANSYS Composite Prep Post
- Workshop 10: Scripting
- Workshop 11: Lay-up Mapping
- Workshop 12: Submodeling
- Workshop 13: Draping
- Workshop 14: Progressive Damage
- Workshop 15: Race Car Nose
- Workshop 16: Delamination

Ansys Composite PrepPost training is focused on engineers who are designing and analyzing layered composites. The training will cover the correct and efficient use of this technology for the purpose of overcoming some of the inherent challenges in composite modelling - such as capturing fiber orientation, model inspection, failure analysis and parameterization.

3. - BASIC TEXT AND OTHER TEACHING MATERIALS

- ANSYS Composite Prep Post Training
- Software: ANSYS Mechanical and ANSYS Composite Prep-post (ACP)
- Video Tutorials

4. - BIBLIOGRAPHICAL REFERENCES

JONES, R.M. *Mechanics of Composite Materials*. Taylor and Francis 1999.

KAW, A.K. Mechanics of Composite Materials. CRC Press 2006.

BARBERO, E.J. Introduction to Composite Materials Design. CRC Press 2011.

BARBERO, E.J. Finite Element Analysis of Composite Materials Design. CRC Press 2008.

5. – TUTORSHIPS:

Students can contact tutor using the subject's virtual classroom.

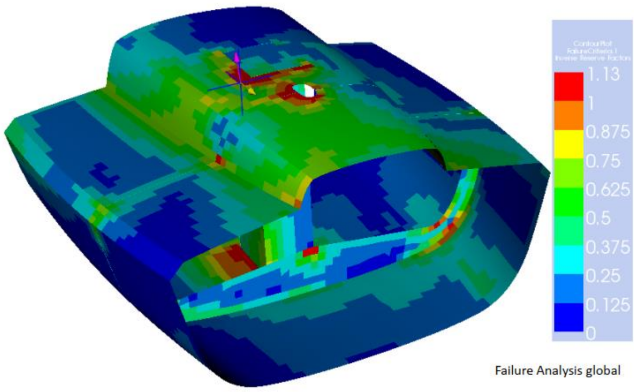
Ronald Siat r.siat@invi.uned.es

COMPOSITE STRUCTURES WITH ANSYS FEA SOFTWARE. EXAMPLES

TEACHING STAFF

Ronald Siat *MSc Civil Eng.*

1. - OBJECTIVES



Failure Analysis global

In this part of the course the student will find some additional exercises to help understand the behavior of composite materials, and acquire the ability to solve different types of composite structures.

The exercises of this subject must be sent to the tutors to be reviewed and graded using the subject’s virtual classroom.

Therefore only the statements will be provided at the beginning. Once the exercises have been sent and graded a complete solution will be provided for checking.

In addition to ANSYS numerical solution, it may be possible introduce an analytic solution to understand the mechanical behavior (stresses, strains and displacements) of composite structures.

Video tutorials are included as well.

2. - CONTENT

The exercises provided in this subject are similar to the ones shown below:

1. Analysis of a flat shell subjected to several loading conditions: solution and interpretation of results in terms of stresses, strains and displacements. Computation of membrane behavior with several ply tailoring lay ups.
2. Study of a cylindrical thin-walled tube loaded in torsion. Analysis on strength and stiffness behavior for different ply tailoring lay ups.

3. Computation of a solid beam with T shape and specific ply tailoring over the cross section (web and flange): analysis of strength and deflection under bending loads.
4. Final Problem: a flat plate with-without reinforcement of a central stringer, and several loading conditions.

Over these elementary problems the specific concepts about mechanic of composite materials and finite element procedures, exposed in the previous subject, will be applied:

- Making a Composite Model, solution and interpretation of results.
- Ply direction tailoring for strength and stiffness.
- Layup of Solid Composite Shells and Beams.
- Failure Criteria and Progressive Failure Analysis (PFA) on laminated composite materials.
- Linear Buckling on composite structures.

A Course Order Index document has been created to help students follow a proper study order combining the different parts with their documentation (Lectures, Workshops and Assessment Exercises).

3. - BASIC TEXT AND OTHER TEACHING MATERIALS

- Exercise statements
- Software: ANSYS ACP
- Video Tutorials

4. - BIBLIOGRAPHICAL REFERENCES

JONES, R.M. *Mechanics of Composite Materials*. Taylor and Francis 1999.

KAW, A.K. Mechanics of Composite Materials. CRC Press 2006.

BARBERO, E.J. Introduction to Composite Materials Design. CRC Press 2011.

BARBERO, E.J. Finite Element Analysis of Composite Materials Design. CRC Press 2008.

GAY, D. Composite Materials Design and Applications. CRC Press 2003.

VOYIADJIS, G.Z. Mechanics of Composite Materials with MATLAB. Springer 2005.

5. - CONTINUOUS ASSESSMENT EXERCISES

The student will upload the continuous assessment exercises in the virtual classroom.

More exercises will be proposed in the virtual classrooms during the course. The exercises must be sent through the virtual classroom.

6. - TUTORSHIPS: OFFICE HOURS

Students can contact the tutor using the subject's virtual classroom.

Ronald Siat r.siat@invi.uned.es

MODULE 11: MASTER'S FINAL PROJECT

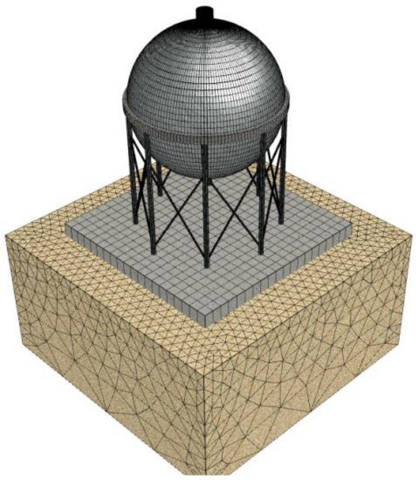
A. MASTER'S FINAL PROJECT ASSIGNMENT

In order to assign the master's final projects, there are two options:

A.1. Doing a Master's Final Project proposed by the course

The course has proposed various Master's Final Projects, related to the student´s specialties, so that the students can choose the most appropriate one (any other project may be proposed):

- Interpolation Methods and Numerical Approximation -1.
- Interpolation Methods and Numerical Approximation -2.
- Posteriori Error Estimation in the Finite Element Method.
- Jules Verne's Cannon.
- Dynamic Analysis Of The Structural Response Of A Tall Building Subjected To Aircraft Impact.
- Dynamic Analysis of a Bridge.
- Design Methods of Reinforced Concrete Shells.
- Tunnel Construction Process.
- Study of Diaphragm Walls.
- Non-linear Transient Analysis of a Dam.
- Advanced Contact Analysis.
- Reinforcement of Beam Elements According to Different Codes.



According to the project chosen, a tutor will be assigned to the student.

A.2. The student wishes to propose a specific project

Students can propose their own topic for their final projects, which may be of interest to the company where the student works, or it can be related to the student's personal interests, or their plans for professional activity.

When proposing the final project, students must take into account the size limitations of the educational practice program unless they have access to university facilities with greater capabilities, or a commercial installation in their respective companies.

Similarly, the final project must be related to the *Specialized Module Group* covered. Students should indicate on the application form the professor/lecturer that they would like to be their tutor for their Master's Final Project. The professor/lecturer should correspond to the modules studied by the students.

The Final Project must have the appropriate scope to be finally accepted.

To apply, students must send the application form according to these guidelines by e-mail to the following address: secretariat@ingeciber.com (the application form has a maximum of three pages).

A.3. Ownership and Submission of the projects

The intellectual property of the projects and the material property of the documents that integrate them will correspond to the Author of these. The Superior School of Industrial Engineers of UNED reserves the right to keep in its documentary collection projects, which it considers to be of special relevance or merit.