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220133 - Finite Elements in Structural Analysis

Coordinating unit: 205 - ESEIAAT - Terrassa School of Industrial, Aerospace and Audiovisual Engineering
Teaching unit: 737 - RMEE - Department of Strength of Materials and Structural Engineering
Academic year: 2019
Degree: BACHELOR'S DEGREE IN MECHANICAL ENGINEERING (Syllabus 2009). (Teaching unit Optional)
BACHELOR'S DEGREE IN INDUSTRIAL DESIGN AND PRODUCT DEVELOPMENT ENGINEERING (Syllabus 2010). (Teaching unit Optional)
BACHELOR'S DEGREE IN AEROSPACE VEHICLE ENGINEERING (Syllabus 2010). (Teaching unit Optional)
BACHELOR'S DEGREE IN INDUSTRIAL TECHNOLOGY ENGINEERING (Syllabus 2010). (Teaching unit Optional)
BACHELOR'S DEGREE IN AEROSPACE TECHNOLOGY ENGINEERING (Syllabus 2010). (Teaching unit Optional)
ECTS credits: 3 Teaching languages: English

Teaching staff

Coordinator: Joaquín A. Hernández Ortega

Others: Joaquín A. Hernández Ortega

Learning objectives of the subject

The goal of this course is to introduce finite elements in the context of structural analysis. We will consider the basic theory of the method as utilized as a structural engineering tool. Different structural topologies will be considered, from truss elements (based on the matrix structural analysis) to shell elements; passing through beam, solid, and axisymmetric elements. The primary tool we will use to learn about the basis of the method will be programming some elements in the software MATLAB. The key steps of the computer implementation will be presented in sufficient detail so that the student can understand what goes on behind the scenes of a typical commercial code.

Study load

Total learning time: 75h	Hours large group:	30h	40.00%
	Hours medium group:	0h	0.00%
	Hours small group:	0h	0.00%
	Guided activities:	0h	0.00%
	Self study:	45h	60.00%

Content

Module 1: Direct approach for discrete systems	Learning time: 10h Theory classes: 4h Self study : 6h

Description:
Description of a single bar element
Displacement, strain, stress, constitutive relation
Internal and external forces
Equations for Assembly
Boundary Conditions and Solution of the system
2D and 3D Truss, transformation law

Module 2: One-Dimensional element (FEM 1D)	Learning time: 8h Theory classes: 3h 12m Self study : 4h 48m

Description:
One-dimensional elastic problem (strong form)
The weak form in one dimension with arbitrary boundary conditions
Equivalence between weak and strong forms
Spatial discretization. Shape functions in one dimension.
Elemental stiffness matrix. Assembling.
Global stiffness matrix
Development of discrete equation system
Convergence by numerical experiments

Module 3: Beam element	Learning time: 12h Theory classes: 5h Self study : 7h

Description:
Review of general concepts
Governing equations of the beam (strong form)
Weak form. Integration by parts.
Hermite polynomials for both the displacements and the derivatives of the displacements (rotations)
Discrete equations
Moments and shear forces diagrams

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Module 4: Finite element in solids	Learning time: 20h Theory classes: 8h Self study : 12h

Description:
General review. Displacements, strains, stresses, Hooke law, equilibrium equations, boundary conditions
Virtual work principle (general case)
Plane stress. Plane strain
Triangular element. Quadratic element.
Numerical integration. Gauss quadrature in two dimensions

Module 4: Solids of revolution	Learning time: 10h Theory classes: 4h Self study : 6h

Description:
Elasticity relations for axial symmetry
Axisymmetric solid element
Discrete equations. Examples

Module 5: Plate and shell elements	Learning time: 15h Theory classes: 6h Self study : 9h

Description:
Reissner-Mindlin plate theory
Plate-bending elements
Doubly curved shells

Qualification system

The final grade is based on three assignements, each contributing 33.3% of the final mark. Students whose grade happens to be below 50% will be allowed to present a complementary work in order to raise their grade up to 50% (but not higher). The contents of the complementary work will be at the discretion of the teacher, depending of the circumnstances of each student. The deadline for delivering the complementary work will be 2 weeks after the end of the classes.

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Bibliography

Basic:

Fish, J.; Belytschko, T. A first course in finite elements [on line]. Chichester: John Wiley & Sons, 2007 [Consultation: 30/06/2016]. Available on: <http://onlinelibrary.wiley.com/book/10.1002/9780470510858>. ISBN 9780470035801.

Oñate, E. Cálculo de estructuras por el método de los elementos finitos : análisis estático lineal. 2ª ed. Barcelona: Centro Internacional de Métodos Numéricos en Ingeniería, 1995. ISBN 8487867006.

Cook, R. [et al.]. Concepts and applications of finite element analysis. 4th ed. New York [etc.]: Wiley & Sons, 2002. ISBN 0471356050.