POLITECNICO
MILANO 1863

Prof. A. BERNASCONI
Dr. Luca MARTULLI

Finite Element Simulation for Mechanical Design (FES4MD) also part of MECHANICAL BEHAVIOUR OF MATERIALS AND FINITE ELEMENT SIMULATION

Introduction

Aim and scope

The course aims at developing Finite Element based design skills in the framework of machine design.

Lecture and classwork aim at developing students' knowledge on the principles of Finite Element Analysis, aiming at developing the following application capabilities:

- to model the mechanical behaviour of mechanical structures and components
- to analyse the structure of a machine/component
- to communicate results in an effective and technically correct manner.

Topics

Module 1 Linear analyses

Topic 1.1 The finite element method: introduction, review of truss element formulation, shape functions, assembly of the stiffness matrix and handling of boundary conditions.

Topic 1.2 Solution techniques for FE problems. FE formulation of the Rayleigh-Ritz method.

Topic 1.3 2D elements: element types and shape functions; iso-parametric formulation. Integration of the stiffness matrix: Gauss points, full integration, reduced integration, shear locking; Zero energy modes. Stress evaluation and convergence analysis

Topic 1.4 Shell elements: formulation of Kirchhoff and Mindlin elements (shear flexible). Discrete Kirchhoff elements; solid to shell transformation (mid surface extraction).

Topics

Module 2 Non-linear analyses

Topic 2.1 Non-linearities related to large displacements

Topic 2.2 Contact problems: formulation and solution techniques

Topic 2.3 Non-linear behaviour of materials: plasticity

Module 3 Other analyses

Topic 3.1 Dynamic analyses: eigenfrequencies and eigenmodes of a FE model

Topic 3.2 Buckling analyses: critical loads and modes. Post-buckling analysis.

Weekly schedule

Tuesday

15:30 – 18:15 Room BL.27.13

Friday

10:30 – 12:15 Room B8.07

Teachers

Prof. Andrea BERNASCONI (AB)

Dr. Luca MARTULLI (LM)

Calendar

Date	Time	Hours	teacher	Topic/activity
13/09/2022	15:30-18:15	3	AB	Introduction to the course. Bar elements + exercise with bar elements
15/09/2022	10:30-12:15	2	LM	FE model using Bar Element
20/09/2022	15:30-18:15	2	AB	Beam elements + exercises
22/09/2022	10:30-12:15	2	LM	Analysis of a machine tool
27/09/2022	15:30-18:15			Graduation day
29/09/2022	10:30-12:15	2	AB	Geometric non linearities. Analysis of the mast of a fork lift
04/10/2022	15:30-18:15	2	AB	Dynamic analyses
06/10/2022	10:30-12:15	2	AB	Exercise on dynamic analysis
11/10/2022	15:30-18:15	2	LM	The FE form of the Rayleigh-Ritz method. 2D solid elements: element types.
13/10/2022	10:30-12:15	2	LM	2D solid elements: shear locking and comparison of element types.
18/10/2022	15:30-18:15	3	LM	2D solid elements: isoparametric formulation, reduced and full integration, stress evaluation
20/10/2022	10:30-12:15	2	LM	2D solid elements:plate with a hole and internal pressure, element type stresses and integration points.
25/10/2022	15:30-18:15	2	AB	Meshing techniques; Analysis of convergence; Exercise on analysis of convergence
27/10/2022	10:30-12:15	2	AB	Plasticity

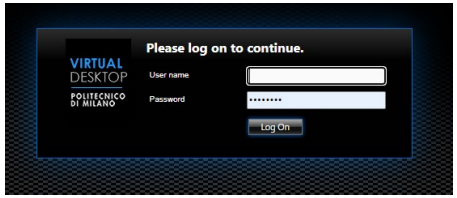
Calendar

01/11/2022 15:30-18:15			Holiday
03/11/2022 10:30-12:15			break for horizontal competencies courses
08/11/2022 15:30-18:15	3	LM	Exercise on plasticity
10/11/2022 10:30-12:15	2	LM	Comparison between 3D and beam element solutions: importance of boundary conditions, coupling + reference points
15/11/2022 15:30-18:15	2	LM	Stability of equilibrium
17/11/2022 10:30-12:15	2	LM	Stability of equilibrium: exercise
22/11/2022 15:30-18:15	2	AB	Plate and shell elements
24/11/2022 10:30-12:15	2	AB	Exercise on plate elements: boundary conditions and reaction forces.
29/11/2022 15:30-18:15	2	AB	Analysis of a machine tool's structure: comparison shell w beam models.
01/12/2022 10:30-12:15	2	AB	Contact problems
06/12/2022 15:30-18:15	3	LM	Exercise on contact problems (disk on half plane)
08/12/2022 10:30-12:15			Holiday
13/12/2022 15:30-18:15	2	AB	Exercise on post-buckling

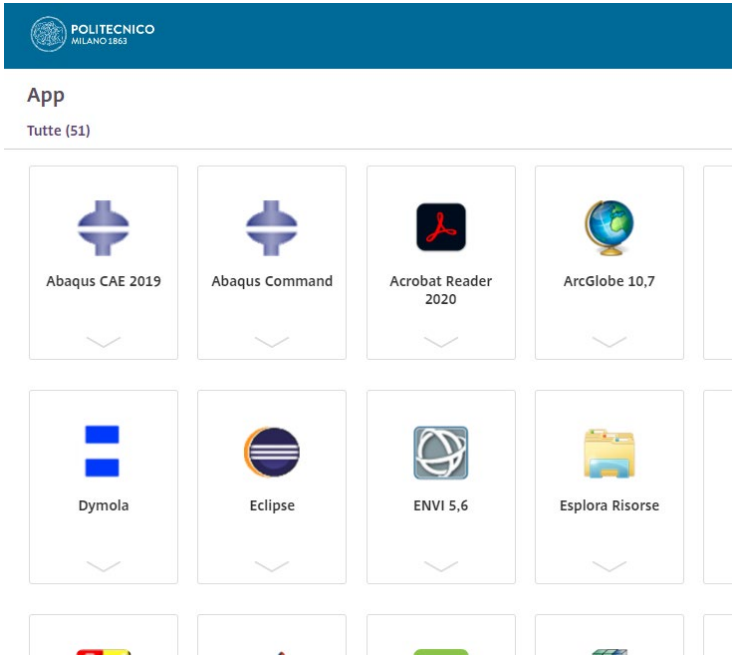
Software tools

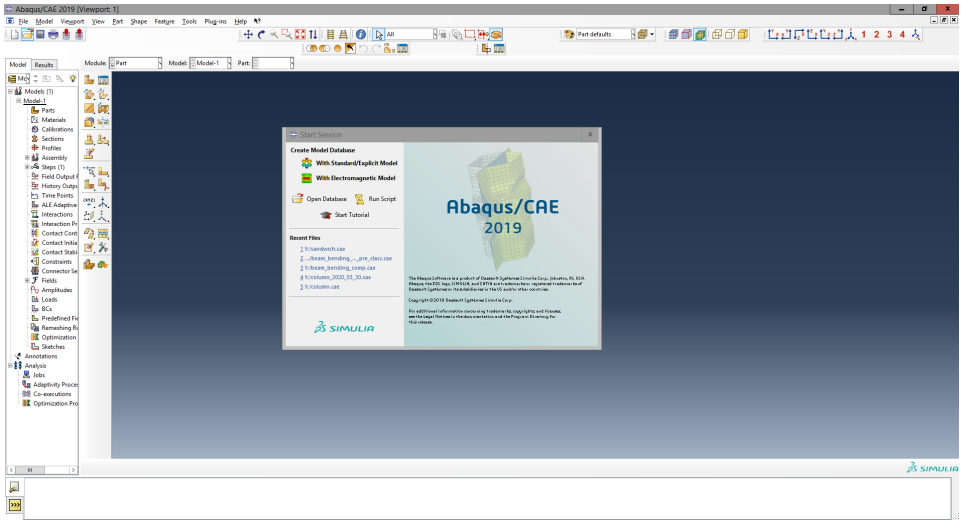
FE software is Abaqus

It can be accessed through Virtual desktop
https://virtualdesktop.polimi.it/vpn/index.html

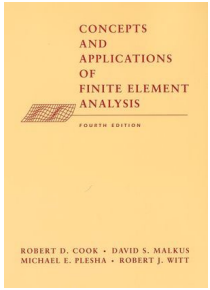


Same access from Polimi rooms and at home





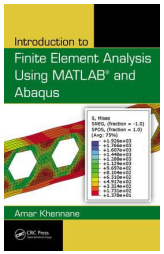
Books



Robert D. Cook, David S. Malkus, Michael E. Plesha, Robert J. Witt, Concepts and Applications of Finite Element Analysis, Editor: Wiley, 2001, ISBN: 978-0-471-35605-9

Unfortunately, it is not available as ebook

Alternatives for FEM, available as free ebooks



https://www.taylorfrancis.com/books/9780429166433

https://onlinelibrary.wiley.com/doi/book/10.1002/9781119107323

Exams: FINITE ELEMENT SIMULATION FOR MECHANICAL DESIGN

Students will pass the course after successfully taking an **oral** exam.

At the oral, they have to give a 10 minutes presentation (ppt slides or equivalent). The subject of the presentation is one Finite Element analysis case study of **their choice**, which will be discussed with the teacher. After the presentation, they may be asked to answer questions on the theoretical topics of all the modules.

Via this exam, it will be possible to test students':

- ability to communicate results in an effective and technically correct manner
- acquired knowledge of the principles of structural analysis by the finite element method
- ability to make decisions about the most appropriate modeling techniques.

EXAMS - 059688 - MECHANICAL BEHAVIOUR OF MATERIALS AND FINITE ELEMENT SIMULATION

To pass the course, students must successfully:

- Complete the numerical activity to be presented and discussed during the oral exam.
- Complete the experimental activity and write a report to be presented and discussed during the oral exam.
- Pass the oral exam.

The exam will be marked based on the oral exam.

The **oral exam** covers the full program of the course including numerical and experimental activities. The exams take the form of a one-to-one, face-to-face oral assessment.

At the oral, they have to give a 10 minutes presentation (ppt slides or equivalent). The subject of the presentation is one Finite Element analysis **case study of their choice**, which will be discussed with the teacher.

Via this presentation, it will be possible to test students':

- ability to communicate results in an effective and technically correct manner
- acquired knowledge of the principles of structural analysis by the finite element method
- ability to make decisions about the most appropriate modeling techniques.

After the presentation, the students shall answer theoretical questions. Via the oral exam, it will be possible to test students' acquired knowledge and understanding of theoretical aspects, the ability to communicate learnt contents and the ability to use the acquired knowledge in design mechanical components against failure.

Additional info about the Oral Exam

059686 - FINITE ELEMENT SIMULATION FOR MECHANICAL DESIGN

059209 - FINITE ELEMENT SIMULATION FOR MECHANICAL DESIGN

057270 - FINITE ELEMENT SIMULATION FOR MECHANICAL DESIGN

One presentation at the oral

In this case, the Finite Element case study must include an analysis type form the topic of the course

The structure must be chosen by the student

Examples:

- Evaluation of the stress concentration in a connecting rod, with convergence analysis
- Buckling analysis of a rod of a connecting rod

Suggested presentation outline

- Objective of the work
- Description of the structure
- Description of the loading and the boundary conditions
- Description of the model:
  - material's model
  - translation of the loading and boundary conditions in the corresponding FE ones
  - choice of the element type and size
  - ….
- Results
- Discussion of the results (with comparison with simplified, analytical solutions)
- Conclusions

Max 10 slides (not including the titlepage)

Additional info about the Oral Exam

059688 - MECHANICAL BEHAVIOUR OF MATERIALS AND FINITE ELEMENT SIMULATION 10 CFU

Two options:

- One single presentation at the oral, covering both Finite Element and Mechanical Behaviour of Materials

In this case, the Finite Element case study must include a material's model from Mechanical Behaviour of Materials

- Two separate presentations

In this second case, the Finite Element case study should be developed according to the rules set for 059686 - FINITE ELEMENT SIMULATION FOR MECHANICAL DESIGN

Oral exam on the same day for both parts

Additional info about the Oral Exam

Students enrolled in both

057270 - FINITE ELEMENT SIMULATION FOR MECHANICAL DESIGN

and

059687 - MODELING OF MECHANICAL BEHAVIOUR OF MATERIALS

097497 - MODELING OF MECHANICAL BEHAVIOUR OF MATERIALS A

097547 - MODELLING OF MECHANICAL BEHAVIOUR OF MATERIALS B

One presentation or two distinct presentations, like for students enrolled to 059688 - MECHANICAL BEHAVIOUR OF MATERIALS AND FINITE ELEMENT SIMULATION 10 CFU

Oral exam on the same day is neither mandatory - it is possible to sit for it on different dates - nor guaranteed.