THE DOCTORAL SCHOOL OF IPPT PAN

COURSE OFFERED IN THE DOCTORAL SCHOOL OF IPPT PAN

<table>
<tr><td rowspan="2">Name of the course</td><td>Polish</td><td colspan="4">Kurs wprowadzający z automatyzacji metody elementów skończonych</td></tr>
<tr><td>English</td><td colspan="4">An introductory course on automation of finite element method</td></tr>
<tr><td>Type of the course</td><td colspan="5">Specialized course</td></tr>
<tr><td>Course coordinator</td><td colspan="2">Prof. Tomasz Szolc, Ph.D., D.Sc., Mech. Eng.</td><td>Course teacher</td><td colspan="2">Dr. Mohsen Rezaee Hajidehi</td></tr>
<tr><td>Implementing unit</td><td>ZMM</td><td>Scientific discipline / disciplines</td><td colspan="3">Mechanical engineering</td></tr>
<tr><td>Level of education</td><td>Doctoral studies</td><td>Semester</td><td colspan="3">Summer or winter</td></tr>
<tr><td>Language of the course</td><td colspan="5">English</td></tr>
<tr><td>Type of assessment</td><td>Exam or project</td><td>Number of hours in a semester</td><td>36</td><td>ECTS credits</td><td>3</td></tr>
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<tr><td colspan="2">Type of classes</td><td>Lecture</td><td>Auditory classes</td><td>Project classes</td><td>Laboratory</td><td>Seminar</td></tr>
<tr><td rowspan="2">Number of hours</td><td>in a week</td><td>2</td><td>0</td><td>0</td><td>0</td><td>0</td></tr>
<tr><td>in a semester</td><td>36</td><td>0</td><td>0</td><td>0</td><td>0</td></tr>
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1. Prerequisites

Participants are expected to have a fundamental understanding of the finite-element method and basic knowledge of continuum mechanics. Knowledge of mathematics, including matrix algebra and differential equations is essential. Familiarity with numerical methods and programming is beneficial, as the course involves the use of the automatic differentiation (AD) technique in the finite-element method. Prior experience with symbolic computation is advantageous.

2. Course objectives

Advanced modeling techniques for addressing cutting-edge scientific questions and complex industrial challenges require sophisticated numerical simulations. Emerging computational formulations and advanced nonlinear material models often involve severe nonlinearities, making their numerical treatment highly challenging. One of the most demanding and error-prone tasks in finite-element code development is the manual derivation of finite-element matrices and vectors. Automated Computational Modeling, enabled by symbolic computation and automatic differentiation, offers an efficient solution for generating accurate, fast finite-element codes for linear and nonlinear problems.

The focus of this course is to familiarize the students with the Automated Computational Modeling in the finite-element method. Participants will be introduced to basic concepts of combined symbolic-numeric coding, highlighting the advantages gained in the presence of material and geometrical nonlinearities. Students will learn how to use the AceGen symbolic code generation tool for automating finite element derivations and AceFEM for solving boundary-value problems, both integrated within Wolfram Mathematica. A brief introduction to the finite element method is also included as a foundation for the course.

3. Course content (separate for each type of classes)

Lecture
1. Introduction to the finite-element method
2. Symbolic-numeric programming: introduction to AceGen

3. Automation of the finite-element models in AceGen • Formulation of standard material (linear and nonlinear elasticity) models • Solving boundary-value problems: introduction to AceFEM • Efficient coding and debugging • Formulation of multi-physics problems in AceGen • Computational plasticity: global-local problems • More complex boundary conditions: contact problems • Finite-element technology: more advanced elements • The use of Ace tools in solving complex research problems
Laboratory
Does not apply

4. Learning outcomes			
Number of the learning outcome	Learning outcomes description	Reference to the learning outcomes according to the 8th level of PRK	Learning outcomes verification methods*
Knowledge			
1	The student will acquire the knowledge of the finite-element method in solid mechanics.	P8S_WG	Exam/Active participation during the classes
2	The student will acquire the basic knowledge of the automatic differentiation technique and its applicability to finite-element formulations.	P8S_WG	Exam/Active participation during classes/project
3	The student will acquire the knowledge to approach real-world industrial and scientific problems by formulating and solving them as boundary-value problems.	P8S_WK	Exam/Active participation during the classes/project
Skills			
1	The student will be able to solve differential equations by using the Galerkin method.	P8S_UW	Active participation during the class
2	The Student will be able to formulate the real-world mechanical problems as boundary value problems and solve them by using the finite-element method.	P8S_UW	Exam/active participation during the class
3	The student will be able to apply the automatic differentiation tool in AceGen system to streamline the finite-element code derivation procedure and use the AceFEM system to solve boundary-value problems more efficiently.	P8S_UW	Exam/project
Communication			

1	The students will be able to use sophisticated material models to tackle their own research problems.	P8S_UU	Exam/project
2			
3			
Social competences			
1	The student will become familiar with recent advances in finite element technologies for addressing mechanically challenging problems.	P8S_KK	Active participation during classes
2	The graduate is ready to critically evaluate the achievements of the represented scientific discipline, including his or her own contribution to the development of this discipline.	P8S_KK	Active participation during classes

*Allowed learning outcomes verification methods: exam; oral exam; written test; oral test; project evaluation; report evaluation; presentation evaluation; active participation during classes; homework; tests

5. Assessment criteria
Active participation during classes, exam results and project evaluation

6. Literature

Primary references:

[1] **J. Korelc** and **P. Wriggers**, Automation of Finite Element Methods, 2016.

[2] **O. C. Zienkiewicz** et al., The finite element method: its basis and fundamentals, 2005.

[3] AceGen documentation (symech.fgg.uni-lj.si)

Secondary references:

[1] **J. C. Simo** and **T. J. R. Hughes**, Computational Inelasticity, 1998.

[2] …

7. PhD student's workload necessary to achieve the learning outcomes**

No.	Description	Number of hours
1	Hours of scheduled instruction given by the lecturer in the classroom	**36**
2	Hours of consultations with the lecturer, exams, tests, etc.	**20**
3	Amount of time devoted to the preparation for classes, preparation of presentations, reports, projects, homework	**24**
4	Amount of time devoted to the preparation for exams, test, assessments	**20**
	Total number of hours	**100**
	ECTS credits	**3**

** 1 ECTS = 25–30 hours of the PhD students work (2 ECTS ≈ 60 hours; 4 ECTS ≈ 110 hours, etc.)