Nonlinear FEM - BMEEOTMMN62

I. Subject Specification

1. Basic Data

1.1 Title

Nonlinear FEM

1.2 Code

BMEEOTMMN62

1.3 Type

Module with associated contact hours

1.4 Contact hours

Type	Hours/week / (days)
Lecture	2

1.5 Evaluation

Midterm grade

1.6 Credits

3

1.7 Coordinator

name	Dr. Nagy Róbert
academic rank	Assistant professor
email	nagy.robert@emk.bme.hu

1.8 Department

Department of Structural Mechanics

1.9 Website

https://epito.bme.hu/BMEEOTMMN62
https://fiek2.mywire.org/course/view.php?id=2001

1.10 Language of instruction

hungarian and english

1.11 Curriculum requirements

Recommended elective in the Specialization in Numerical modelling, Strcutural Engineering (MSc) programme

1.12 Prerequisites

1.13 Effective date

1 September 2017

2. Objectives and learning outcomes

2.1 Objectives

The main goal in this subject is, that the students get to know the solution with the finite element method (FEM) of the nonlinear mechanical problems typical in engineering practice, alongside with the mathematical background of the solutions. The specialities of one- and multidimensional problems will be discussed. There will be interpreted the nonlinear behaviour of the most important stuctures (beams, frames, plates, shells) from the practical use, with a focus on the important questions about the effect of large displacements and plastic deformations. Beyond the general nonlinearity the students will learn the special techniques (finite strip method, finite volume method, boundary element method, meshfree methods, smooth and finite particle methods, etc.). As an organic part of the course, students will analyse case studies solved by computer simulation, in order to deeper understand the modeling techniques of various nonlinearities and connect theory and practice.

2.2 Learning outcomes

Upon successful completion of this subject, the student:

A. Knowledge

1. understands the mathematical and mechanical reasons of the principal differences between the linear and nonlinear FEM,
2. understands the variational priciples required for the nonlinear modeling, and the strategy of a finite element analysis based on that,
3. knows the calculation methods of strain, stiffness, mass matrices and load vectors in modified and general Lagrangianand Eulerian description in the case of 1D, 2D and 3D modeling,
4. is familiar with the basic variations of the mathematical solution methods of the nonlinear finite element modeling, wiht an emphasis on the most important engineering problems,
5. understands the application of the Kármán-model for the calculation of beams and plates,
6. is familiar with the return algorithms for the calculation of the limit states of structures with elastic-hardening plastic materials, knows the material models of the calculation and the background of the crack propagation,
7. knows the basic finite element models of mixed- and hybrid variational formulations,
8. is familiar with the basic of the finite strip, finite volume, meshfree and boundary element method,
9. knows the principles of the finite element modeling using the particle based-, spline-, smoothening-techniques, and the possibilities of these mthods,

B. Skills

1. handels the finite element programs reliably for the solution of nonlinear mechanical problems and interprets the variables of the programs with their mechanical content,
2. elaborates necessary algorithms for the modeling of structures undergoing large displacements and deformations,
3. is able to elaborate algorithms for the analysis of engineering structures with physically nonlinear material behaviour (nonlinear elastic, plastic, damage models, etc.),
4. designs the complex algorithms required for engineering problems with multiple nonlinearities,
5. chooses and handels the appropriate finite element model for a technical problem with nonlinear effects,
6. designs the algorithms of special finite elements (splines, meshfree, smooth and particle elements), and

applies the softwares based on the special elements,
7. processes and critically interprets the literature,
8. uses clear and precise expressions in the oral and written communication,

C. Attitudes

1. works together with the tutor/lecturer and the fellow students while learning,
2. endeavors to discover and logical use the tools necessary to the problem solving of nonlinear mechanical problems,
3. endeavors to the precise and error-free problem solving,
4. aspires to prepare a well-organized documentation in writings, and pursues the precise self-expression in oral communication

D. Autonomy and Responsibility

1. independently carries out the conceptual and numerical analysis of structural engineering problems,
2. is open to accept well-founded critical comments.

2.3 Methods

Lectures, exercises, oral and written communication, application of IT tools and technologies.

2.4 Course outline

Week	**Topics of lectures and/or exercise classes**
1.	Classification of the numerical solution methods of mechanical problems based on error estimation. Stationarity and orthogonality conditions in Finite element modeling.
2.	Basics of finite elemnt analysis of nonlinear problems with Euler- and Lagrange description. Solution steps of a finite element analysis of a nonlinear 1-dimensional problem.
3.	Solution of 2- and 3-dimensional nonlinear problems using FEM.
4.	Types of numerical solutions, stabilty, convergence.
5.	Large deflections of beams and plates calculated with the Kármán-model.
6.	Large displacements of 3D frames.
7.	Calculation of the load carrying capacity of plates made of metals with elasto-plastic behaviour. Return algorithms.
8.	Calculation of the load carrying capacity of structures made of reinforced conrete with elasto-plastic

	behaviour.
9.	Analysis of transient problems. Application of mixed and hybrid variational formulations.
10.	Application of finite stip and fnite volume method.
11.	Application of the Boundary Element Method.
12.	Application of splines. Meshfree methods.
13.	Smooth and particle finite element modeling.
14.	Summary.

The above programme is tentative and subject to changes due to calendar variations and other reasons specific to the actual semester. Consult the effective detailed course schedule of the course on the subject website.

2.5 Study materials

Books: Kuczma-Wilmanski, Computer Methods in Mechanics, 2009.
Lecture notes: Bojtár Imre – Gáspár Zsolt, Nonlinear FEM, 2017.

2.6 Other information

1. Attendance at lectures is mandatory.
2. Students attending tests/exams must not communicate with others without explicit permission during the test/exam, and must not have an electronic or non-electronic device capable of communication switched on.

2.7 Consultation

The instructors are available for consultation during their office hours, as advertised on the department website. Special appointments can be requested via e-mail: bojtar.imre@epito.bme.hu.

This Subject Datasheet is valid for:

Inactive courses

II. Subject requirements

Assessment and evaluation of the learning outcomes

3.1 General rules

- Evaluation of learning outcomes described in Section 2.2. is based on one mid-term written checks and one homework.
- The duration of the mid-term test is 60 minutes.
- The dates of checks and the deadlines of homeworks can be found in the "Detailed semester schedule" on the website of the subject

3.2 Assessment methods

Evaluation form	Abbreviation	Assessed learning outcomes
Mid-term test (summarizing check)	ZH	A.1-A.9; B.1-B.6
Homework (continuous partial check)	HF	A.1-A.6; B.1-B.8; C.1-C.4; D.1-D.2

Dates and deadlines of evaluations can be found in the "Detailed course schedule" on the subject's website.
The dates of deadlines of assignments/homework can be found in the detailed course schedule on the subject's website.

3.3 Evaluation system

Abbreviation	Score
ZH	60%
HF	40%
Sum	**100%**

3.4 Requirements and validity of signature

There is no signature from the subject.

3.5 Grading system

- A minimum presence of 70% is required to gain a signature
- In the case of complying with the requirements on attendance the results are determined as follows.
- No requirements are made on the successfulness of the midterm-test.
- Homework must be submitted and must be accepted as completed to gain a semester mark.
- The midterm result is computed by the results of the mid-term tests and of the homework.
- The semester result is computed by the weighted average A of the mid-term test and the homework as in section 3.3.:

Grade	Average (A)
excellent (5)	80%≤A
good (4)	70%≤A<80%
satisfactory (3)	60%≤A<70%

passed (2)	50%≤A<60%
failed (1)	A<50%

3.6 Retake and repeat

- In this subject mid-term test can be retaken once.
- There is no second retake in this subject.
- Homeworks not submitted by deadline can be submitted after paying late fee until the end of the last class of the semester.

3.7 Estimated workload

Activity	**Hours/semester**
contact lesson	14×2=28
preparation for lessons during the semester	14×2=28
preparation for the checks	14
preparation of homework	20
Sum	**90**

3.8 Effective date

1 September 2017

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Inactive courses