Structural Optimization - BMEEOTMDT83

I. Subject Specification

1. Basic Data

1.1 Title

Structural Optimization

1.2 Code

BMEEOTMDT83

1.3 Type

Module with associated contact hours

1.4 Contact hours

Type	Hours/week / (days)
Lecture	2

1.5 Evaluation

Exam

1.6 Credits

3

1.7 Coordinator

name	Dr. Lógó János
academic rank	Professor
email	logo.janos@emk.bme.hu

1.8 Department

Department of Structural Mechanics

1.9 Website

https://epito.bme.hu/BMEEOTMDT83
https://edu.epito.bme.hu/course/view.php?id=2559

1.10 Language of instruction

hungarian and english

1.11 Curriculum requirements

Ph.D.

1.12 Prerequisites

1.13 Effective date

1 September 2022

2. Objectives and learning outcomes

2.1 Objectives

The purpose of the subject is, that the students acquire the basic concepts and methods of structural optimization. In the frame of this they will get to know the mathematical background. Namely: optimality conditions and duality with coverage of the nature, interpretation, and value of the classical Fritz John (FJ) and the Karush-Kuhn-Tucker (KKT) optimality conditions; the interrelationships between various proposed constraint qualifications; and Lagrangian duality and saddle point optimality conditions
Algorithms and their convergence, with a presentation of algorithms for solving both unconstrained and constrained linear and nonlinear programming problems.
Optimality criteria methods. Minimum weight design. Fundamental theories in topology optimization. Stress-constrained topology optimization. Governing equations. The “singularity problem” in stress-constrained optimization. Handling of constraints via local and global approaches. Mixed finite elements for the optimal design of structures. The displacement-based FEM. Analysis and design of no-tension structures, by formulating optimization problems. A constrained force density method (FDM).
Energy-based method, based on topology optimization, for the finite element analysis of no-tension solids (walls and vaults).
Overview of the currently used methods in SHM: Damage-sensitive sensor placement for sparsity constrained optimization; Modelling of damage in circular flange bolted connections.
Numerical Methods in Probabilistic Topology Optimization.

2.2 Learning outcomes

Upon successful completion of this subject, the student:

A. Knowledge

1. knows the fundamental mathematical theories of operational calculus,
2. knows the fundamental theories of structural design of elastic bar structures with the displacement method in matrix algebraic formulation,
3. knows the fundamental theories of structural design of elasto-plastic bar structures with the displacement method in matrix algebraic formulation,
4. knows the knows the fundamental theories of structural design of elastic membrane structures in matrix algebraic formulation,
5. knows the derivations of the optimality conditions of different structural models and their mathematical formulations,
6. knows the main steps of the finite element based optimization ,
7. knows the main steps of the finite element based topology optimization,
8. knows the main steps of the finite element based stress-constrained topology optimization
9. knows the main steps of the finite element based probabilistic topology optimization,

B. Skills

1. is able to derive the general formulas describing a structural optimization problem by the use of elasto-plastic materials,
2. is able to derive optimality condition in topology design
3. is able to solve a linear programming problem by the use of simplex method,

4. derives the static theorem of the constant stress of plasticity, and uses it accordingly,
5. derive the static theorem of plastic limit state analysis, and applies it to beam structures,
6. speaks out the kinematic theorem of plastic limit state analysis, and applies it to beam structures,
7. derives the fundamental formulations of topology design of membrane structures
8. derives the fundamental formulation of topology design of membrane structures by the use of stress constraints
9. shows the shakedown analysis with its static theorem and applies it for the shakedown analysis of a beam structure,

C. Attitudes

1. co-operates with the teachers in improving his/her knowledge,
2. expands his/her knowledge by constant learning,
3. endeavors to discover and routinely use the tools necessary to the problem solving of optimization problems,
4. aspires to prepare a well-organized documentation in writings, and pursues the precise self-expression in oral communication
5. is open to the use of IT devices

D. Autonomy and Responsibility

1. is able to individually think over the extremum problems of structural mechanics and to solve them using the given resources,
2. is open to valid criticism,
3. applies a systematic approach in his/her reasoning

2.3 Methods

Lectures with theoretical knowledge and computational examples, written and oral communication, use of IT devices and techniques, optional practice problems solved individually.

2.4 Course outline

Week	**Topics of lectures and/or exercise classes**
1.	Optimization of structures: basics. Governing equations. Problem formulation.
2.	Solution of the minimization problem. Applications.
3.	Stress-constrained topology optimization. Governing equations.
4.	The “singularity problem” in stress-constrained optimization. Handling of constraints via local and global approaches.
5.	Problem formulations. Applications.
6.	Mixed finite elements for the optimal design of

	structures. The displacement-based FEM.
7.	The use of “truly-mixed” fem is investigated to address specific applications.
8.	Analysis and design of no-tension structures, by formulating optimization problems. A constrained force density method (FDM).
9.	Energy-based method, based on topology optimization, for the finite element analysis of no-tension solids (walls and vaults).
10.	Introduction to Structural Health Monitoring
11.	Overview of the currently used methods in SHM: Damage-sensitive sensor placement for sparsity constrained optimization; Modelling of damage in circular flange bolted connections.
12.	Overview of the currently used methods in SHM: Detectability of loosened bolts in lap connections. Substructural methods for damage localization in skeletal structures.
13.	Reviewing Numerical Methods in Probabilistic Topology Optimization
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

a) Suggested readings:

- Mokhtar S. Bazaraa, Hanif D. Sherali, C. M. Shetty: Nonlinear Programming: Theory and Algorithms, 3rd Edition, Wiley, ISBN: 978-0-471-48600-8
- Prekopa A: Stochastic Programming, ISBN-13: 978-0792334828
- Kirsch, U. : Structural Optimization. Springer, Berlin, Heidelberg. https://doi.org/10.1007/978-3-642-84845-2_1

b) Online materials:

- on the website of the subject https://edu.epito.bme.hu/course/view.php?id=2559

c) Lecture notes:

- on the website of the subject https://edu.epito.bme.hu/course/view.php?id=2559

2.6 Other information

The exam is a ppt. presentation . Topic is a virtual optimization work based on the own research activity.

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

This Subject Datasheet is valid for:

2024/2025 semester II

II. Subject requirements

Assessment and evaluation of the learning outcomes

3.1 General rules

The exam is a ppt. presentation . Topic is a virtual optimization work based on the own research activity.

3.2 Assessment methods

Evaluation form	Abbreviation	Assessed learning outcomes
ppt presentation	ppt	A.1-A.9; B.1-B.9; C.1-C.5; D.1-D.3

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
ppt. presentation	100%
Sum	**100%**

3.4 Requirements and validity of signature

Attending the classes

3.5 Grading system

Grade	Points (P)
excellent (5)	80%≤P
good (4)	70%≤P<80%
satisfactory (3)	60%≤P<70%
passed (2)	50%≤P<60%
failed (1)P	<50%

3.6 Retake and repeat

general rules of study are apply

3.7 Estimated workload

Activity	Hours/semester
contact lessons	14×2=28
preparation for lessons during the semester	14×2=28
preparing to exam	34
Sum	**90**

3.8 Effective date

1 September 2022

This Subject Datasheet is valid for: