EUROPEAN UNIVERSITY FOR CUSTOMISED EDUCATION

STUDY GUIDE

THE NEW PARADIGM FOR LIGHTWEIGHT DESIGN – BIOMIMETIC STRUCTURAL OPTIMIZATION

Organised by

Poznan University of Technology

1. IDENTIFYING DATA.	
· Course Name.	*The new paradigm for lightweight design – biomimetic structural optimization*
· Coordinating University.	*Poznan University of Technology*
· Partner Universities Involved.	*None*
· Course Field(s).	*Optimal design, Mechanics, Engineering: vehicles,, aircrafts*
· Related Study Programme.	*None*
· ISCED Code.	*Broad field - 07 Engineering, manufacturing and construction, Narrow field - 071 Engineering and engineering trades, Detailed field - 0715 Mechanics and metal trades 0716 Motor vehicles, ships and aircraft*
· SDG.	*4, 9*
· Study Level.	*B*

· Number of ECTS credits allocated.	*2*
· Mode of Delivery.	*"Online live"*
· Language of Instruction.	*English*
· Course Dates.	*1.10.2024 – 10.12.2024*
· Schedule of the course.	*Number of hours: Lecture 6, Tutorials 14, Projects/seminars 10* *Classes every Tuesday at 10 a.m. (CET) starting from October*
· Key Words.	*Structural optimization, topology optimization, lightweight design, additive manufacturing, biomimetics*
· Catchy Phrase.	*The biomimetic structural optimization method - an extremely efficient approach to shape and topology optimization with the ability to create shapes that blend seamlessly with additive manufacturing methods, opening up new design possibilities and enabling greater innovation.* *“Opening up new design possibilities and enabling greater innovation - the biomimetic structural optimization method.”*

· Prerequisites and co-requisites.	*Knowledge: knowledge of methods of geometry modelling in CAD systems, basic knowledge of the construction of computer systems, basic knowledge in the field of structural analysis.*

	Skills: ability to use computer systems, the CAD system in the basic scope, model geometry in a CAD system and use finite element method in practice. *Social competencies: ability to work in a team, understanding the need to learn and acquire new knowledge.*
· Number of EUNICE students that can attend the Course.	*20 [2 students per university]*
· Course inscription procedure(s).	*Registration through EUNICE website*

2. CONTACT DETAILS.	
· Department.	*Faculty of Mechanical Engineering*
· Name of Lecturer.	*prof. dr hab. inż. Michał Nowak*
· E-mail.	*michal.nowak@put.poznan.pl*
· Other Lecturers.	-

3. COURSE CONTENT.
1. Introduction to the problem of structural optimization, review of software for structural optimization (introduction to the problem of structural optimization, parameterization of geometric models, the finite element method and its role in structural optimization procedures). *2. Size and shape optimization – basics.* *3. Topology optimization – basics.* *4. The essence and theoretical basis of structural optimization, practical application of structural optimization methods (configuration of a size optimization task, configuration of a shape optimization task, configuration of a topology optimization task, interpretation of the results of topology optimization, biomimetic structural optimization methods).* *5. Well known MATLAB topology based optimization code, developed by Ole Sigmund, is used as a tool for the new approach presentation. The code was modified and the comparison of the original and the modified, biomimetic optimization algorithm is also presented.* *6. The biomimetic optimization method reflects the real process of trabecular bone remodeling phenomenon. Cosmoprojector – the optimization system is presented in details. The industry ready optimization system joins in one procedure optimization of shape and topology. New paradigm lightweight design allows to start from the existing solution and natural implementation of multi load case approach.*

4. LEARNING OUTCOMES.
Knowledge

Student knows and understands:
1) , [P8S_WG/SzD_W01] global achievements, covering theoretical foundations as well as general and selected specific issues of structural optimization, to the extent that enables revision of existing paradigms,
2) . [P8S_WG/SzD_W02] key developmental trends of of structural optimization

Skills
Student can:
1) , [P8S_UW/SzD_U01] use knowledge from mathematics, mechanics, computer science to creatively identify formulate and innovatively solve complex problems or to perform research tasks.
- characterize the goals of structural optimization,
- apply practical structural optimization algorithms in the industrial environment.
2) . [P8S_UW/SzD_U01] A student can:
- characterize the goals of structural optimization,
- apply practical structural optimization algorithms in the industrial environment.

Social competences
Student is ready to:
1) . [P8S_KK/SzD_K01] describe the algorithms and available software in the field of structural optimization and critically assess achievements within structural optimization discipline

5. OBJECTIVES.

Transfer of knowledge about methods and processes related to advanced virtual design. Indication of the role of structural optimization in the design process. In the course new paradigm for structural optimization without volume constraint is presented. Since the problem of stiffest design (compliance minimization) has no solution without additional assumptions, usually the volume of the material in the design domain is limited. The biomimetic approach, based on trabecular bone remodeling phenomenon is used to eliminate the volume constraint from the topology optimization procedure. Instead of the volume constraint, the Lagrange multiplier is assumed to have a constant value during the whole optimization procedure. With the use of the new optimization paradigm, it is possible to minimize the compliance by obtaining different topologies for different materials. It is also possible to obtain different topologies for different load magnitudes. Both features of the presented approach are crucial for the design of lightweight structures, allowing the actual weight of the structure to be minimized.

6. COURSE ORGANISATION.

UNITS	
1.	*Introduction to the problem of structural optimization, review of software for structural optimization*

2.	*Size and shape optimization – basics*
3.	*Topology optimization – basics*
4.	*The essence and theoretical basis of structural optimization, the new paradigm*
5.	*Multiple load case problem – solved by Nature*
6.	*Numerical implementation of the optimization method and discussion of the use of additive manufacturing*

LEARNING RESOURCES AND TOOLS.

- Website with the basic material for learning: cosmoprojector.com
- Web based software for structural optimization

PLANNED LEARNING ACTIVITIES AND TEACHING METHODS.

The learning activities:
- lectures
- seminars on various ways to solve the structural optimization problem
- working with cloud computing optimization systems

7. ASSESSMENT METHODS, CRITERIA AND PERIOD.

Test for:
- level of knowledge,
- application of knowledge,
- potential problem solving skills

OBSERVATIONS.

8. BIBLIOGRAPHY AND TEACHING MATERIALS.

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[2] M. Nowak, J. Sokołowski, and A. Żochowski, "Biomimetic approach to compliance optimization and multiple load cases", J. Optim. Theory Appl., vol. 184, no. 1, pp. 210–225, 2020, doi: 10.1007/s10957-019-01502-1.
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Additional
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