POZNAN UNIVERSITY OF TECHNOLOGY

EUROPEAN CREDIT TRANSFER AND ACCUMULATION SYSTEM (ECTS)

COURSE DESCRIPTION CARD - SYLLABUS

Course name
Tissue modelling including adaptation and evolution [S2IBio1E-IIiP>MBiET]

Course

Field of study
Biomedical Engineering

Year/Semester
2/3

Area of study (specialization)
Engineering of Implants and Prosthesis

Profile of study
general academic

Level of study
second-cycle

Course offered in
English

Form of study
full-time

Requirements
compulsory

Number of hours

Lecture
15

Laboratory classes
15

Other
0

Tutorials
0

Projects/seminars
0

Number of credit points

2,00

Coordinators

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Lecturers

Prerequisites

KNOWLEDGE: Knowledge of geometry modeling methods in CAD systems. Basic knowledge of the construction of computer systems. basic knowledge of structural analysis. SKILLS: Ability to use computer systems. Ability to use a basic CAD system. Ability to model geometry in the CAD system. Ability to use the finite element method in practice. SOCIAL COMPETENCES: Ability to work in a team. Understanding the need for learning and acquiring new knowledge.

Course objective

The solid body evolution and growth modeling area combining two main scientific domains which are biology and engineering. In both those domains the important scientific aspects were the models of evolutionary solid bodies from biological and engineering point of view. The solid body evolution and growth modeling thus encompasses those two aspects, which have entered into the realm of continuum mechanics in the 1990's. Thereby, one attempts to incorporate time-dependent phenomena, basically consisting of a variation of material properties, mass, shape and topology of the solid body. The tools needed for simulation of these biological phenomena involve the following fields: - open systems thermodynamics, - configurational mechanics, - biological evolution in relation to the mechanobiology of the cell, - shape and topology optimization in relation to functional adaptation, - multiscale approaches and homogenization techniques. One main objective of the course is to present the computational techniques known in structural optimization and combine them with rigorous mechanical models for open systems and modifications in material space, which are typical for biological systems. The perfect illustration of these concepts flow is modeling of the phenomenon of trabecular bone functional adaptation. The models for bone internal and external remodeling at both trabecular and macroscopic levels, based on a description of the modification of internal density and the evolution of the surface of trabeculae due to mechanical and chemical stimuli.

Course-related learning outcomes

Knowledge:
1. The student has basic knowledge of engineering design and engineering graphics, allowing to design objects and processes, systems in terms of systems, machine elements; formulate and analyze problems; look for solution concepts; apply engineering calculations, select and evaluate solution variants; use modeling, optimization and knowledge bases in engineering design, computer-aided design process, technical drawing; read drawings and diagrams of machines, devices and technical systems; describe their structure and principles of operation. K_W05
2. The student has detailed knowledge covering the key issues of the functioning and growth of tissues, has an ordered, theoretically founded general knowledge covering the issues of modeling and numerical simulation of tissue growth and evolution, with particular emphasis on bone structures. K_W14
3. The student has a basic knowledge of development trends in the issues of modeling and numerical simulation of tissue growth and evolution. K_W20

Skills:
1. The student is able to obtain information from literature, databases and other properly selected sources; in particular, can describe the issues of biochemistry and biophysics and combine them with technical issues and engineering design, can integrate the obtained information, interpret it, and find similarities of the developed methods in the field of engineering and the achievements of Nature. K_U01
2. The student is able to use information and communication techniques appropriate to the implementation of tasks typical for engineering activities. K_U07
3. The student is able to carry out computer simulations, interpret the obtained results and draw conclusions. He can use computer aids to solve technical tasks, in particular in the field of configuration mechanics. K_U08
4. Can solve technical problems based on the laws of mechanics; should understand the essence of biological evolution in relation to cell mechanobiology, and use numerical tools for the needs of growth modeling also using the multiscale approach and homogenization technique. K_U15

Social competences:
1. The student can interact and work in a group, assuming different roles in it. K_K03
2. The student is able to set priorities for the implementation of the tasks set by himself or others, especially in the area of modeling changes in living organisms. K_K04

Methods for verifying learning outcomes and assessment criteria

Learning outcomes presented above are verified as follows:

Learning outcomes presented above are verified as follows:
Oral and written tests. Individual assessment of completed projects.
Test for:
- level of knowledge,
- application of knowledge,

- potential problem-solving skills.
The condition for receiving a positive evaluation is obtaining at least 50% of the possible points. This applies to all forms of classes.

Programme content

Lecture topics:
1. Introduction to the modeling of tissue growth and evolution.
2. Biological and chemical aspect of the processes taking place in living organisms.
3. Structural optimization and the way of its implementation by living organisms.
4. The essence of the process of adaptive reconstruction of the trabecular bone - biological process and its characteristics from the point of view of mechanical engineering.
5. Issues of building computational models and the problem of discretization.
6. Practical problems and methods of modeling tissue growth and evolution.
7. Numerical aspects of practical implementation of tissue growth and evolution modeling procedures.
8. Summary and discussion of the directions of development of methods of modeling the growth and evolution of tissues.
Practical classes (computer lab):
1. Parameterization of geometric models.
2. Finite element method and its specificity in the case of procedures modeling tissue growth and evolution.
3. The problem of structural optimization of the living world - software examples.
4. Methods of obtaining information and a geometric description of the growth and remodeling of biological tissues - available software.
5. Practical application of algorithms for modeling tissue growth and evolution.
6. Similarities and differences in the practical implementation of the biomimetic algorithm of structural optimization and topological optimization based on the evolution of the density of artificial material.
7. Final test.

Course topics

none

Teaching methods

An interactive lecture using multimedia presentations.

Bibliography

Basic
1. Będziński, R., Biomechanika inżynierska : zagadnienia wybrane, Oficyna Wydawnicza Politechniki, 1997
2. Tkacz E., Borys P., Bionika, ISBN: 9788320434040, WNT, 2015
3. Samek A., Bionika w kształceniu, Wydawnictwa AGH, 2013
4. Huiskes R If bone is the answer, then what is the question? J Anat 197:145–156, 2000
5. Huiskes R et al (2000) Effects of mechanical forces on maintenance and adaptation of form in trabecular bone. Nature 404:704–706, 2000
6. Klarbring A, Torstenfelt B, Lazy zone bone remodelling theory and its relation to topology optimization. Ann Solid Struct Mech 4(1):25–32, 2012
7. Nowak M, Structural optimization system based on trabecular bone surface adaptation. J Struct Multidiscip Optim 32(3):241– 251, 2006
8. Nowak M, On some properties of bone functional adaptation phenomenon useful in mechanical design. Acta Bioeng Biomech 12(2):49–54, 2010
9. Sigmund O, On the optimality of bone microstructure. Synthesis in Bio Solid Mechanics, Kluwer 221–234, 1999
10. Nowak M., Projektowanie konstrukcji o wysokiej sztywności z zastosowaniem optymalizacji strukturalnej, HYPERLINK "https://sin.put.poznan.pl/organizations/details/wydawnictwo-politechniki-poznanskiej"Wydawnictwo Politechniki Poznańskiej , ISBN 978-83-7775-460-3, 2017.
Additional
1. Nowak M., Gnarowski W. and Abratowski P., Structural Optimization of Helicopter AirLanding Rope Console with Multiple Loading Conditions, The 40th Solid Mechanics Confrence SolMech2016, 29.08-2.09 2016, Warsaw, 2016

2. Ohlsen J., Herzog F., Raso S. et al., Function Integrated, Bionic Optimised Vehicle Lightweight Structure in Flexible Production. ATZ Worldw 117, pp. 34–39, https://doi.org/10.1007/s38311-015-0060-7, 2015.
3. Zander K., Sokolov D., Schwarz W. et al., Headlamp of 2025 Bionically Inspired, Additively Manufactured. ATZ World 118, pp. 36–41, https://doi.org/10.1007/s38311-015-0099-5, 2016.

Breakdown of average student's workload

	Hours	ECTS
Total workload	50	2,00
Classes requiring direct contact with the teacher	30	1,00
Student's own work (literature studies, preparation for laboratory classes/ tutorials, preparation for tests/exam, project preparation)	20	1,00