Focus Specialisation in Design, Mechanics and Materials

Prof. Kristina Shea + Colleagues
Outline

- Introduction and Motivation
- Lectures
- Bachelor Theses and Research
- Beyond Your Bachelor Degree
Diverse Industry Domains: Beyond the Traditional!

Image credit: Audi

Image credit: robotics & automation news
Mechanical Systems are Highly Interdisciplinary

- Materials
- Engineering Design
- Mechanics
- New Technologies
- Computing

Image credit: Audi
The design, analysis, simulation, optimization and evaluation of modern mechanical and mechatronic systems is one of the main tasks of a mechanical engineer.
The Team

Outline

• Introduction and Motivation
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Bachelor Focus

Methods and Tools
- Computational Methods
- Artificial Intelligence
- Theoretical Methods
- Product Development and Engineering Design
- Materials and Processes
- Experimental Methods
Lecture Overview: You select five lectures freely
Courses in Fall Semester

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
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<tr>
<td>151-3209-00L</td>
<td>Engineering Design Optimization</td>
<td>W</td>
<td>4</td>
<td>4G</td>
<td>K. Shea, T. Stankovic</td>
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<tr>
<td>151-3213-00L</td>
<td>Integrative Ski Building Workshop</td>
<td>W+</td>
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**Engineering Design**

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<td>151-0364-00L</td>
<td>Lightweight Structures Laboratory</td>
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<td>151-0509-00L</td>
<td>Acoustics in Fluid Media: From Robotics to Additive Manufacturing</td>
<td>W</td>
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<td>151-0524-00L</td>
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**Mechanics**

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<td>327-1204-00L</td>
<td>Materials at Work I</td>
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<td>327-0513-00L</td>
<td>Mechanical Properties</td>
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<td>R. Spolenak, F.J. Clemens, M. Schinhammer, A. Wahlen</td>
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Lecture Overview: You select five lectures freely
Courses in Spring Semester

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<td>151-0552-00L</td>
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<td>327-3002-00L</td>
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Please see the websites of each professor for current available student projects and theses!

• Prof. Kristina Shea, Engineering Design and Computing Laboratory https://edac.ethz.ch/
• Prof. Paolo Ermanni, Laboratory of Composite Materials and Adaptive Structures https://structures.ethz.ch/
• Prof. Dennis Kochmann, Mechanics and Materials Laboratory https://mm.ethz.ch/
• Prof. Laura De Lorenzis, Computational Mechanics Group https://compmech.ethz.ch/
• Prof. Eduoardo Mazza, Experimental Continuum Mechanics https://ecm.ethz.ch/
• Prof. Mirko Meboldt, pd|z Product Development Group Zurich https://pdz.ethz.ch/
• Prof. Dirk Mohr, Computational Modelling of Materials in Manufacturing https://mohr.ethz.ch/
• Prof. Elizabeth Tilley, Global Health Engineering https://ghe.ethz.ch/
• Dr. Paolo Tiso, Nonlinear Dynamical Systems Group http://www.georgehaller.com/
Prof. Elizabeth Tilley

Global Health Engineering: *understanding the social, economic, and technical reasons for poor environmental and human health*

We work with small businesses, NGOs, government and openly available data to test, design and optimize technologies and systems related to:

- Human Excreta
- Air Quality
- Solid Waste
- Organic Waste
Experimental investigations on different types of fracture phenomena

X-ray tomography + in-situ testing and Digital Volume Correlation for cavitation and fracture phenomena or for 3D full-field data collection on different material behaviors

Efficient Unsupervised Constitutive Law Identification and Discovery (EUCLID)

Material model + Uncertainty

\[ W = \frac{1}{2} (I_1 - 3) + \frac{3}{2} (J - 1)^2 \]

or

Neural Cellular Automata, Physics Informed Neural Networks
A quartic polynomial solution to the Navier-Stokes equation has the following form [1]:

\[ u(x, t) = \begin{pmatrix} \sin(4t) & \cos(4t) + 2 \\ \cos(4t) - 2 & -\sin(4t) \end{pmatrix} x + \alpha(t) \begin{pmatrix} x^4 - 6x^2 y^2 + y^4 \\ -4x^3 y + 4xy^3 \end{pmatrix} \]

The intersecting stable and unstable manifolds of the fixed point of the Poincaré map show a very complex particle motion in stark contrast to the vortical motion suggested by both the instantaneous streamlines and the Okubo-Weiss criterion [1].

Over 13% of all hip protheses require complicated repeated surgery because of bone loss around the implant due to a stiffness mismatch and lacking biocompatibility.

Architected metamaterials together with topology optimization allow us to create superior implants with tailored properties.

This project develops a patient-specific implant with optimized properties by computational design, prototyping by 3D printing.

Prof. Kristina Shea
Engineering Design and Computing Laboratory

Designing Novel Machines with 4D Printing

Computational Design of Structures and Metamaterials
(Dr. Tino Stankovic)

Design for Additive Manufacture: Personalized Artificial Spinal Disc

Development Engineering: Medical Devices for Low Resource Settings
Thermomechanical simulation for residual stress prediction in SLM parts

Project tasks:
- Literature review on “inherent strain method” for additive manufacturing
- Application of Ansys or Abaqus for thermomechanical simulations
- Sensitivity analysis of distortion and stresses to process parameters

Development of suction protocols for skin biomechanics characterization

Project tasks:
- Literature review on histology of skin layers
- FE simulation: protocol optimization for characterization of specific skin layers
- Verification on elastomer substrates (in-vitro experiments)
- Validation with in-vivo skin measurements
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Relevant Industries

- Automotive
- Aerospace
- Space
- Rail
- Robotics
- Manufacturing
- Additive Manufacturing
- Product Development and Consumer Products
- Buildings and Civil Structures
- Energy
- Sports Industries
- Biomedical and Medical Technology
- Many more!
Relevant Master Studies

- Mechanical Engineering
- Micro and Nanosystems
- Robotics, Systems and Control
- Biomedical Engineering
- Energy Science and Technology
- Integrated Building Systems
- ...

Bachelor Focus Design, Mechanics and Materials
Any Questions?