Focus Specialization in Design, Mechanics and Materials

Prof. Kristina Shea & Friends
3 April 2017
Outline

- Introduction and Motivation
- Lectures
- Bachelor Theses and Research
- Industry and after the Bachelor Degree
The design, analysis, simulation, optimization and evaluation of modern mechanical and mechatronic systems is one of the main tasks of a mechanical engineer.

The Focus offers a broad selection of courses covering the main aspects of mechanical systems.

- Engineering Design
- Materials & Manufacturing
- Analysis
- Experimental Methods

- Function
- Reliability & Quality
- Environmental Aspects
- Performance
- Costs
The Team

- K. Shea, D. Mohr, J. Dual, P. Ermanni, D. Kochmann, P. Hora, E. Mazza, M. Meboldt
One Grand Challenge in Engineering: Sustainable Energy

Renewable Energy
- water, wind, sun, etc.

Efficiency
- improved engines & drive-trains
- lightweight structures (accelerated masses)
- reduced losses (aerodynamic, friction, etc.)

Sufficiency
- less mobility, less living-room, less etc.

How to satisfy the demand for energy in an affordable, safe and sustainable way?

- climate change: How to reduce CO₂ emissions?
- peak oil: How to replace missing crude oil?
- limited clean water and food: How to feed everyone?
- nuclear risks: How to keep people safe?
Mechanical Systems are Highly Interdisciplinary
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Bachelor Focus

Methods and Tools
Computational Methods, Analysis Methods, Dynamics, Engineering Design, Materials and Processes, Experimental Methods

Application in Research and Industry Projects
Bachelor Thesis
Labs

Computational Methods
Analysis Methods
Dynamics
Materials and Processes
Experimental Methods
Engineering Design
**Lecture Overview: You select five lectures freely**

<table>
<thead>
<tr>
<th>Elective Courses</th>
<th>LE-Nr.</th>
<th>ETCS HS 16</th>
<th>ETCS FS 17</th>
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<tbody>
<tr>
<td>Procedures for the Analysis of Structures</td>
<td>151-0360-00</td>
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<td>Lightweight Structures Laboratory</td>
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<td>Microscale Acoustofluidics</td>
<td>151-0509-00</td>
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<td>Continuum Mechanics 1</td>
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<td>Nonlinear Dynamics and Chaos I</td>
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<td>Forming Technology I – Basic Knowledge</td>
<td>151-0731-00</td>
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<td>Dynamic Behavior of Materials and Structures*</td>
<td>151-0735-00</td>
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<td>Grand Challenges in Engineering Design</td>
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<td>Lightweight</td>
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<td>Engineering Design Optimization*</td>
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<td>Metals I</td>
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<td>Materials at Work I</td>
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*) Master course
Lecture Overview: You select five lectures freely

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<td>Engineering Design II</td>
<td>151-0304-00</td>
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<td>Visualization, Simulation and Interaction – Virtual Reality I</td>
<td>151-0306-00</td>
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<td>Engineering Design with Polymers and Polymer Composites</td>
<td>151-0324-00</td>
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<tr>
<td>Interdisciplinary Product Development: Definition, Realisation and Validation of Product Concepts</td>
<td>151-0332-00</td>
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<td>An Introduction to the Finite-Element Method*</td>
<td>151-0361-00</td>
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<td>Experimental Mechanics</td>
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<td>Dynamic Behavior of Materials and Structures</td>
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<td>Engineering Design Methods</td>
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<td>Coaching, Leading and Organising Innovation Projects</td>
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<td>Systemic Design for Sustainability</td>
<td>151-3206-00</td>
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Grand Challenges in Engineering Design

- Introduces students to the engineering design research and practice in a multitude of mechanical engineering disciplines
- Guest lectures by academics and industry

Studies on Engineering Design

- Identify a topic in engineering design for further investigation.
Integrative Ski Design and Fabrication Workshop

Integrative Ski Design and Fabrication Workshop

Learn fundamental topics in engineering design and product development.

Learn a product development and design process and its benefits.

Introduction to a variety of design methods and models used in product development and design.

Focus on the early design phases and conceptual design.

Apply the methods immediately to a team design project carried out in the exercises.

Develop design reasoning and critical thinking skills.
Engineering Design Optimization
Fall Semester
K. Shea and T. Stankovic

- Learn the fundamentals of optimization in the context of engineering design.
- Express engineering design problems as formal optimization problems.
- Learn about different optimization methods and how to select, apply and implement them.
- Understand the links to design more efficient and performance optimized products.
- Exercises are MATLAB based.

Optimization of a butterfly valve disc and housing using simulated annealing (with Georg Fischer).
Fundamentals of sustainability and systemic design: theory, methods, frameworks.

Develop systems thinking and specific sustainable design skills.

Learn and apply systemic design concepts, e.g. cradle-to-cradle, life cycle analysis, upcycling, biomimicry, permaculture, passive house, blue/circular economy, etc.

Design and build a product applying the learnt systemic design approaches.

Case studies, field visits, exercises motivated by sustainability challenges.
Innovation und Entwicklung ist geprägt von Teamarbeit, neben Ingenieurwissenschaftlichen Grundlagen ist das Leiten und Coachen von Projektteams eine Schlüsselkompetenz.

- Die Vorlesung behandelt das Strukturieren von Entwicklungsprojekten und Leiten von Teams
- Im Praxisteil: arbeiten sie als Coach im Innovationsprojekt um dort Leadership Erfahrung zu sammeln und zu reflektieren
Dislocation theory:
- Properties of dislocations, motion and kinetics of dislocations, dislocation-dislocation and dislocation-boundary interactions, consequences of partial dislocations, sessile dislocations

Hardening theory:
- a. solid solution hardening: case studies in copper-nickel and iron-carbon alloys
- b. particle hardening: case studies on aluminium-copper alloys
- c. Taylor hardening, Hall-Petch hardening

High temperature plasticity:
- thermally activated glide
- power-law creep
- diffusional creep: Coble, Nabarro-Herring
- deformation mechanism maps
Erweiterung der Grundlagen zur Behandlung strukturmechanischer Auslegungsproblemen.

Einführung in die Dimensionierung von Flächentragwerken.

Stabilitätsanalyse. Verständnis des Zusammenhangs zwischen Materialverhalten, Strukturtheorien und Auslegungskriterien.
Continuum Mechanics 1
Fall Semester
E. Mazza

- Models to predict the mechanical response of a wide range of materials.
- Anisotropic linear elastic, viscoelastic, plastic, viscoplastic material behavior.
- Theoretical fundamentals for small strain continuum mechanics
- Examples of engineering applications
Acquire knowledge and skills needed to predict the deformation and failure response of modern engineering structures under extreme loading conditions.

Learn about temperature and rate-dependent plasticity and fracture of polymers and metals.

Become familiar with the development and implementation of user material subroutines for non-linear finite element analysis.
Konkrete Aufgabe wird in Gruppen bearbeit.
Ziel: möglichst einfache und leichte Konstruktion
Inhalte: Design, Auslegung, Herstellung, Test
Bauteil wird anschliessend mechanisch getestet, und im Hinblick auf konstruktive und strukturmechanische Aspekte diskutiert und verbessert.
Verständnis, Modellierung und praktische Anwendung von:
- Schwingungsmessung,
- optische Methoden,
- Piezoelektrizität
- Ultraschall,
- Sensoren und Aktoren
Verbindung von Theorieverständnis mit der Fähigkeit Strukturanalysen mit einem Anwenderprogramm durchführen zu können.

Ergebnisqualität der Strukturanalysen

Eigene FEM-Programmierung.

Modell mit linearen Flächenelementen

Elementbeiträge zur Systemmatrix
Forming Technology I – Basis Knowledge
Fall Semester
P. Hora

- Umformspezifische Beschreibung von Materialeigenschaften und ihre experimentelle Erfassung
- Stoffgesetze, Eigenspannungen, Wärmebilanz, Tribologie von Umformsystemen
- Werkstück- und Werkzeugversagen
- Einführung in umformtechnische Verfahren
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Computational: Shape Synthesis with the Superformula (K. Shea)

- Motivation for superformula:
  - compact surface modelling representation
  - easily represents complex and natural shapes
- Shape synthesis of a mono-hull cargo ship

Andrea Nessi, Bachelor Thesis, 2015
Design and Testing: 3D Printer RAPTYPE (K. Shea)

- Investigating the relation between speed and print quality:
  - Goal: same quality at similar speed compared to uPrint
  - Faster printing possible of simple parts or for reduced quality prints
  - Comparison of alternative motors for improved accuracy
Material modeling: An interdisciplinary research field (P. Hora)

- Mathematical description of the material behavior for large plastic deformations
  - Determination of model parameters based on experiments: linear/non-linear strain paths
- Validation of material models on real forming processes (FEM simulation)
  - Optical measurements of the surface strains (DIC - Digital Image Correlation)
  - Thickness distribution (DIC)
Material Labs IVP

Zugversuch
Torsionsversuch
Bulge-Versuch
Goniometer
Experimental: Biomechanical Gait Cycle Analysis Of Different Ski Touring Systems (K. Shea)

Analysis of different ski systems on treadmill:

- motion of markers on shoes and human subjects are recorded by 13 infrared cameras and analyzed according to five parameters

Results:

- A specific pattern in ski touring motion is found (larger range of motion in hip and pelvis joint)
- Longer stride length with TourBo system

Rudolf Maculan, Bachelor Thesis, 2014
Industrial: Mechanics of high voltage conductors (E. Mazza)

Collaboration with Sefag AG, Swisselectric and Swissgrid

- Lifetime prediction of high voltage conductors
- Finite element modeling of helical structure, considering internal stresses from manufacturing process
- Experimental verification of long term creep response at elevated temperatures
- Specific task for the bachelor project: the student investigates the influence of the creep model formulation on the long term stress-strain evolution and uses the model to rationalize experimental data from strain gauges applied along the conductor
Please see the websites of each professor for current available student projects and theses!

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Diverse Industry Domains

- Consumer Products
- Automotive
- Aerospace
- Structures and Buildings
- Rail Systems
- Manufacturing
Any Questions?