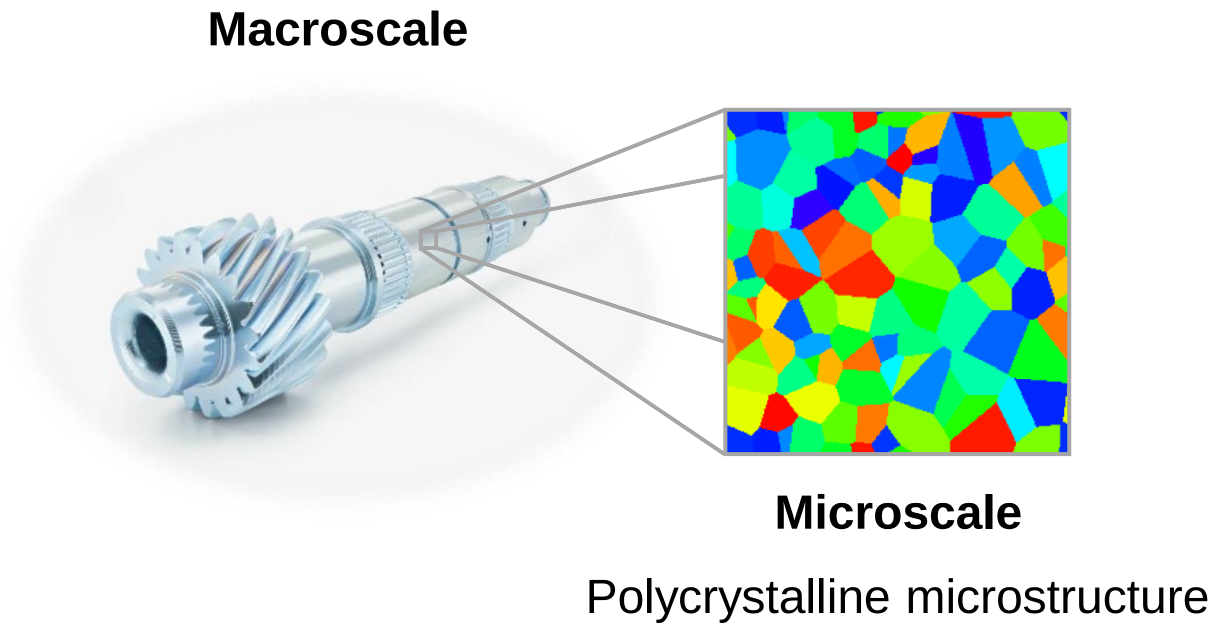
MECHMAT MECHANIK - MATERIALTHEORIE

RUHR UNIVERSITÄT BOCHUM RUB

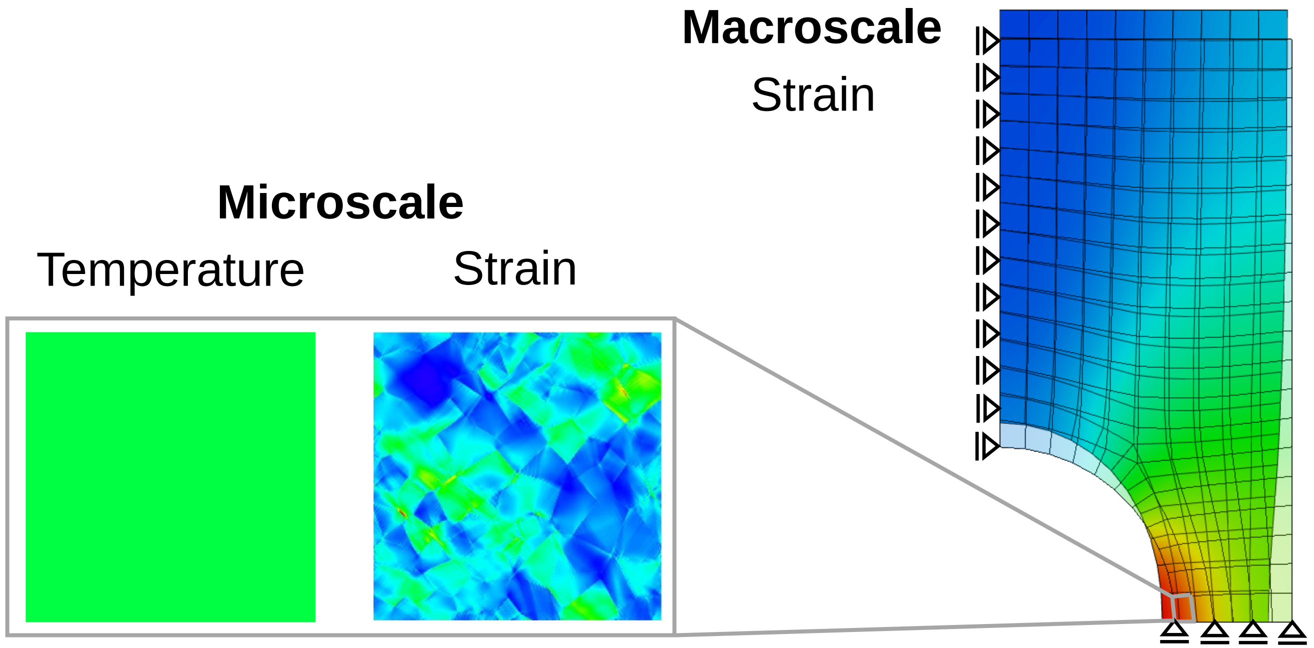
Thermo-mechanically coupled FE-FFT simulation of polycrystalline materials

Motivation

In various engineering applications components are made out of metals, which are characterized by polycrystalline microstructures. In order to predict the material behavior accurately, multi-scale approaches, such as the two-scale finite element (FE) – fast Fourier transformation based (FFT) simulation approach, have been developed.



Thermo-mechanically coupled two-scale simulation



Possible topics for Student Research Projects and Theses

- Considering microscopic phenomena, such as martensitic phase transformation
- Two-scale FE-FFT-based simulations

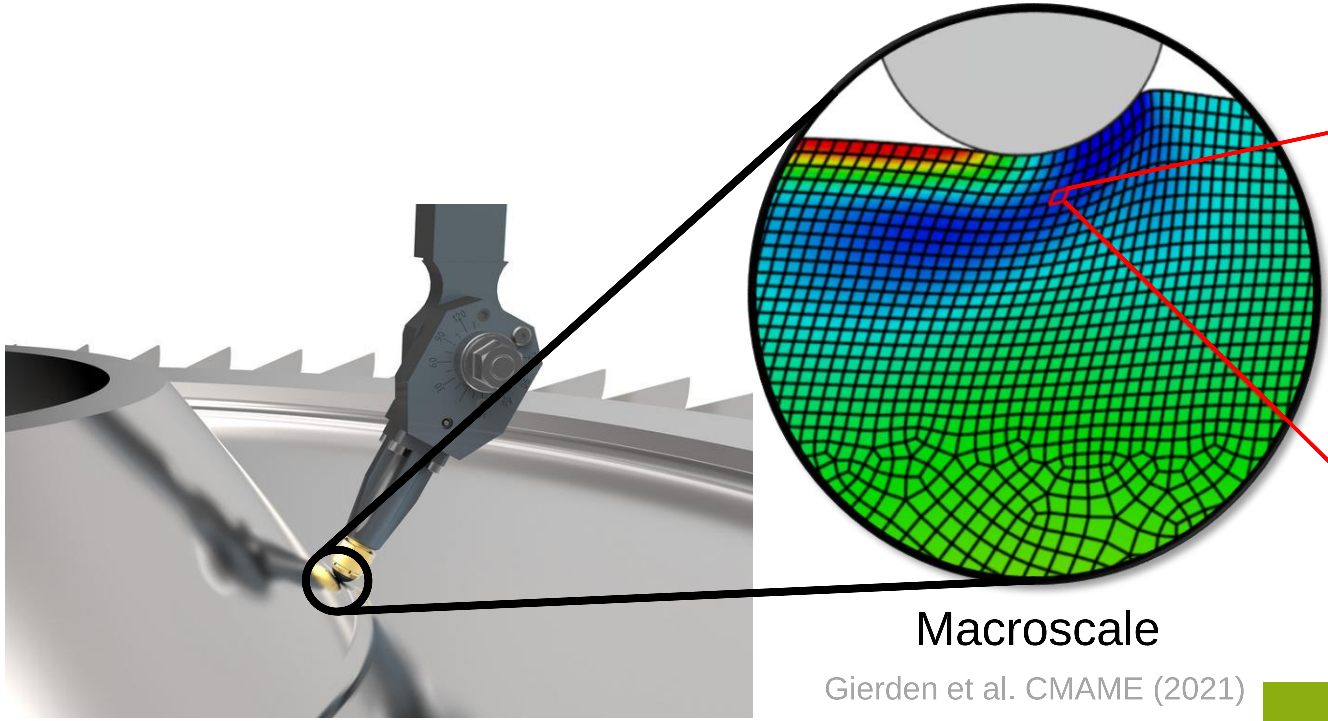
Annika Schmidt (Room IC 03-705)
annika.schmidt-u86@ruhr-uni-bochum.de

Efficient and highly resolved simulation of periodic microstructures

Motivation: In general, the macroscopic material behavior is significantly influenced by the underlying **microstructure**. Considering periodic microstructures, the microscopic material behavior may be investigated using a **fast Fourier transform (FFT)-based simulation**.

Possible topics for Student Research Projects and Theses:

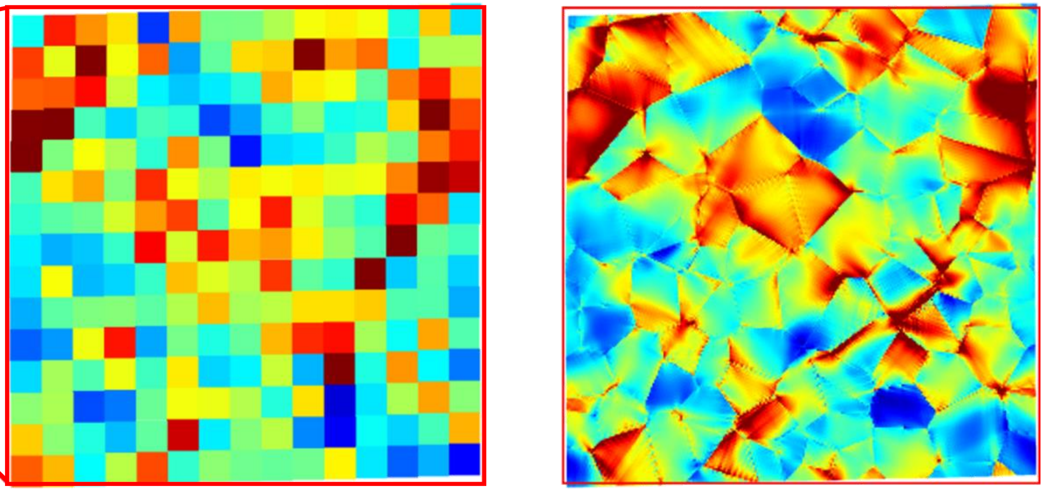
- Developing and investigating **model order reduction techniques** for the FFT-based simulation
- Developing techniques to **increase the accuracy** of FFT-based solvers
- Performing FFT-based simulations e.g. to generation a **data base for data driven solvers**



Macroscale

Gierden et al. CMAME (2021)

© Ecoroll AG



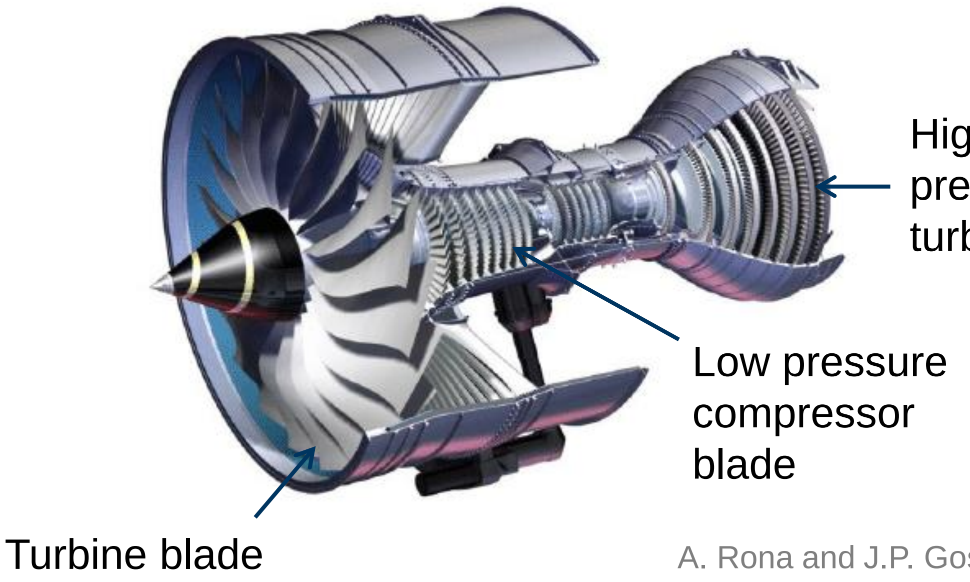
Polycrystalline microstructure

Christian Gierden (Room IC 03-715)
christian.gierden@ruhr-uni-bochum.de

Modeling of polycrystalline materials during electrochemical machining

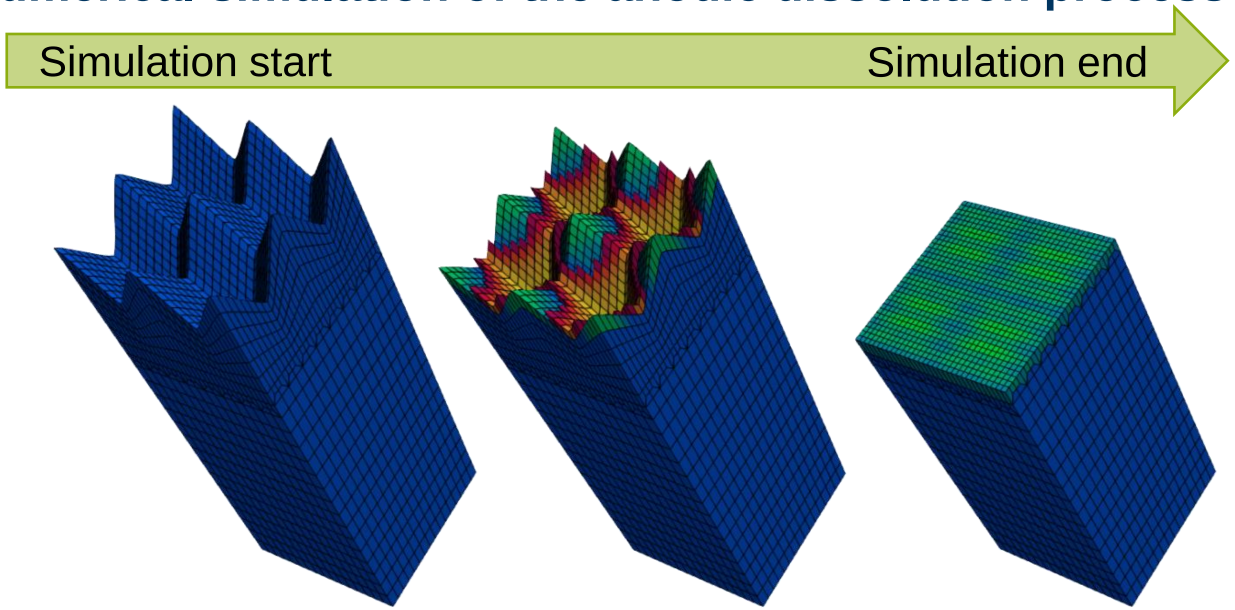
Motivation

Electrochemical machining (ECM) is a powerful machining process which is based on the principle of electrolysis. It allows to cut high-strength and high-temperature resistant polycrystalline metals without causing residual stresses while obtaining crack free and high surface qualities. Thus, ECM is frequently used in the aerospace industry to machine the critical and stress-prone high-precision components of jet engines.



A. Rona and J.P. Gostelow (2014)

Numerical simulation of the anodic dissolution process



Dissolving work piece at different times of the numerical simulation

Possible topics for Student Research Projects and Theses

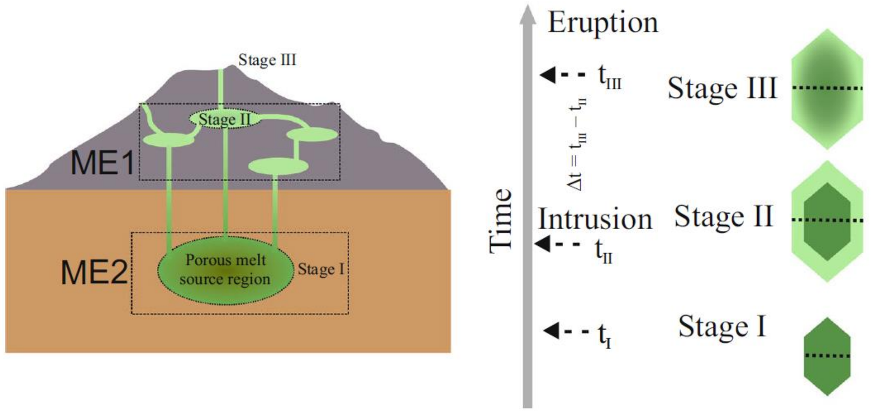
- Performing 2D and 3D finite element simulations
- Extension of the finite element model
    - ➥ Modeling the influence of the formation and dissolution of an oxide layer
    - ➥ Implementation based on a phase field approach

Annika Schmidt (Room IC 03-705)
annika.schmidt-u86@ruhr-uni-bochum.de

Modeling of diffusion and growth processes of olivine crystals

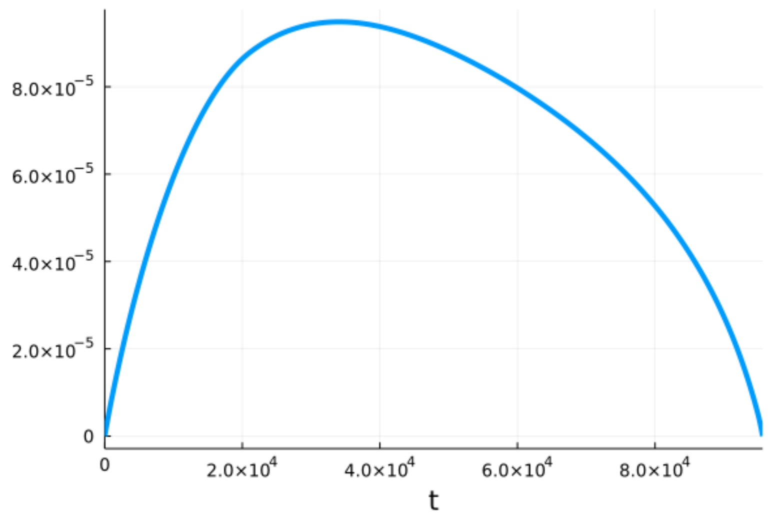
Motivation

In the lower magma chambers of volcanoes olivine crystals are formed. These crystals grow as they rise into the higher magma chambers until the volcano erupts. In some cases diffusion processes lead to crystals becoming unstable and to start shrinking until the crystal recrystallizes. The aim is to develop models to improve the understanding of the shrinkage processes.



Growth process of olivine crystal

Evolution of the size of a crystal over time



Possible topics for Student Research Projects and Theses

- Implementing a temperature field
- Considering different approaches to model dislocation density
- PINN-based simulations

Hendrik Haddenhorst (Room IC 03-707)
hendrik.haddenhorst@ruhr-uni-bochum.de

MECHMAT
MECHANIK - MATERIALTHEORIE

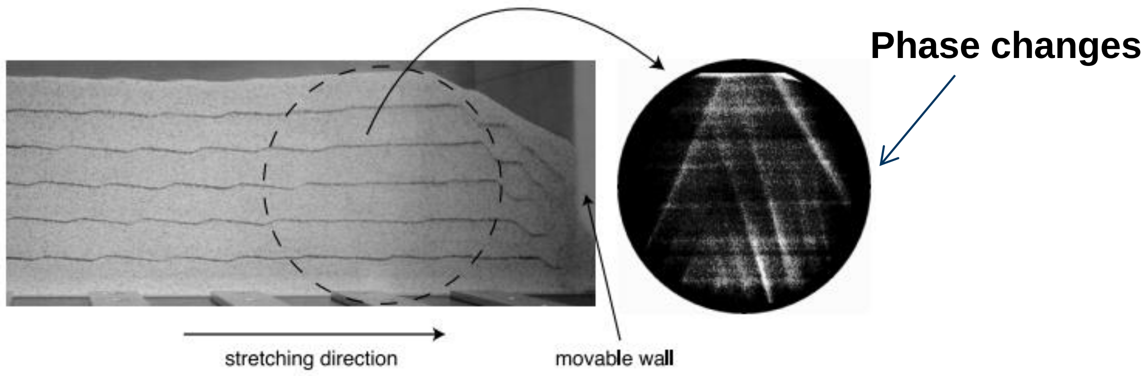
RUHR UNIVERSITÄT BOCHUM RUB

Variational modeling of parameter-dependent materials

Motivation

Shear bands can be observed in natural and synthetic materials including soils, amorphous metals and amorphous oxides.
These are often coupled with **phase changes**, such as transitions between density phases, whose properties can be analyzed using finite element (FE) simulations.

Sandbox experiment



Wolf et al. (2002)

Solids SPP 2256
Variational Methods

Possible topics for Bachelor/ Master theses or Case study A/B

- FE/ material point simulations
- Parameter analyses

Interests in

- Finite element method
- Continuum mechanics
- Variational modeling
- Programming languages (Julia)

Sarah Dinkelacker-Steinhoff (Raum 03-713)
sarah.dinkelacker-steinhoff@ruhr-uni-bochum.de

MECHANIK - MATERIALTHEORIE

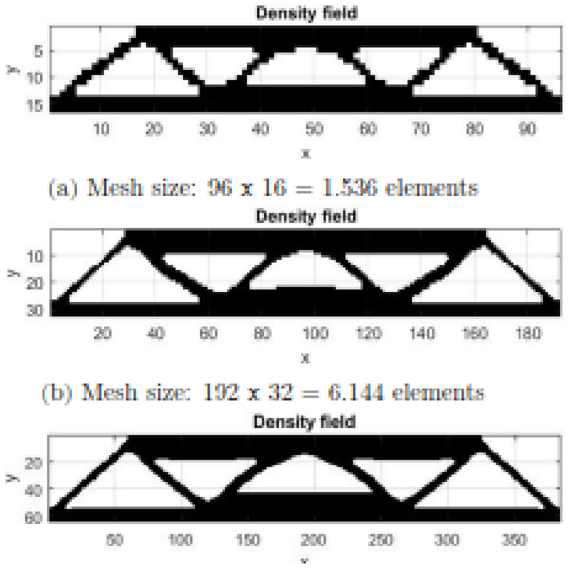
UNIVERSITÄT BOCHUM

Simple topology optimization algorithm

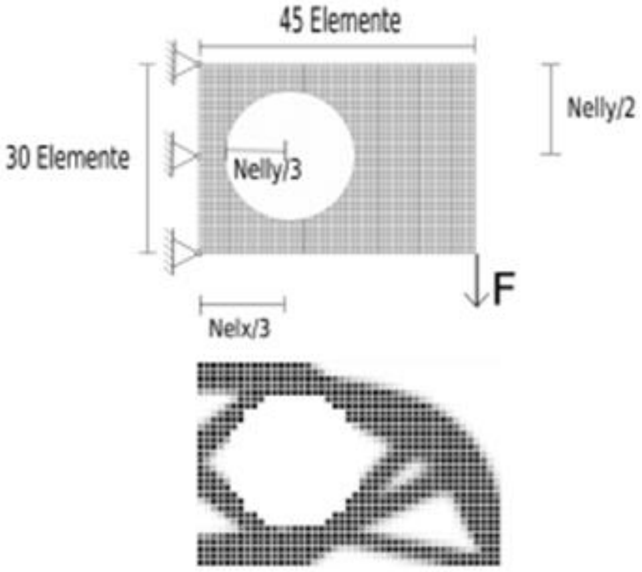
Motivation

Topology optimization describes a computer-based process for optimizing components using algorithmic procedures in order to achieve a more favorable basic shape of the components with regard to certain criteria (e.g. mechanical load, weight, manufacturing costs).

Topology optimization examples



[Bui Quoc Phuong 2023]



[Martin Schmidt 2021]

Type of work: Case study, Bachelor‘s or Master‘s Thesis

Content

- Creation of a topology optimization program based on templates in a well-founded, comprehensible manner
- Application to simple 2-dimensional problems
- Clear presentation of the results
- Parametric studies
- Bachelor's or Master’s Theses: Extension to additional restrictions and/or nonlinear material behavior

Useful knowledge / interests

- Programming knowledge (preferably Julia, Matlab or Python)
- Continuum mechanics, strength of materials

Ulrich Hoppe (Room IC 03-553)
ulrich.hoppe@ruhr-uni-bochum.de

MECHMAT MECHANIK - MATERIALTHEORIE

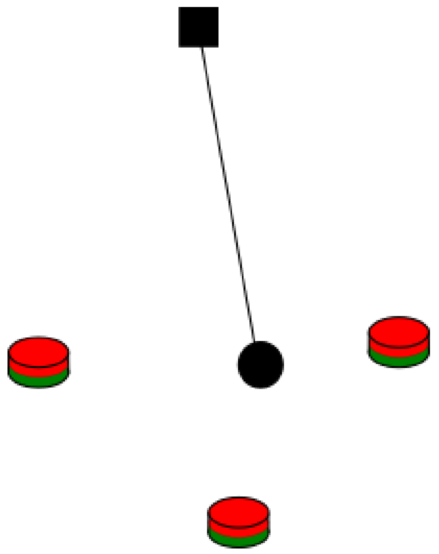
RUHR UNIVERSITÄT BOCHUM RUB

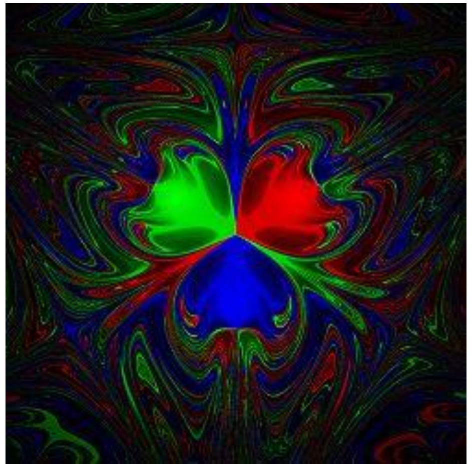
Simulation of non-linear motion processes (magnetic pendulum)

Motivation

A magnetic pendulum exhibits chaotic behavior if the initial deflection is sufficiently large. Even the slightest changes in the initial values lead to a completely different movement sequence after a certain time (sensitive dependence on the initial conditions). Unpredictable behavior emerges that appears to develop irregularly (chaotically) over time.

Sketch of the pendulum and stability map for a pendulum with 3 magnets





[Wikipedia 2024]

Type of work: Case study

Content

- Establish the equation of motion for an arbitrary number of magnets and a physical pendulum in a well-founded, comprehensible manner
- Numerical solution of the differential equations
- Clear visualization of the solutions (stability map)
- Parametric studies
- Discussion of the results using basic concepts of chaos theory (e.g. phase space, attractor)

Useful knowledge / interests

- Dynamics (Mechanics C)
- Programming knowledge (preferably Julia, Matlab or Python)
- Helpful: Computational Methods in Mechanics

Ulrich Hoppe (Room IC 03-553)
ulrich.hoppe@ruhr-uni-bochum.de

MECHMAT MECHANIK - MATERIALTHEORIE

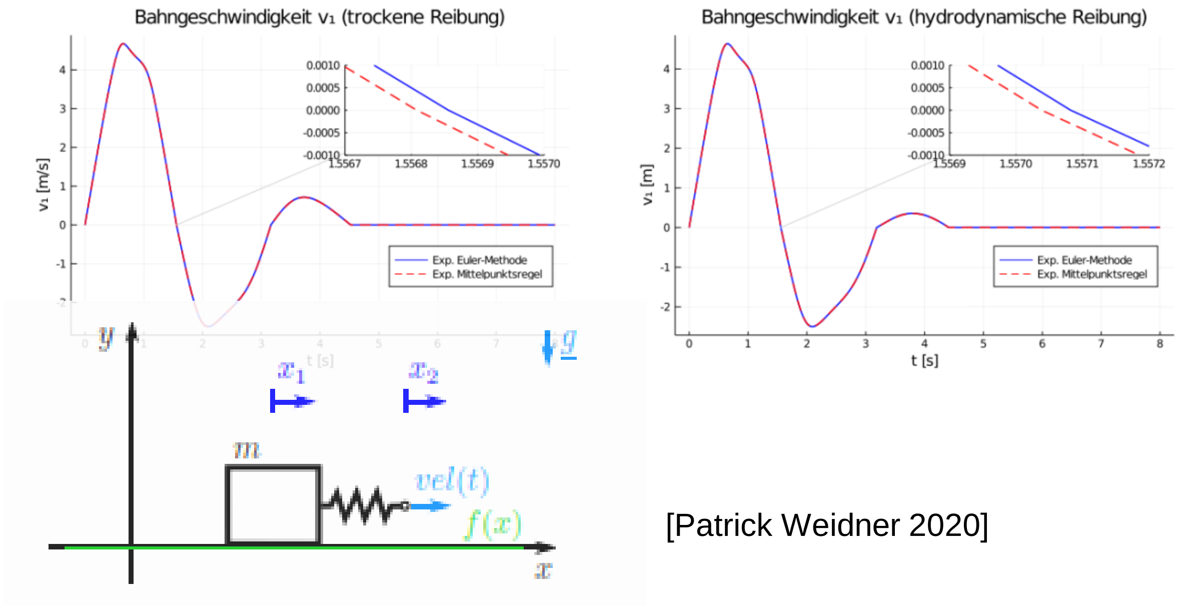
RUHR UNIVERSITÄT BOCHUM RUB

Simulation of non-linear motion processes (stick-slip effect)

Motivation

The stick-slip effect is a form of vibration caused by friction, described by the periodic alternation of sticking and sliding between two surfaces moving relative to one another. In practice, the stick-slip effect is often expressed through noises, e.g. the squeaking of trams or the squeaking of chalk on the blackboard.

Slip-Stick-Effekt bei trockener und hydrodynamischer Reibung



[Patrick Weidner 2020]

Type of work: Case study, Bachelor‘s Thesis

Content

- Establishing the equations of motion in a well-founded, comprehensible manner
- Hydrodynamic friction (e.g. Stribeck law)
- Numerical solution of the differential equations
- Clear visualization of the solutions (animations)
- Parametric studies
- Bachelor thesis: Multidimensional movements

Useful knowledge / interests

- Dynamics (Mechanics C)
- Programming knowledge (preferably Julia, Matlab or Python)
- Helpful: Computational Methods in Mechanics

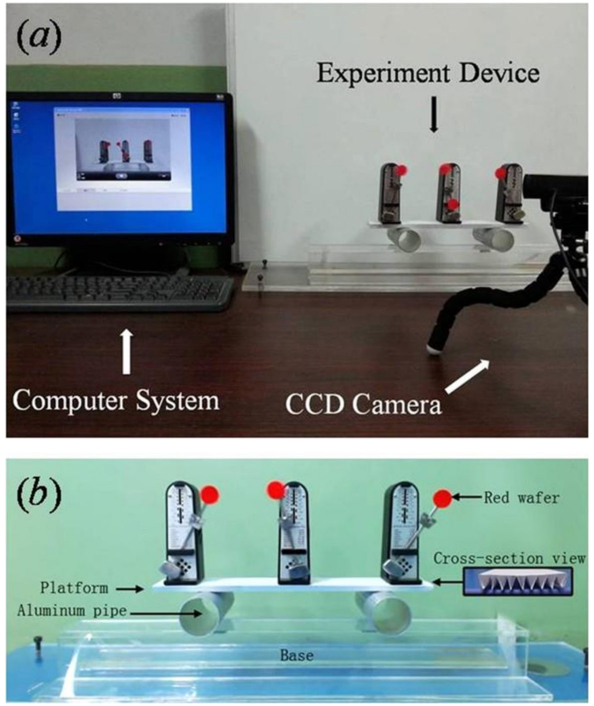
Ulrich Hoppe (Room IC 03-553)
ulrich.hoppe@ruhr-uni-bochum.de

Autonomous synchronization of coupled oscillations

Motivation

Oscillating systems that interact with each other (coupling) can tend to phase synchronization under certain circumstances. As an example, consider metronomes that are coupled via a movable base. After the metronomes have initially been stimulated arbitrarily, after a while they transition into a synchronous oscillation in the same mode.

[Jia, J., Song, Z., Liu, W. et al. Experimental Study of the Triplet Synchronization of Coupled Nonidentical Mechanical Metronomes]



Type of work: Case study, Bachelor‘s or Master‘s Thesis

Content

- Modeling a coupled system of n metronomes in a well-founded, comprehensible manner
- Numerical solution of the differential equations
- Clear visualization of the results
- Parameter studies regarding the influences of dimensions, friction, etc.
- Optional: Experimental investigations, comparison of experiments and simulations
- Optional: Modeling alternative coupled systems

Useful knowledge / interests

- Dynamics (Mechanics C)
- Programming knowledge (preferably Julia, Matlab or Python)
- Helpful: Computational Methods in Mechanics

Ulrich Hoppe (Room IC 03-553)
ulrich.hoppe@ruhr-uni-bochum.de

MECHMAT
MECHANIK - MATERIALTHEORIE

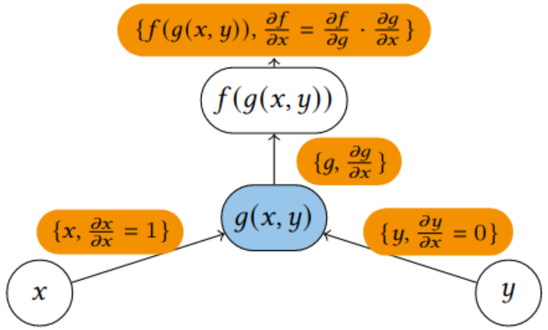
RUHR UNIVERSITÄT BOCHUM RUB

Automatic differentiation in material modeling

Motivation

In material modeling, derivatives of energy or stress functions according to several variables are often required for numerical simulation methods. These gradients are often difficult to determine analytically. A numerical determination is complex and sometimes inaccurate. The idea of automatic differentiation is based on dual numbers and the application of the chain rule in forward or backward mode. This makes it possible for programs to derive mathematical functions.

Forward mode and calculation of a stress tensor from a strain energy



$$\boldsymbol{S} = \frac{\partial W}{\partial \boldsymbol{E}}$$

[Wikipedia 2024]

Type of work: Case study, Bachelor‘s or Master‘s Thesis

Content

- Understanding Automatic Differentiation (Forward/Backward Mode)
- Program material models (e.g. hyperelastic).
- Use automatic differentiation to determine stresses, stiffnesses or sensitivities
- Comparison of results with numerical differentiation
- Optional: Extension to non-elastic material models
- Optional: Investigation of discontinuous functions

Useful knowledge / interests

- Tensor calculation, material modeling
- Programming knowledge (preferably Julia, Matlab or Python)

Ulrich Hoppe (Room IC 03-553)
ulrich.hoppe@ruhr-uni-bochum.de