

Vom Getriebequerträger bis zum Hirneurysma-Modell



Zoltan Major, Institut of Polymer Product Engineering

LIT Factory & Smart Systems Engineering

Smart Processing with Digitization

Smart Composite Extrusion; Company LEISTRITZ



Smart Composite Injection Molding; Company ENGEL



Smart Recycling; Company EREMA



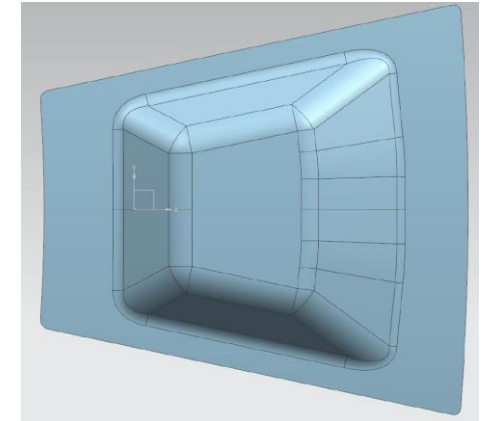
unique production systems, additional 2000 m²



Smart System Engineering

Design of smart polymeric components for industrial applications (industrial components)

- Automotive parts
- Aircraft components

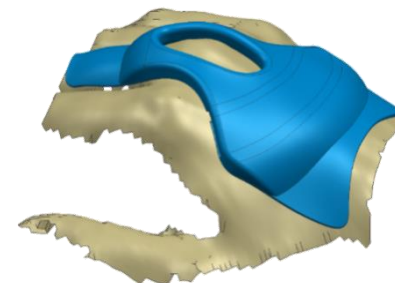


Locomotion Engineering & Personalized Technologies Lab



Design of smart polymeric components for medical and personal assistance systems

- Medical support systems
- Bicycle concepts, micromobility



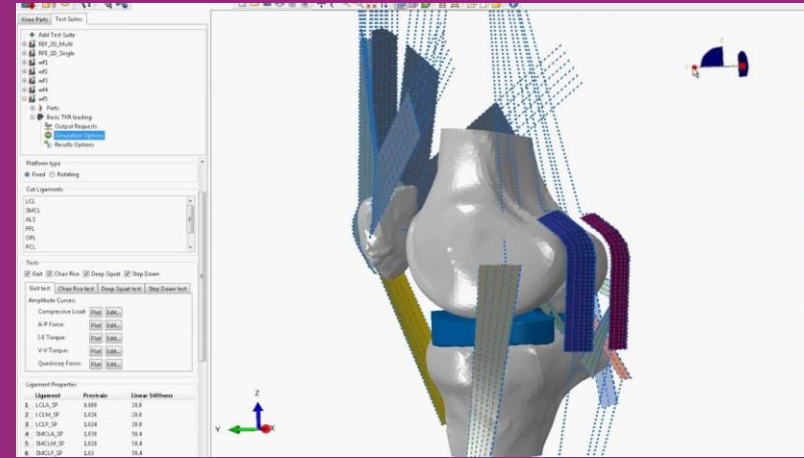
LIT Factory - IPPE LABS

Smart Systems Engineering Lab
(Umut D Cakmak)

Experimental Mechanics



Modeling and Simulation



Additive Manufacturing



Design, CAD and PDM/PLM/LCA



Locomotion Lab and
Personalized Technologies
(Martin Reiter)

LIT Factory - IPPE Labs

Smart Systems Engineering in the LIT Factory (Work Package 2)

Experiments

- Material and component testing
- Additive Manufacturing, physical prototypes



Locomotion Lab



Medical Engineering (various projects, MEDUSA, BRAD2.0, INKPlant)

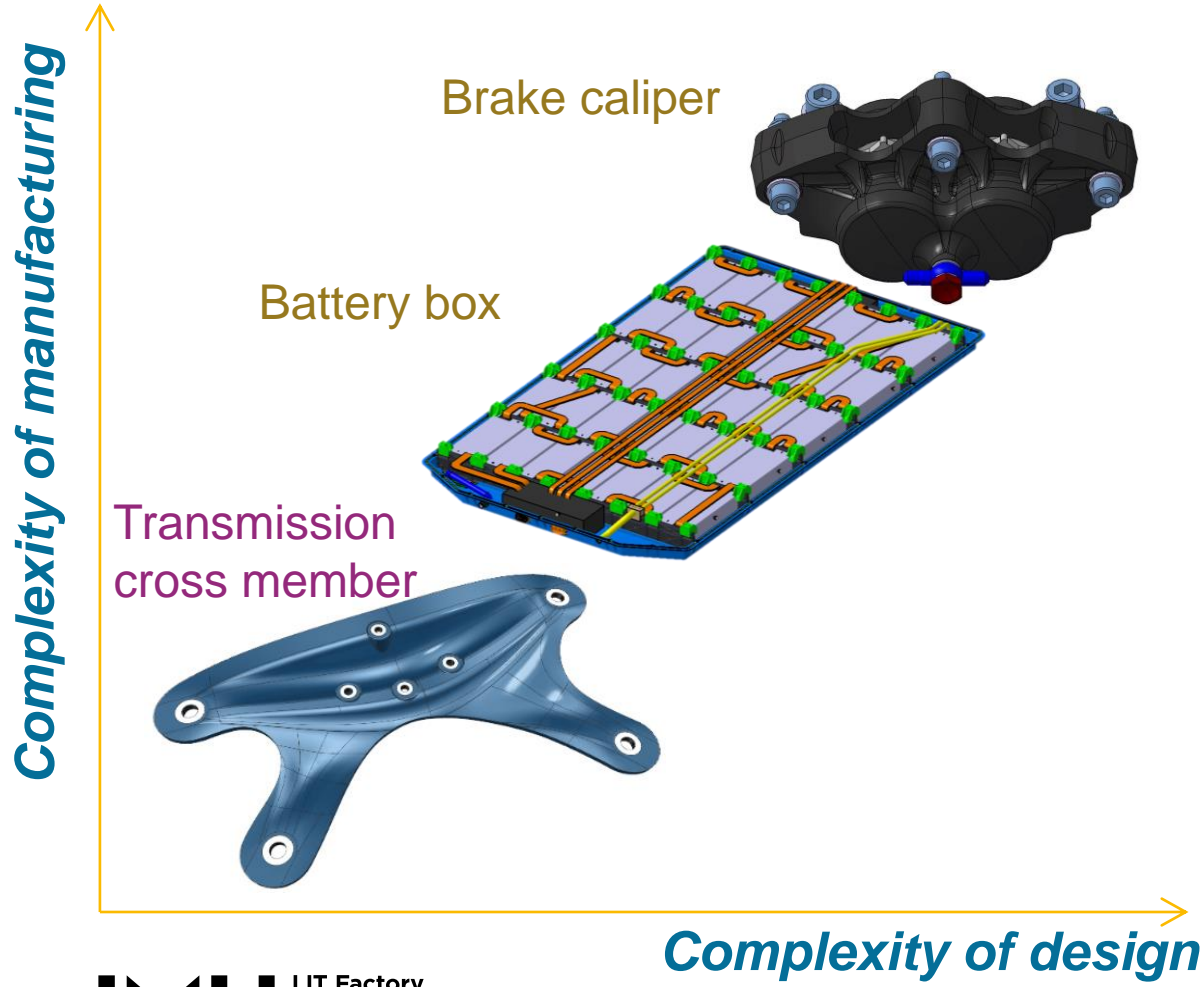
Modelling and Simulations

- Material and component
- Model and Data based

INTRODUCTION

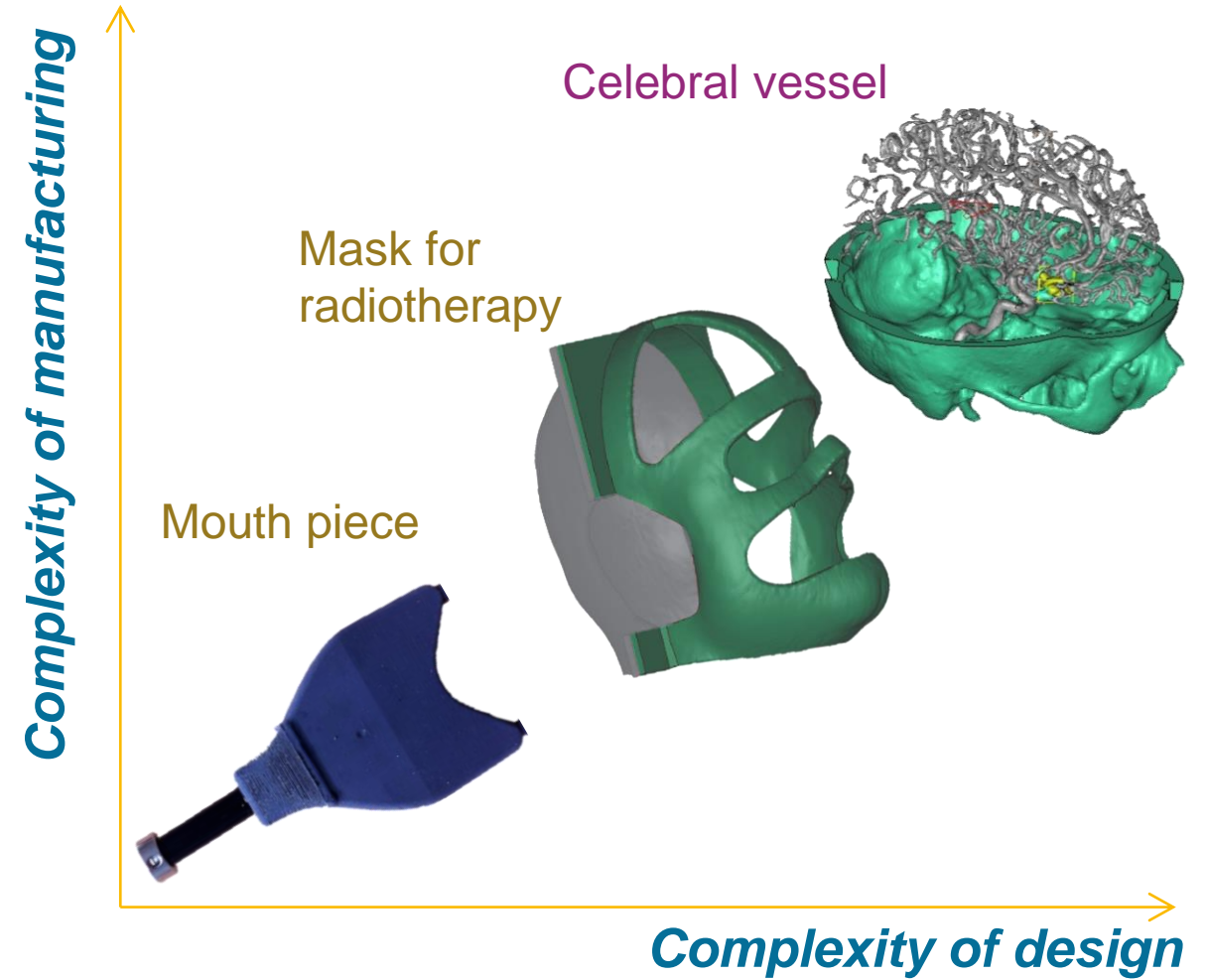
Complexity Management

Engineering Components



Participatory Design

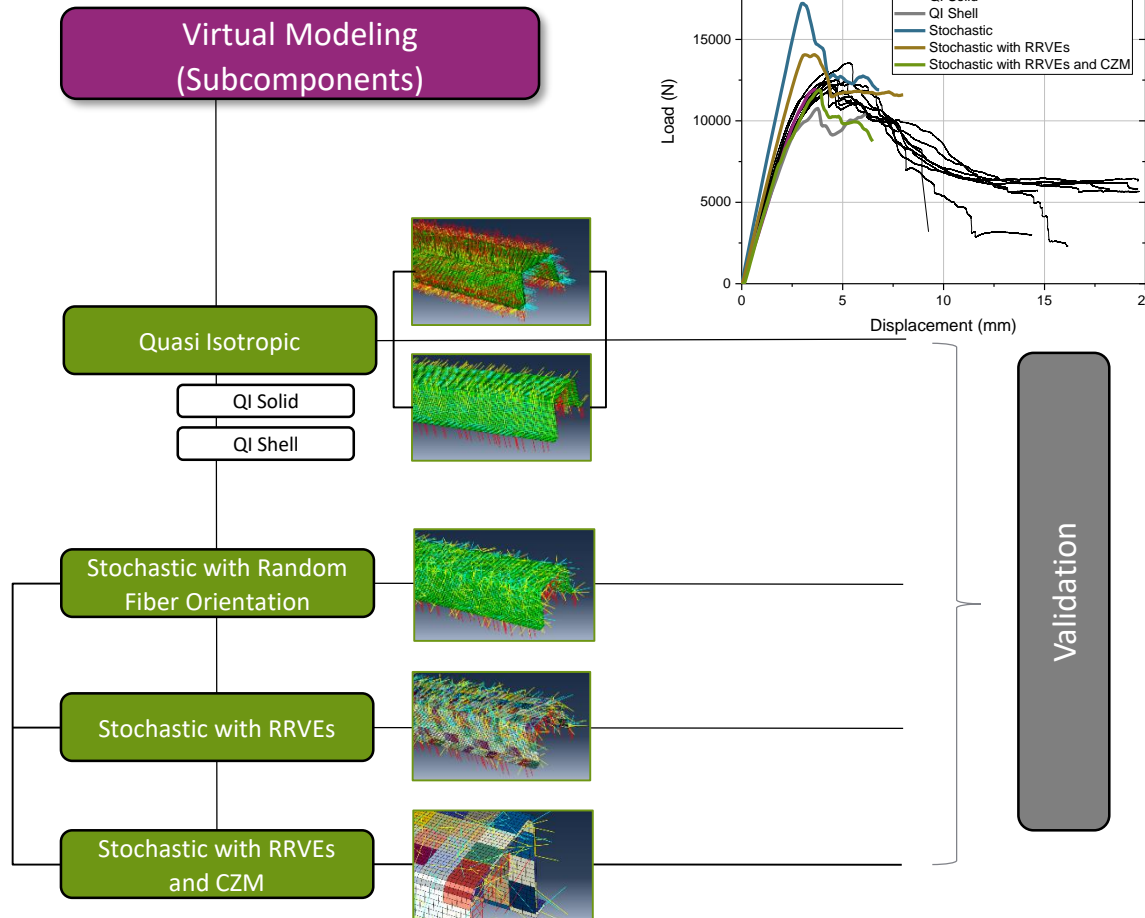
Medical Models&Devices



INTRODUCTION

Complexity Management

Engineering Simulations



Medical Simulations

- Material models for living tissues and organs
- Simplification of the living structures

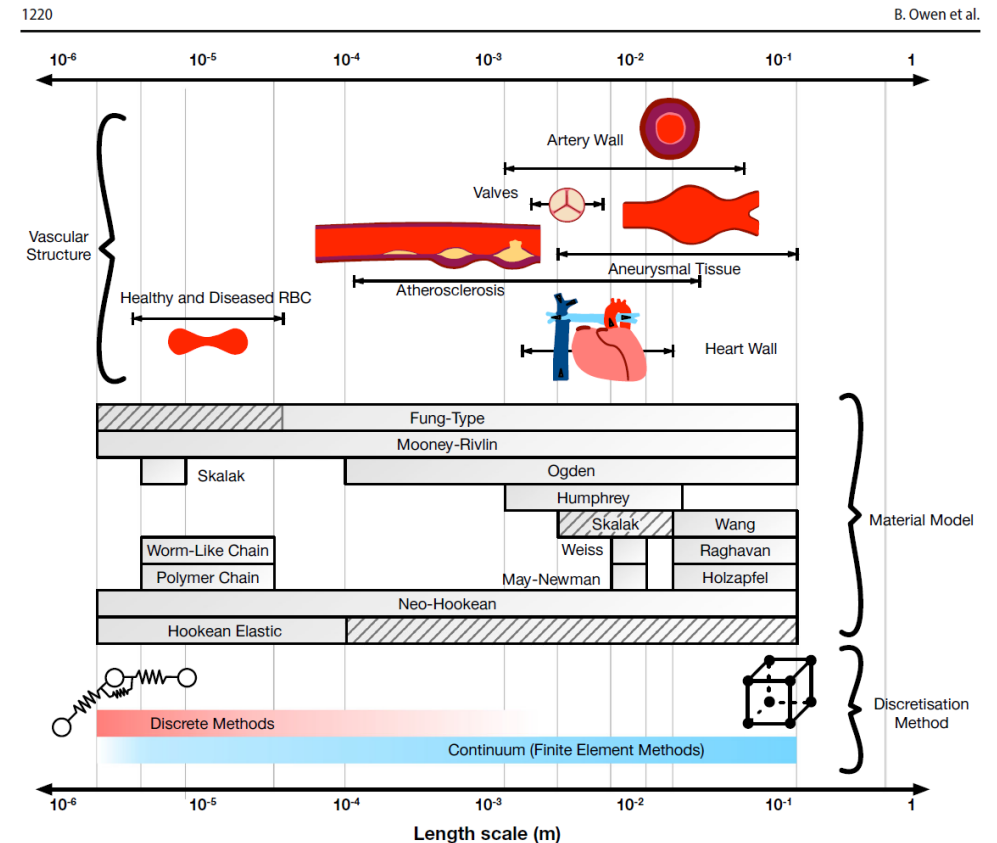


Fig. 1 Structural models used in vascular applications with popular material models and discretisation methods, classified with respect to length scale and the applications to which they have been applied. Hashed lines indicate scales where material models have been used but not commonly

INTRODUCTION

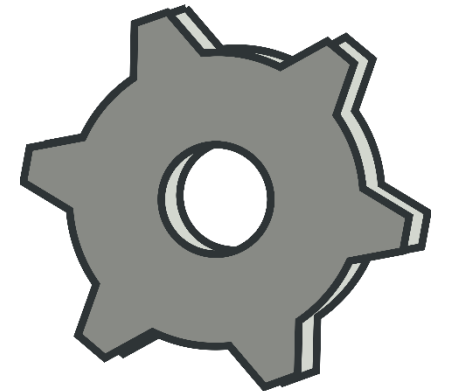
Participatory Design

USER



Manufacturer

real product



INTRODUCTION

Cooperative Engineering

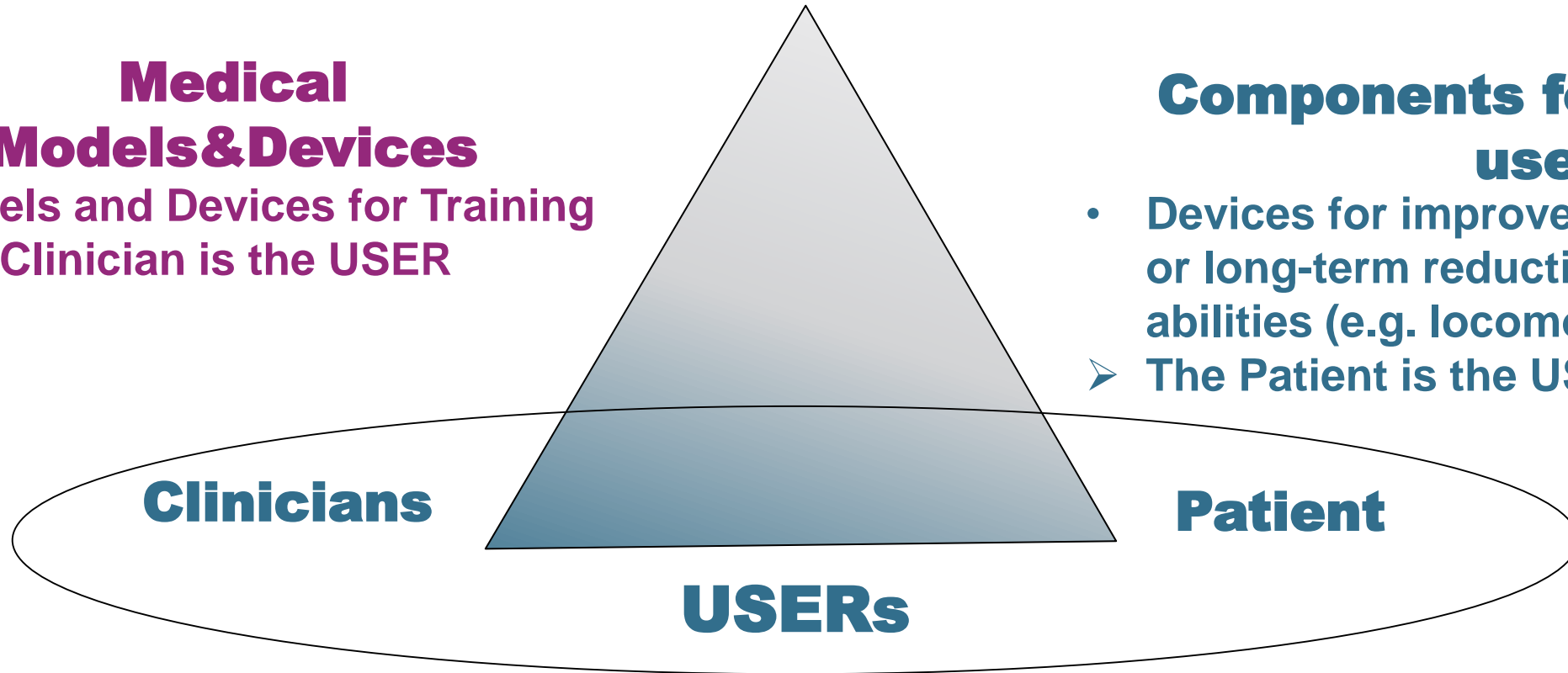
Engineers

Medical Models&Devices

- Models and Devices for Training
- The Clinician is the USER

Components for personal use

- Devices for improvement of temporal or long-term reduction of human abilities (e.g. locomotion)
- The Patient is the USER



INTRODUCTION

How to Make ? ...

HOW TO MAKE A “HORSE”

**HOW TO MAKE A TRANSMISSION CROSS
BEAM**

HOW TO MAKE A LATTICE SHOE SOLE

**HOW TO MAKE A CEREBRAL (BRAIN)
ANEURYSM MODELS**

HOW TO MAKE KNEE MODELS AND A NEW KNEE



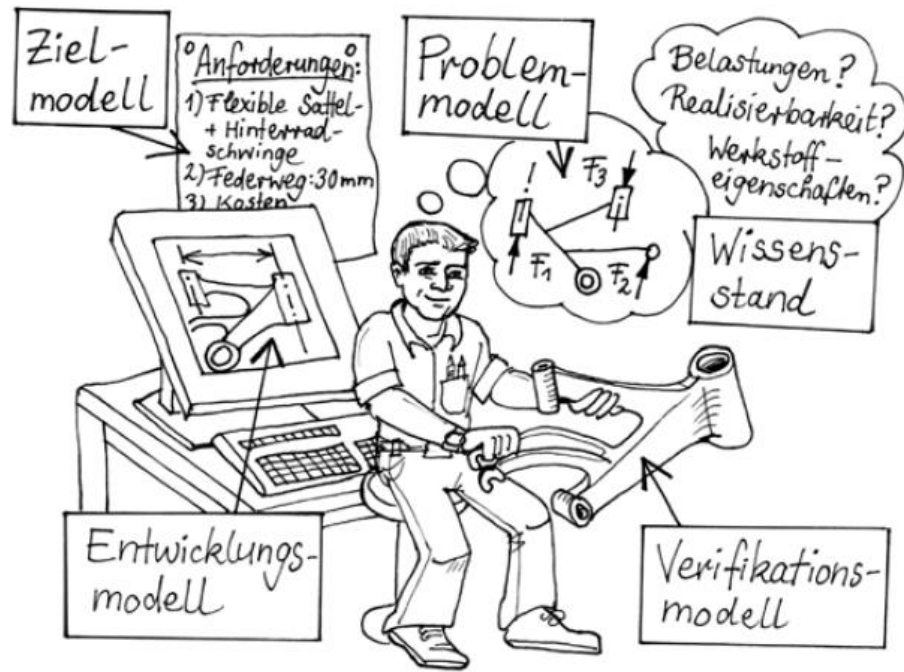
HOW TO MAKE A "HORSE"

"Three Ways to Make a "Trojan Horse"

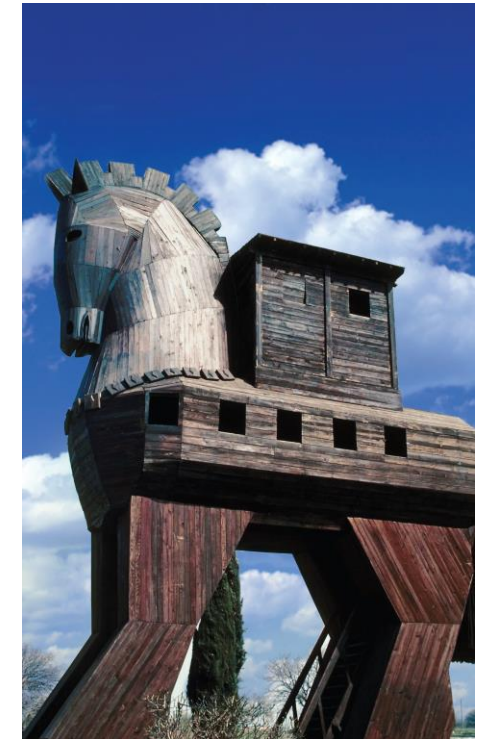
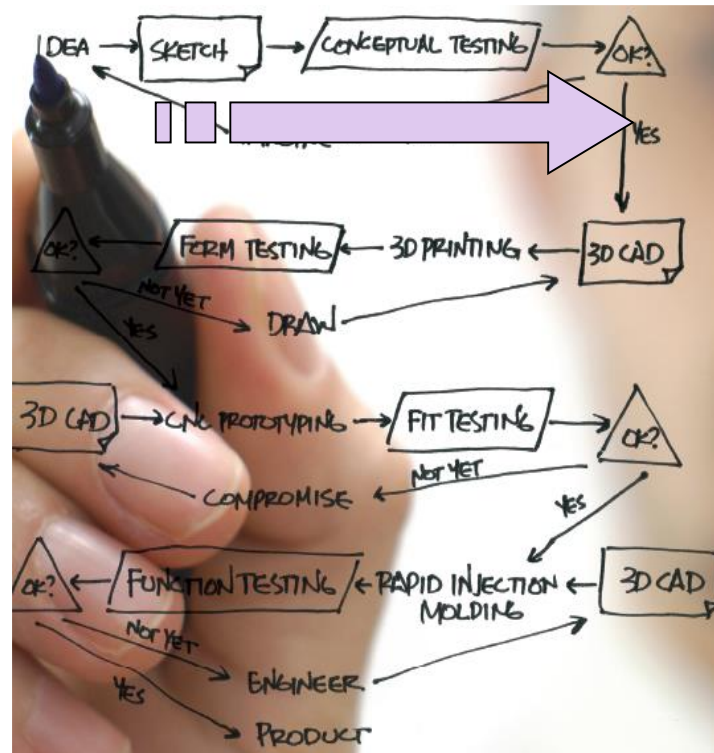
"You can **carve** your **finished product** out of a larger block of material, you can **build it up**, or you can **mold it in place**"

Cleveland, Protolabs, 2009

Modelling



Arten von Modellen im Entwicklungsprozess [Lindemann 2007]



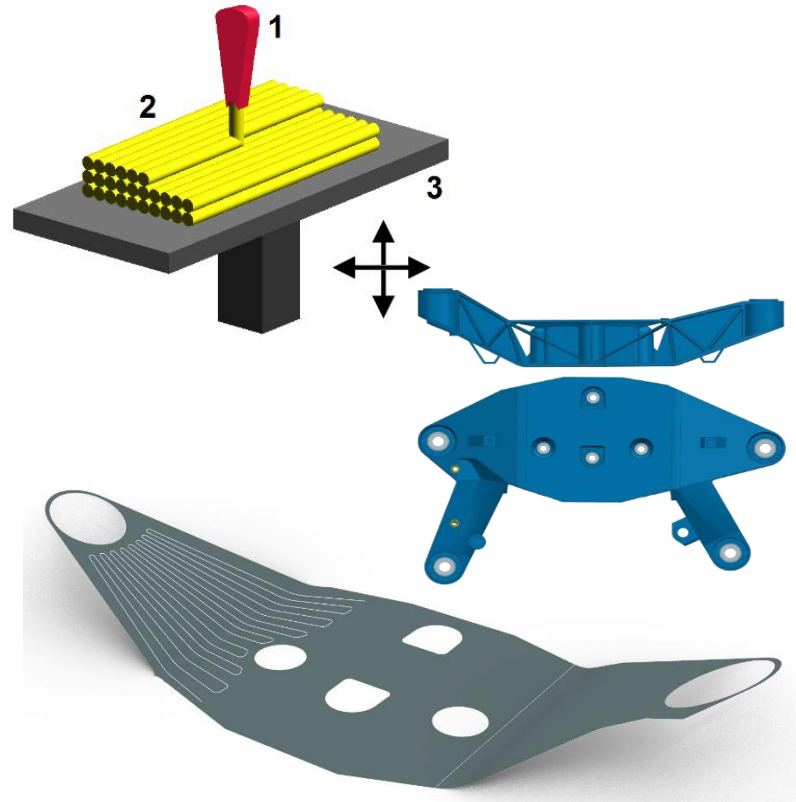
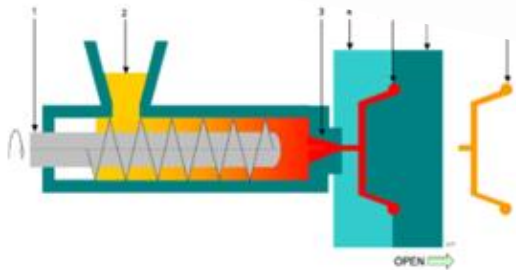
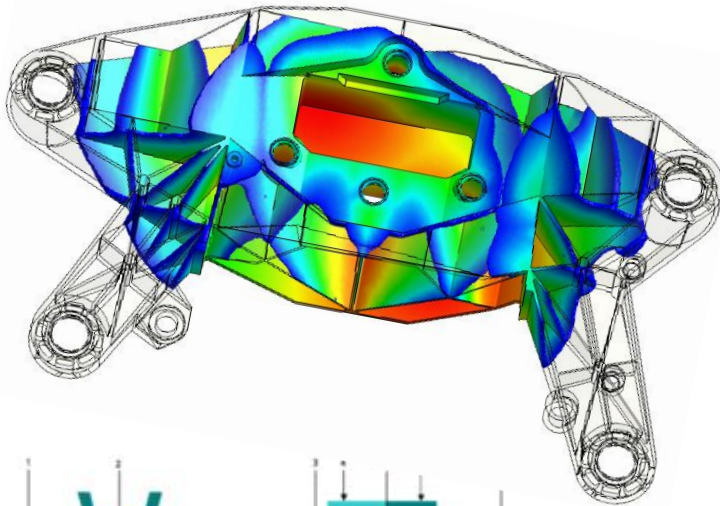
MANUFACTURING PROCESSES & DESIGN

ALTERNATIVE AND COMPETITIVE PROCESSING

Discontinuous Fiber Reinforcement – Thermoplastic Matrix

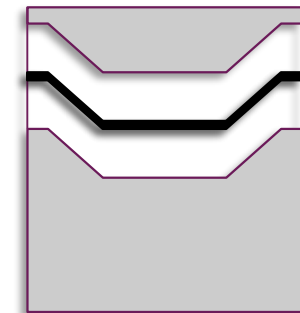
Design Study. Transmission cross member

Injection Moulding (sfrp)



3D-printed structures injection molded parts

Compression Moulding



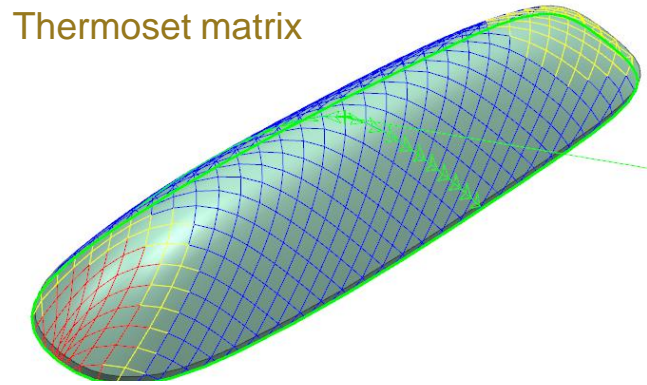
MANUFACTURING PROCESSES & DESIGN

ALTERNATIVE AND COMPETITIVE PROCESSING

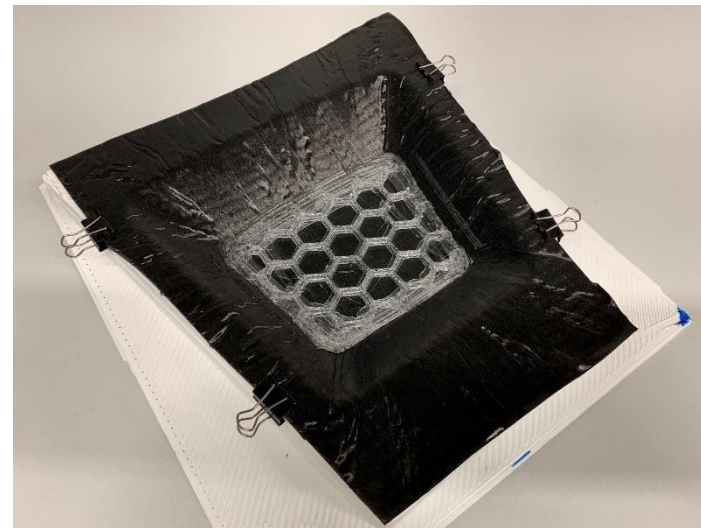
Continuous Fiber Reinforcement

Draping and RTM

Thermoset matrix



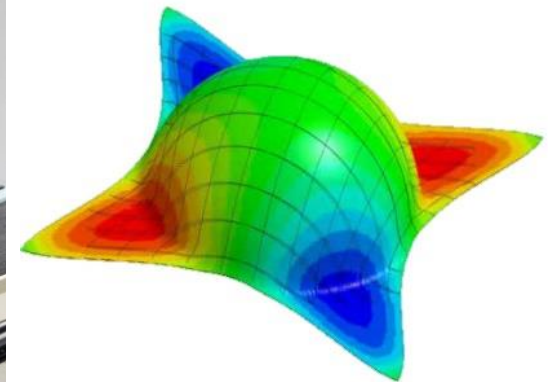
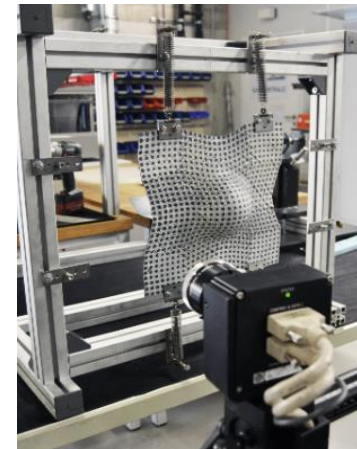
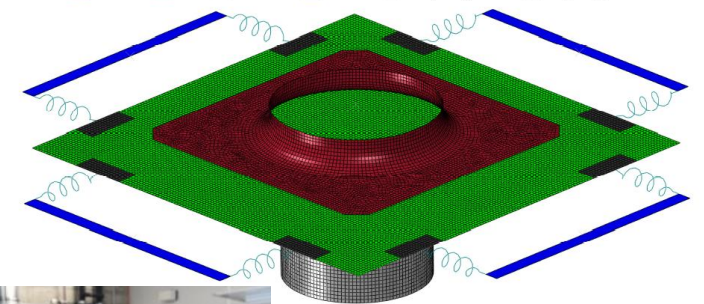
Functionalization: 3D-printed (FFF) honeycomb in thermoformed part



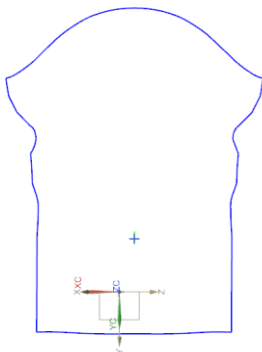
Thermforming

Thermoplastic matrix

■ Sheet ■ Die ■ Punch ■ Frame ■ Grip regions ■ Springs



Flat patterns



Additive Manufacturing

Novel production

POLYMER MATRIX COMPOSITE (PMC) MATERIALS

MATERIALS AND PROCESSING

Primary Structures

Component Performance

Compression mold of CF-SMC



25 mm

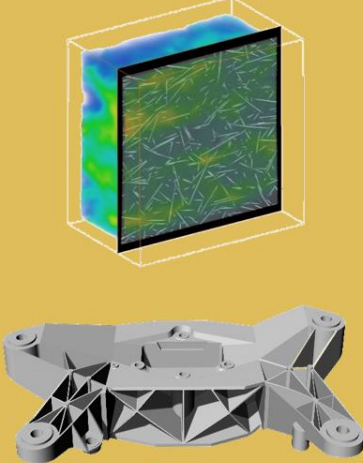
Solidation of UD forming of laminates

UD Tape

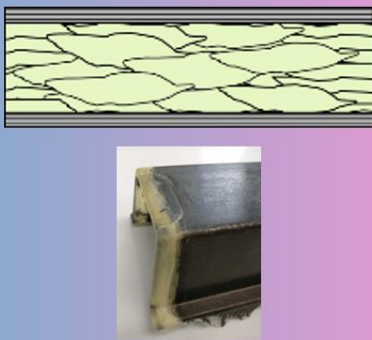
AUTOMATED LAYUP + CONSOLIDATION

Costs

Injection molding of SFRP



UD layers combined with fresh or recycled CF-SMC core layer



SMC-UD tape interface

SFRP overmolding of formed laminates

Preform

Component

FORMING + REMOLDING

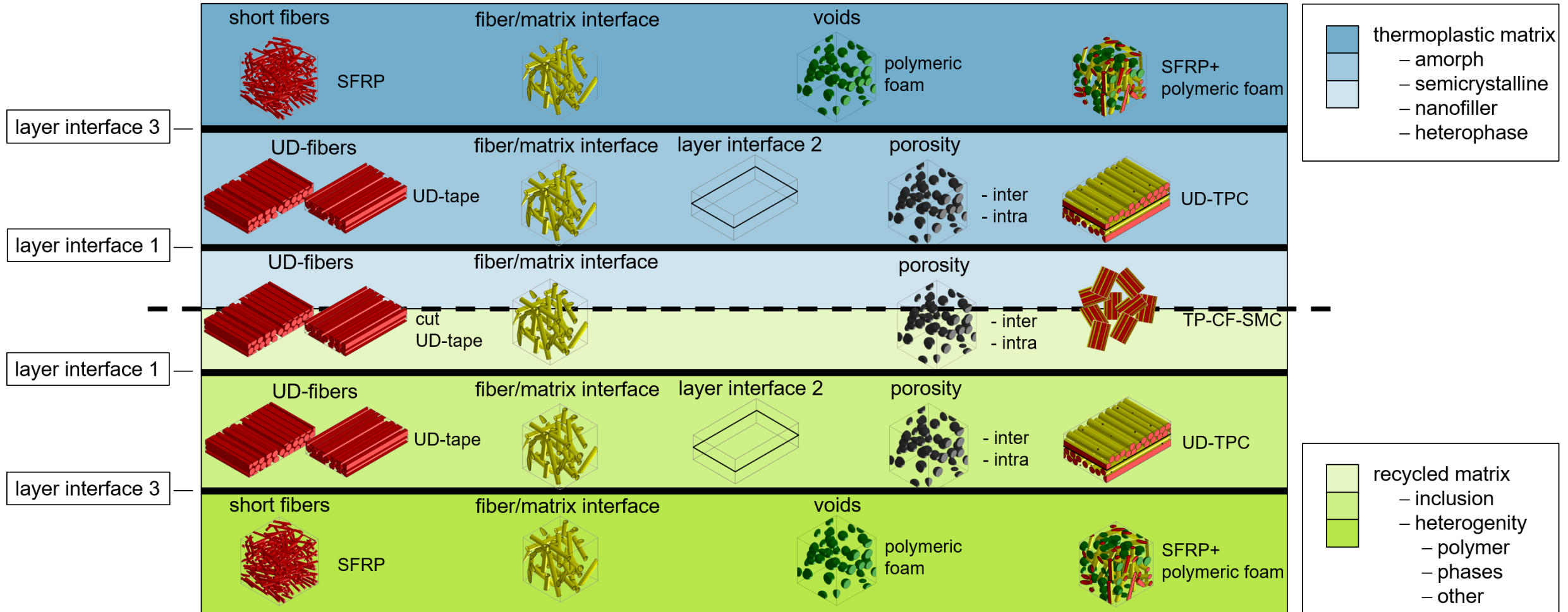
UD tape-SFRP interface

Ecological Behavior

Hybrid Structures

POLYMER MATRIX COMPOSITE (PMC) MATERIALS

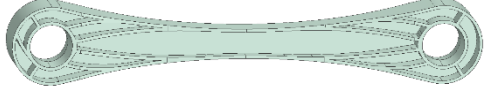


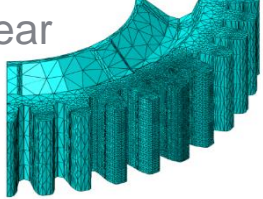

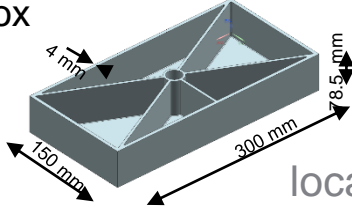
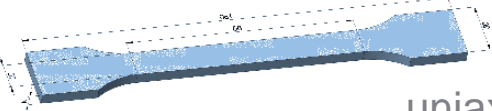
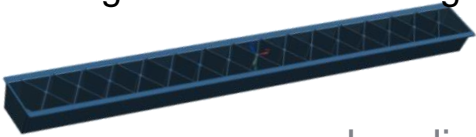
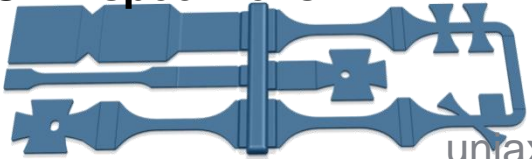
fresh polymers & fibers

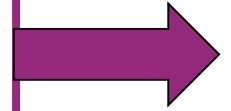


recycled polymers & fibers

SFRP SPECIMENS & COMPONENTS

Complexity of fiber orientation

	<p>Bone</p>  <p>uniaxial → 3PB/4PB-ax/tors</p>	<p>GQT</p>  <p>multiaxial</p>
	<p>TUBE</p>  <p>uniaxial → axial/torsional</p>	<p>Gear</p>  <p>Contact Tooth bending multiaxial</p>
<p>Plate specimens</p>  <p>uniaxial</p>	<p>Box</p>  <p>local/global</p>	
<p>ISO specimens</p>  <p>uniaxial</p>	<p>Bending beam with stiffening ribs</p>  <p>bending</p>	
<p>UD – specimens</p>  <p>uniaxial</p>		

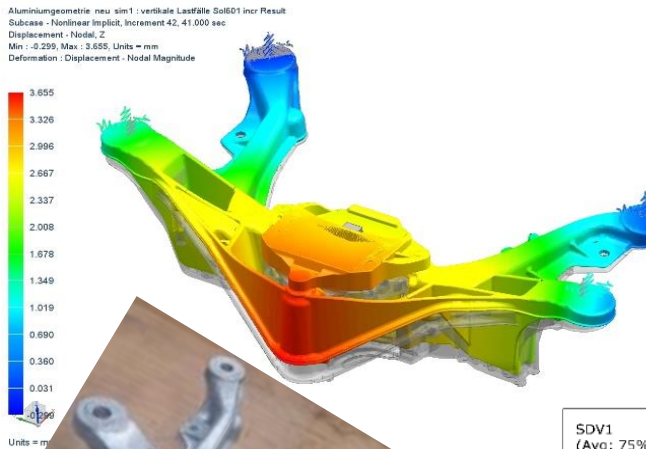


Original, M. Reiter, PhD, 2014

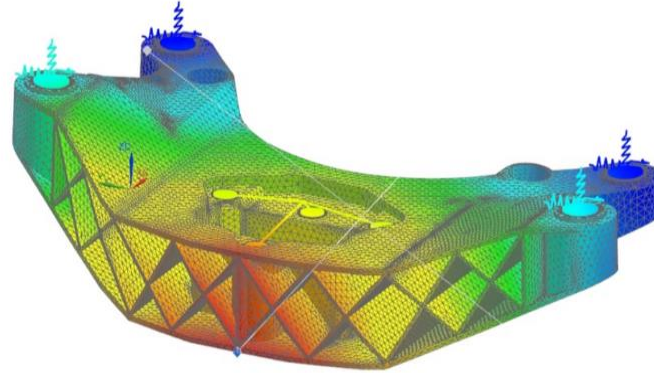
HOW TO MAKE A TRANSMISSION CROSS BEAM

Design

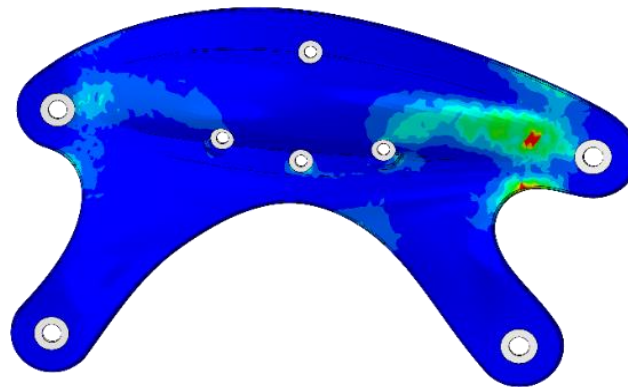
Original (metal) geometry



Injection molded sfrp geometry



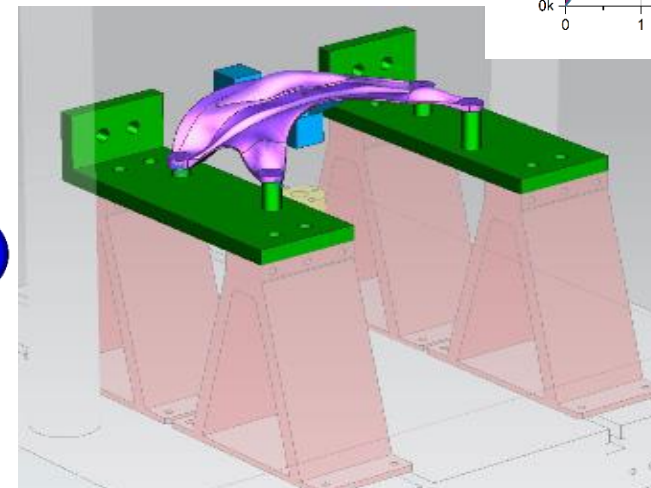
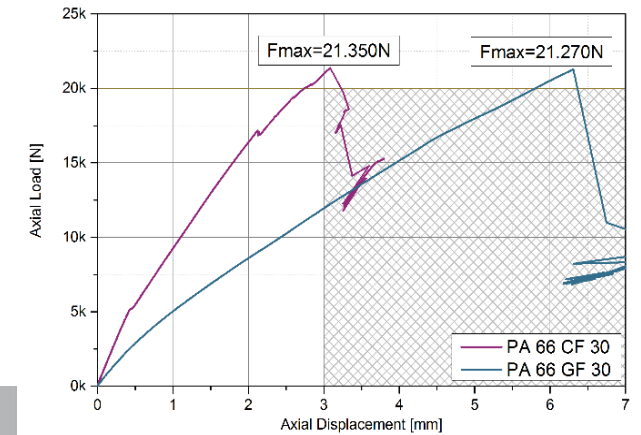
Compression molded (cf-smc) geometry



Component testing



Verification of the FE simulations



Durability testing

MSc Thesis T Hebertinger, 2021

INJECTION MOLDING SIMULATION

Complexity of Fiber Orientation – Venturi Pipe Specimen 1.0 and 2.0

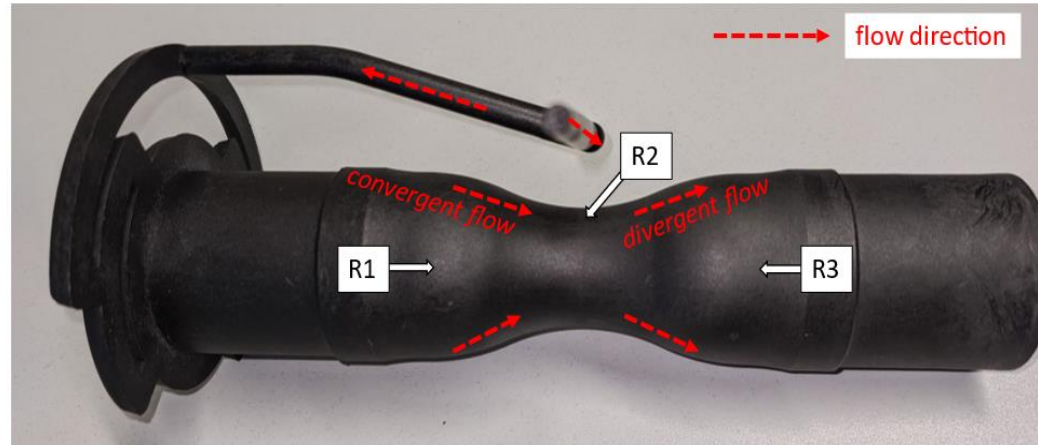
<https://www.frontiersin.org/article/s/10.3389/fmats.2020.00169/full>

ORIGINAL RESEARCH article
 Front. Mater., 16 July 2020
 Sec. Polymeric and Composite Materials
 Volume 7 - 2020 | <https://doi.org/10.3389/fmats.2020.00169>

This article is part of the Research Topic
 Women in Science: Materials
[View all 34 Articles >](#)

Fiber Orientation Distribution Predictions for an Injection Molded Venturi-Shaped Part Validated Against Experimental Micro-Computed Tomography Characterization

Maria C. Quintana^{1*}, Patricia M. Frontini¹, Aitor Arriaga², Bernhard Plank³ and Zoltan Major⁴



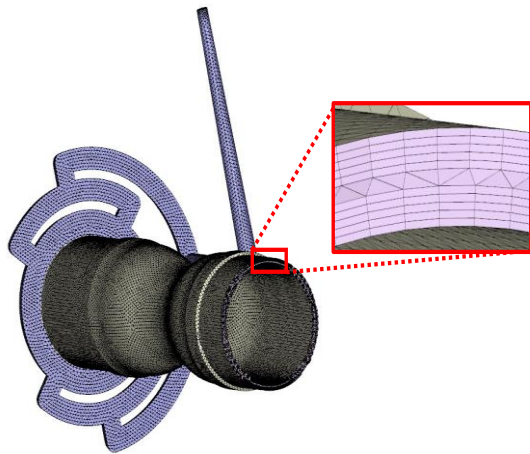
<https://www.frontiersin.org/articles/10.3389/fmats.2023.1152471/full>

ORIGINAL RESEARCH article
 Front. Mater., 18 April 2023
 Sec. Polymeric and Composite Materials
 Volume 10 - 2023 | <https://doi.org/10.3389/fmats.2023.1152471>

This article is part of the Research Topic
 Injection Molding of Polymeric and Composite Materials
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Determination of fiber orientation model parameters for injection molding simulations via automated metamodel optimization

Konrad Rienesl^{1*}, Philipp S. Stelzerl¹, Zoltán Majorl¹, Chih-Chung Hsu², Li-Yang Chang² and Képa Zulueta³



Setting	5 parameter IISO model	3 parameter iARD-RPR model	5 parameter IISO model	3 parameter iARD-RPR model by (Quintana et al. 2020)
Region of optimization	R2 (center)	R2 (center)	50% R2, 25% R1 and R3	
C_l	0.00473451	0.0011682	0.017991	0.005
C_m	0.446426	0.785661	0.792814	0.2
RPR- α	0.569448	0.179347	0.627022	0.7

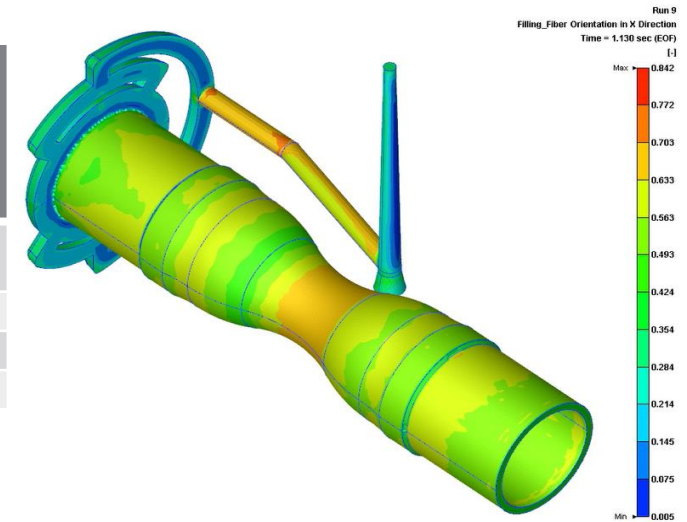
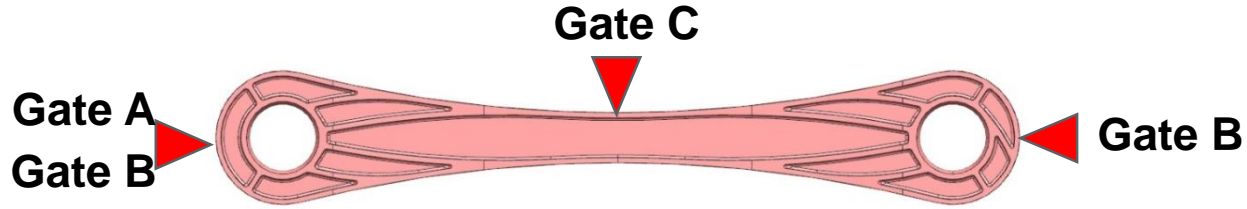
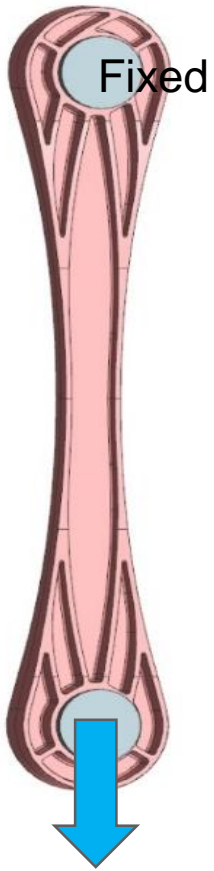


Figure 4: Detail of the meshed Venturi tube geometry

➡ **Axial-Torsional Testing, ongoing**

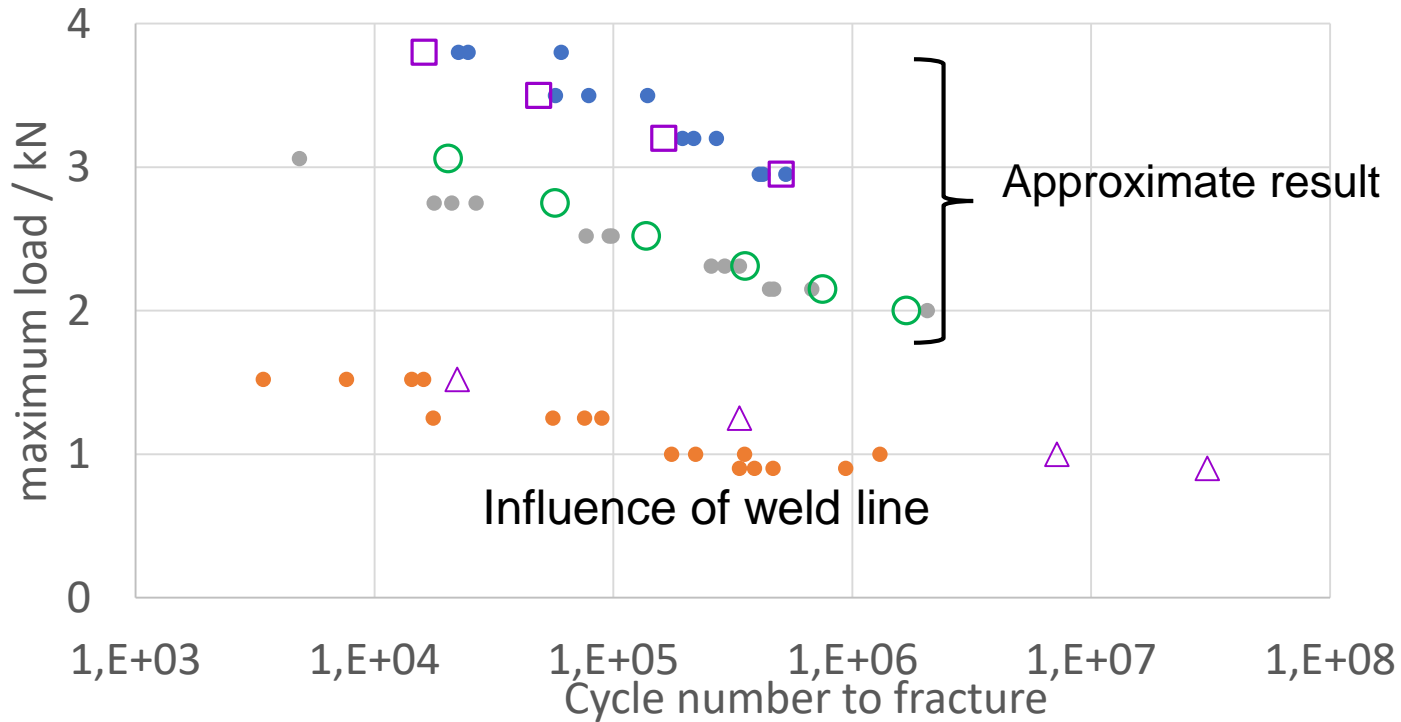
Figure 6: Fiber orientation distribution in flow direction at end of filling

ACCURATE PREDICTION OF ANISOTROPIC FATIGUE ANALYSIS - SFRP



Material: Leona[®] 14G35

Fatigue lifespan 80°C 50%RH



- Experiment Gate A
- Experiment Gate B
- Experiment Gate C
- CAE Gate A
- △ CAE Gate B
- CAE Gate C

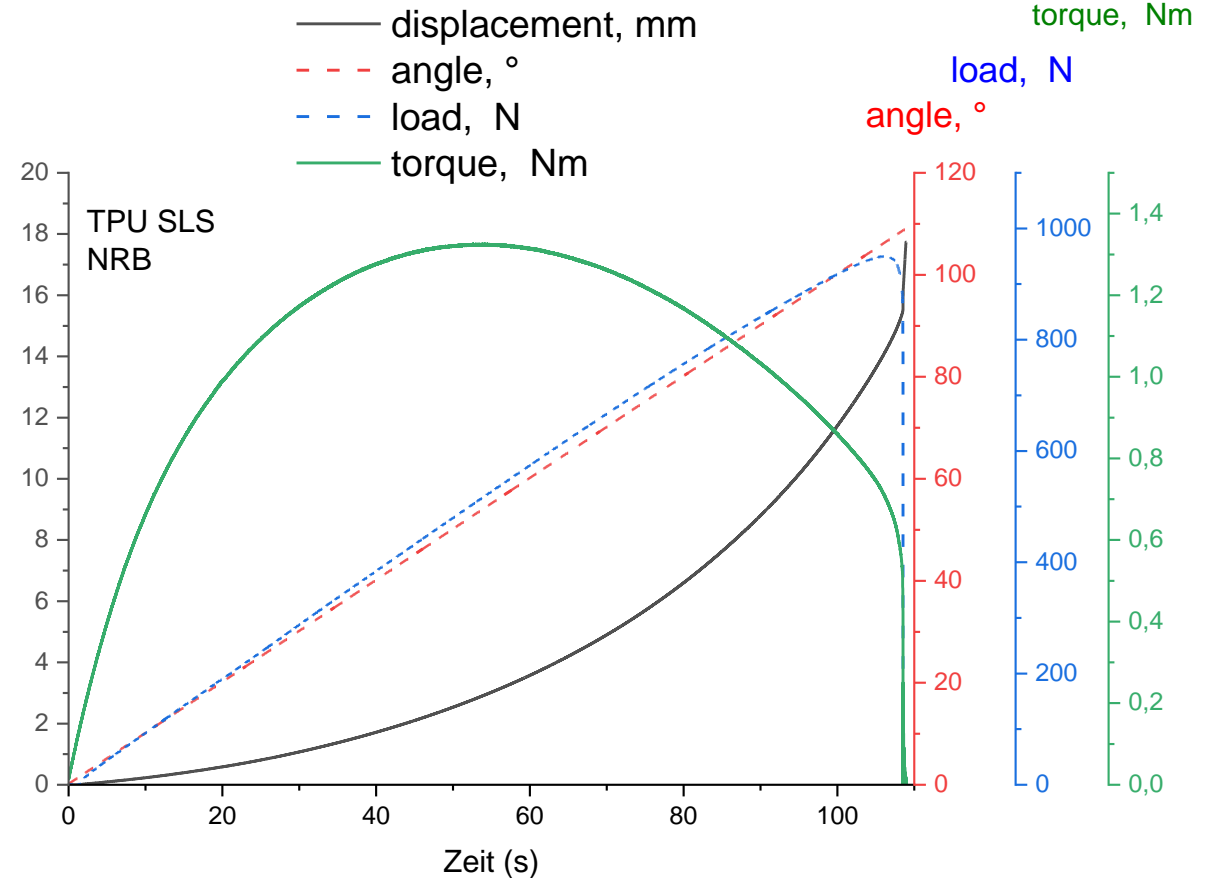
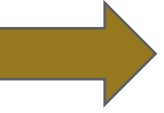


Improving the prediction of fatigue lifespan at weld line position

H. Inaba, 2022, Asahi Kasei, Tuoe IPPE JKU, HxGN Live Global, Hexagon, Las Vegas, 2023

MULTIAXIAL FATIGUE ANALYSIS

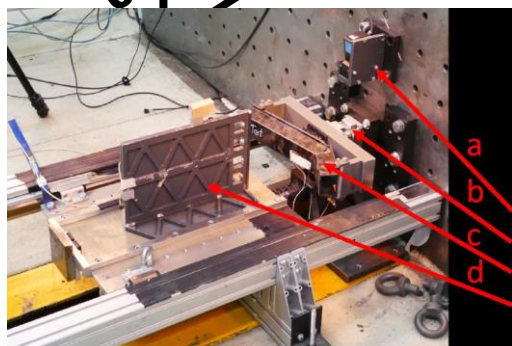
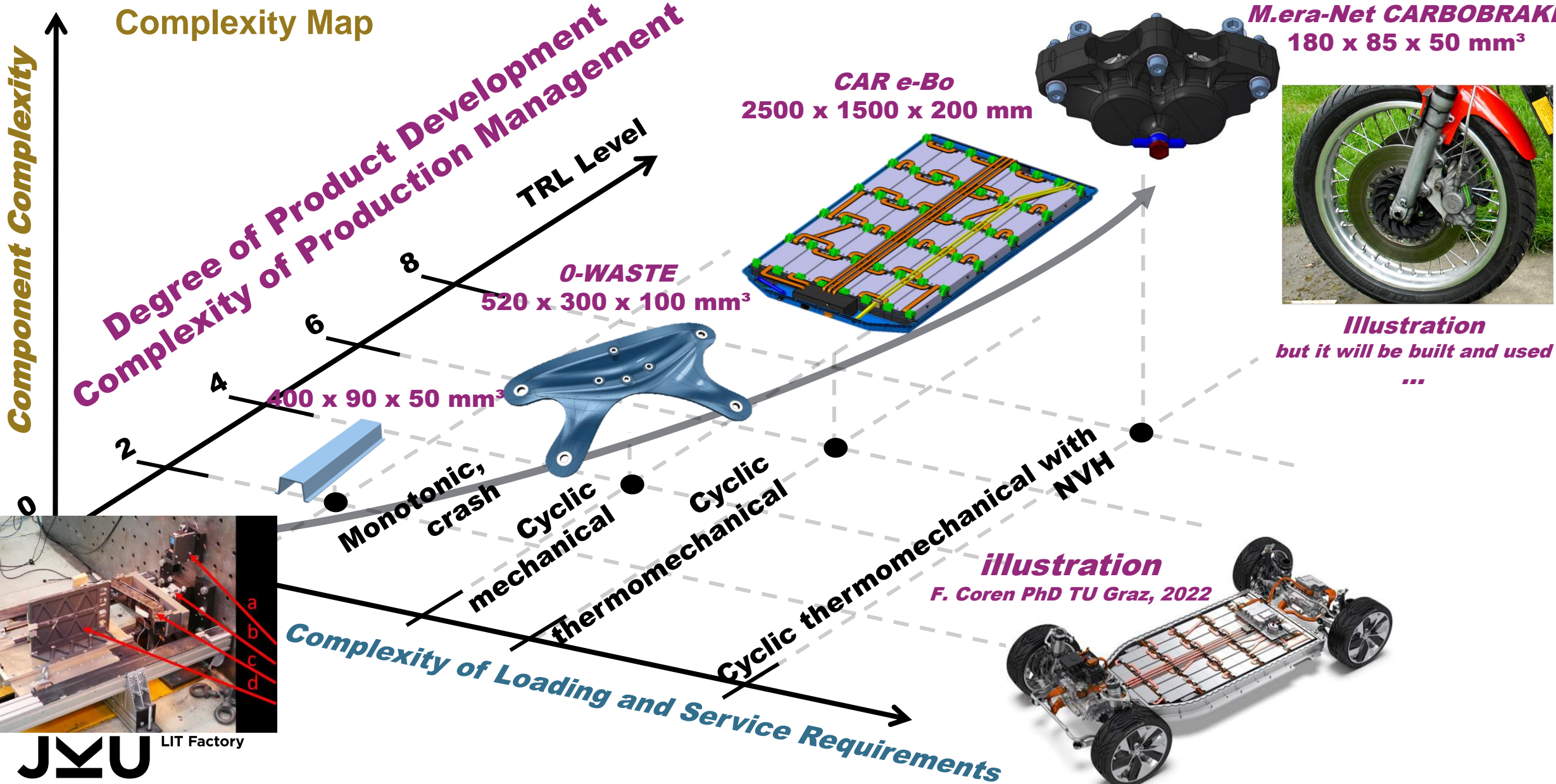
Multiaxial (axial/torsional) Fatigue of Polymers, Lattice Structures and Thermoplastic Composites



LIT Factory investment, machine and temperature chamber and Siemens Durability and hbk nCode software

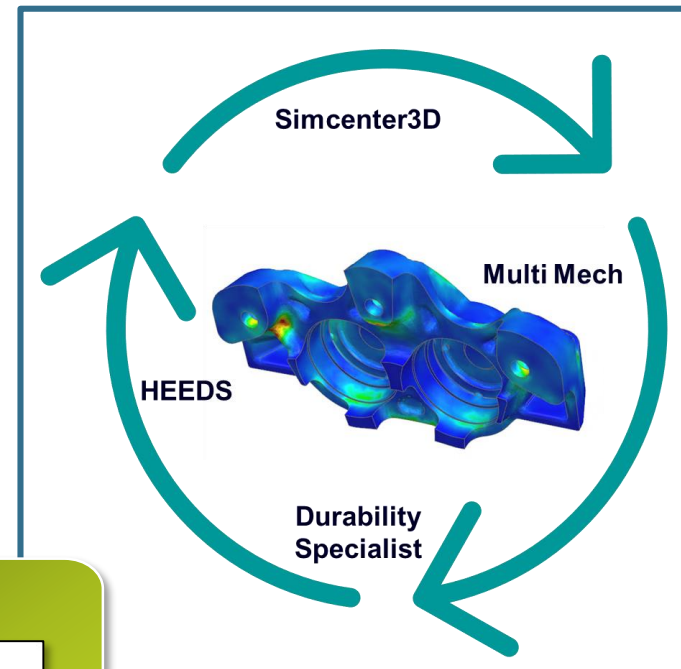
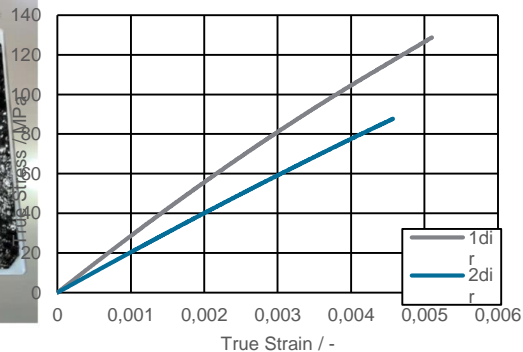
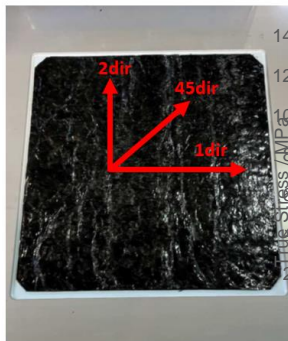
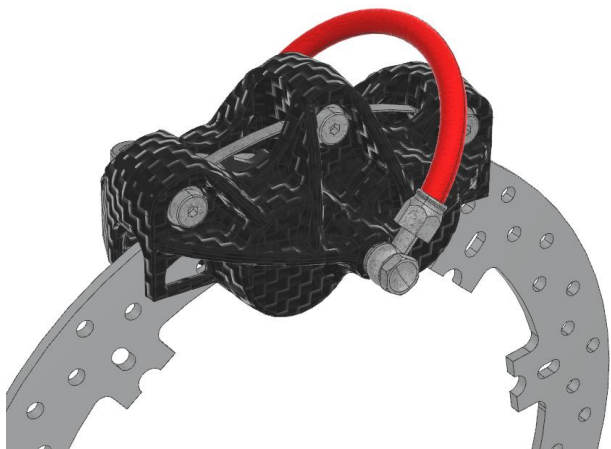
Multiaxial (axial/torsional) Testing of Prostheses (knee, hip joint, spinal disc) ...

DESIGN STUDIES - COMPRESSION MOLDING



HOW TO MAKE A BRAKE CALIPER

Thick-Walled CF-SMC Brake Caliper

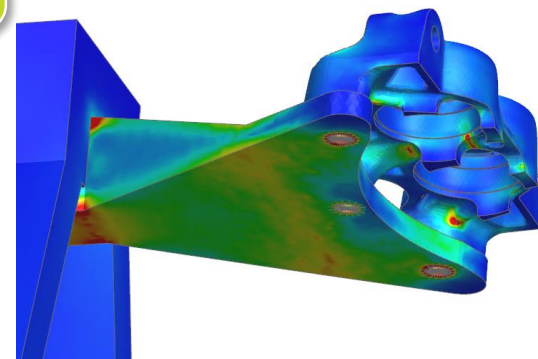
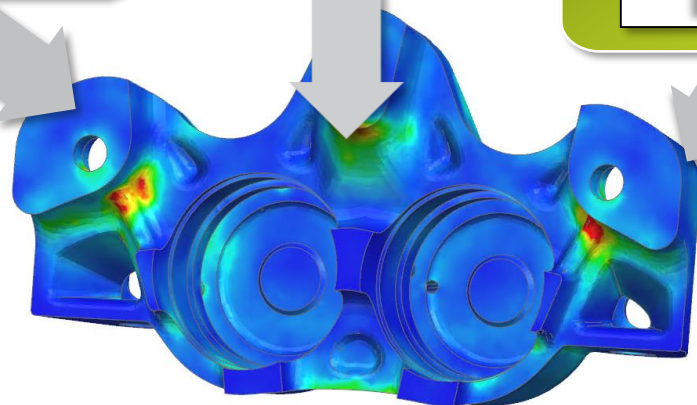


Material

Design

Processing

HOW TO COOPERATE WITH AUTOMOTIVE ENGINEERS ?



HOW TO COOPERATE WITH PRACTICAL MANUFACTURING EXPERTS?

Data Collection: Life Cycle Assessment



General Information

This data collection enables our consultants to prepare and refine a specific model. It will give you insights to the kind of data we need and provide us with a better picture of the products.



Site Specific Information ⓘ

Location production site	Site XY
Reference year	2021
Total production volume (number)	units
Total production volume of product covered (number)	units
Total production volume (revenue)	€
Total production volume of product covered (revenue)	€
Electricity consumption	kWh
Coal share	%
Nuclear share	%
Natural gas share	%
Other fossils	%
Renewable EEG	%
Other renewables	%
...add more if necessary	%
Cooling energy consumption	kWh
...add more if necessary	
Heating energy consumption	kWh
...add more if necessary	
Fuel consumption	kWh
Diesel	l
Natural gas	m³
Oil	l
...add more if necessary	
Waste occurance non-hazardous	t
Total paper waste (example)	t
...add more if necessary	
Waste occurance hazardous	t
Total chemical waste (example)	t
...add more if necessary	

information is confidential.

		Company XY
Name		
E-Mail		
Position		

HOW TO COOPERATE WITH BUSINESS ECONOMISTS ?

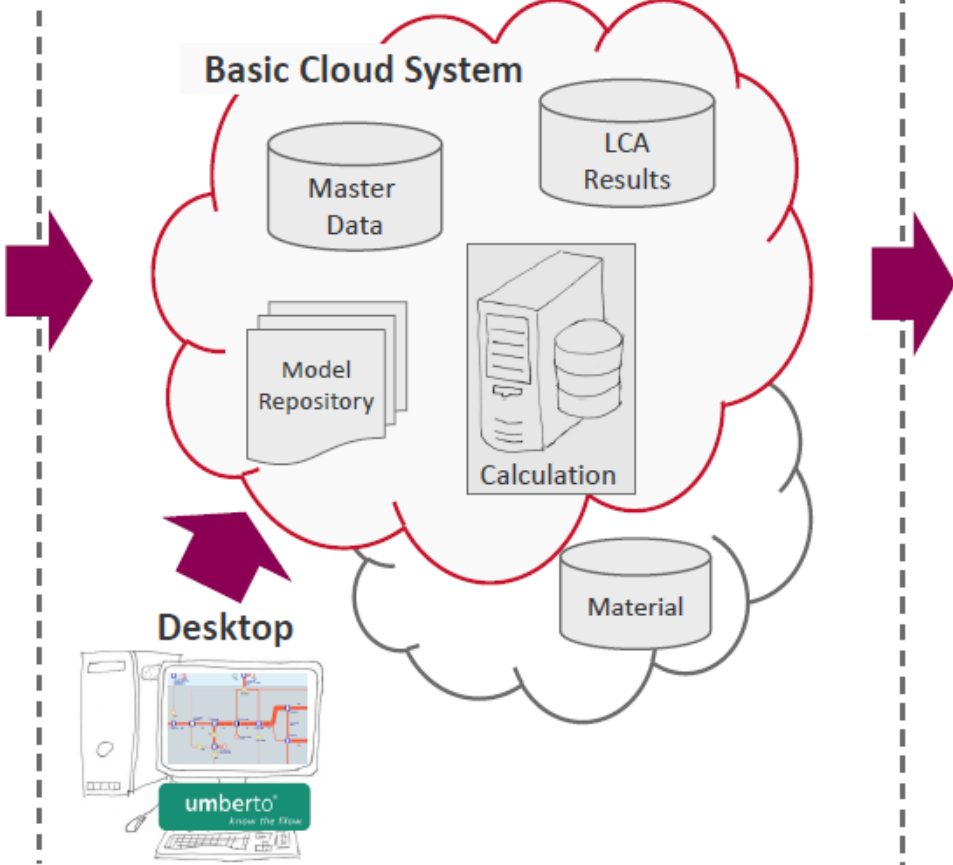
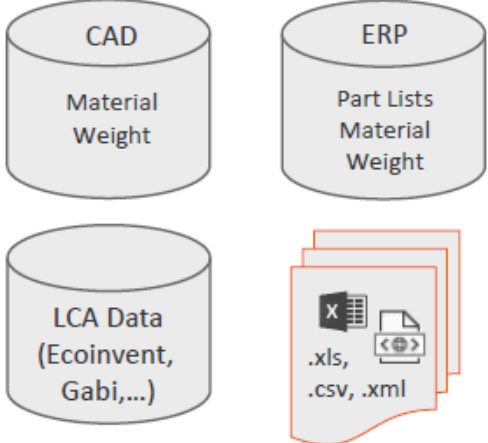


The LCA is an integral part of the design process

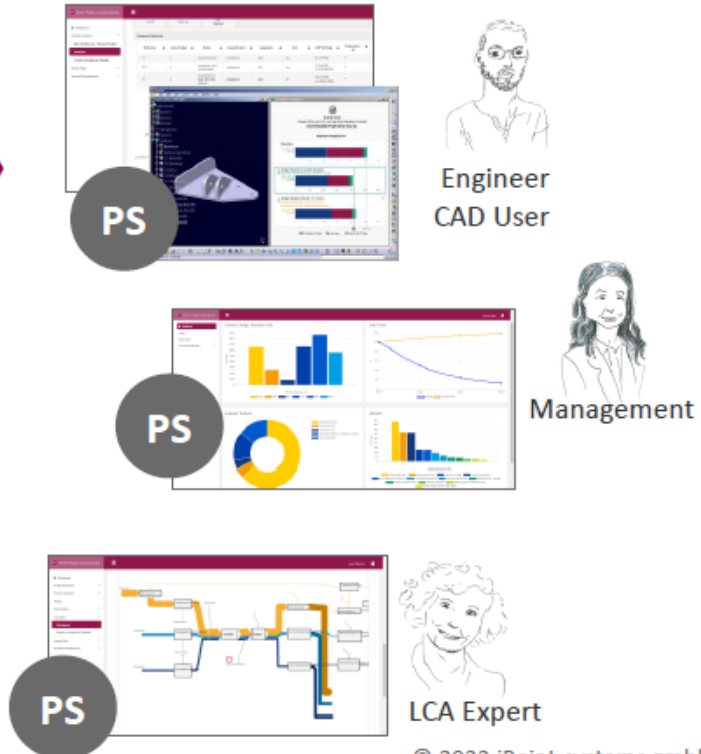
HOW TO MAKE LIFE CYCLE ANALYSIS (LCA)



Data Sources



Web Application



© 2022 iPoint-systems gmbh

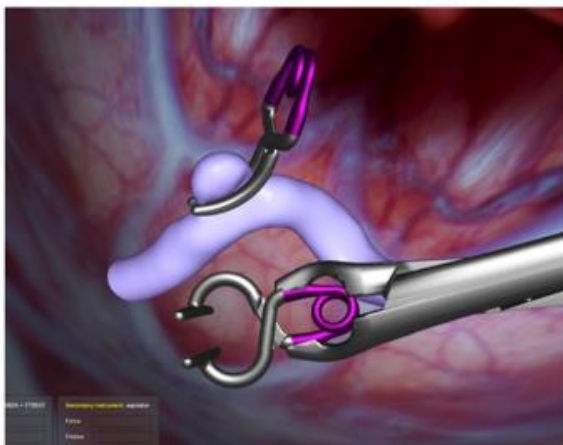
HOW TO MAKE A BRAIN MODELS

**HOW TO COOPERATE WITH NEUROSURGEONS
(CLINICIANS)**

**HOW TO COOPERATE WITH SIMULATION
EXPERTS**

NEUROSURGERY

simulation



Real treatment



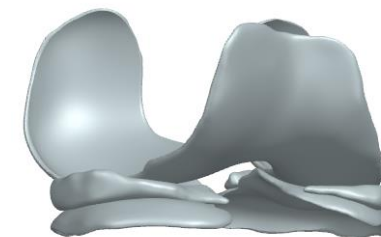
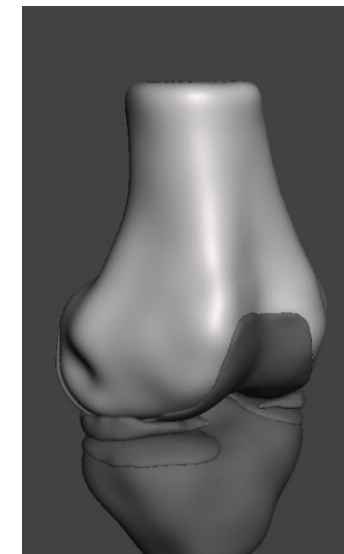
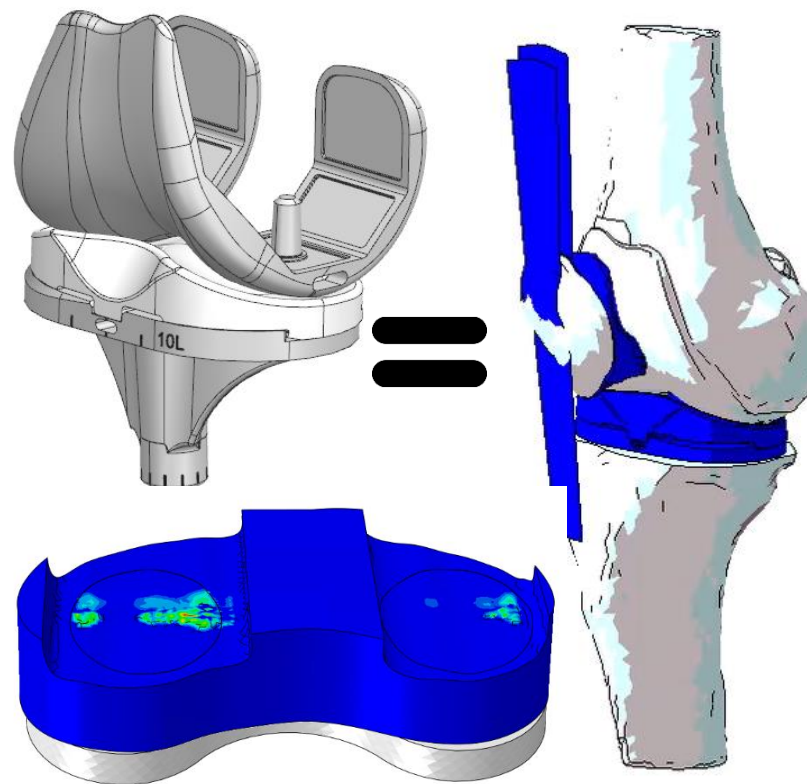
physical model



ORTHOPEDICS

Conventional endoprosthesis

Tissue Engineering



[Johannes Kepler Universität Linz | Digital Representations of the Human Part I](#)

<https://www.youtube.com/watch?v=Vs-ZTymgcdc>

Kapshammer ippe jku, 2021

ADDITIVE MANUFACTURING



Medusa

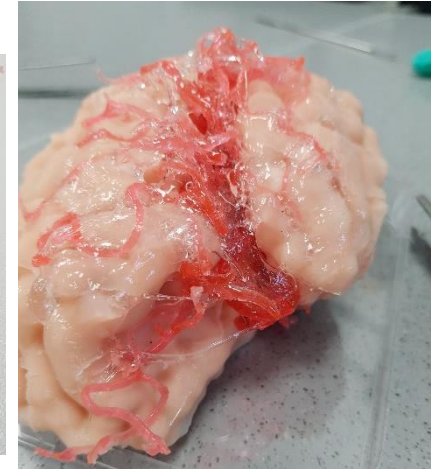
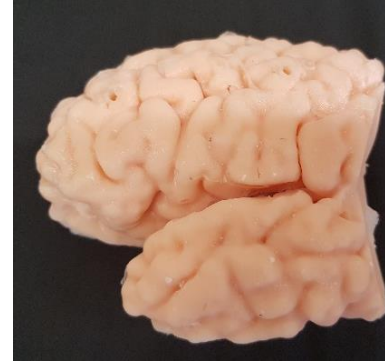
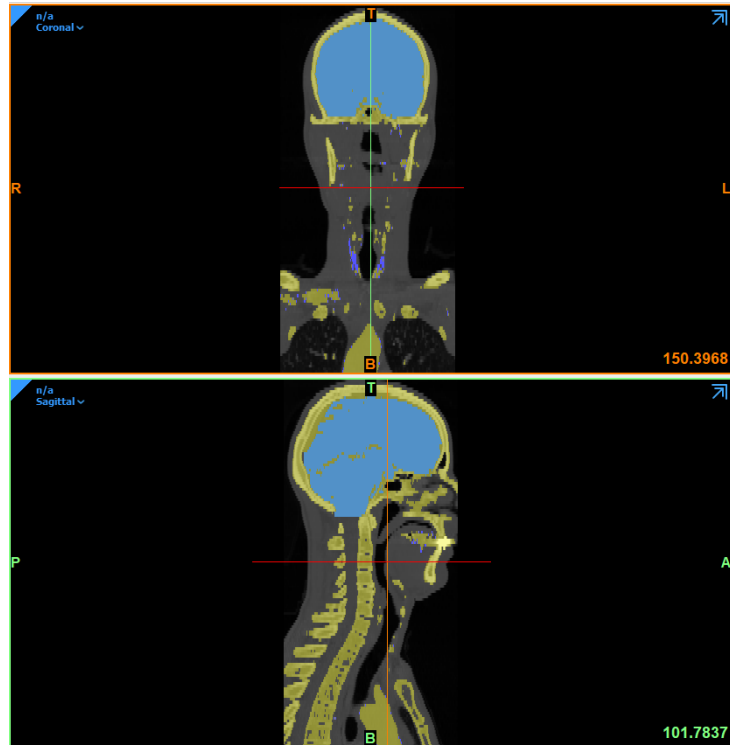
IMAGE PROCESSING

SKULL

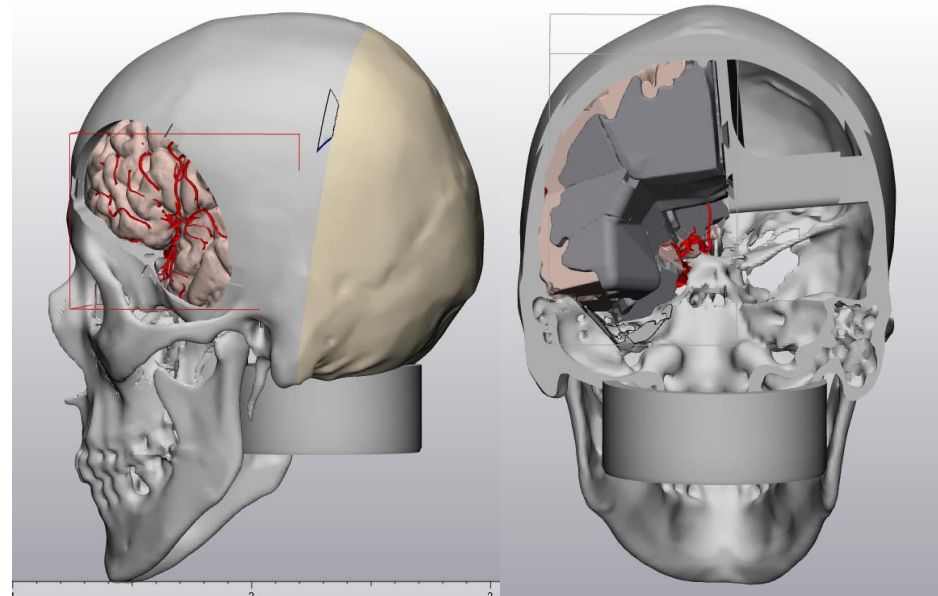
BRAIN

VESSELS

ARACHNOID



ASSEMBLY



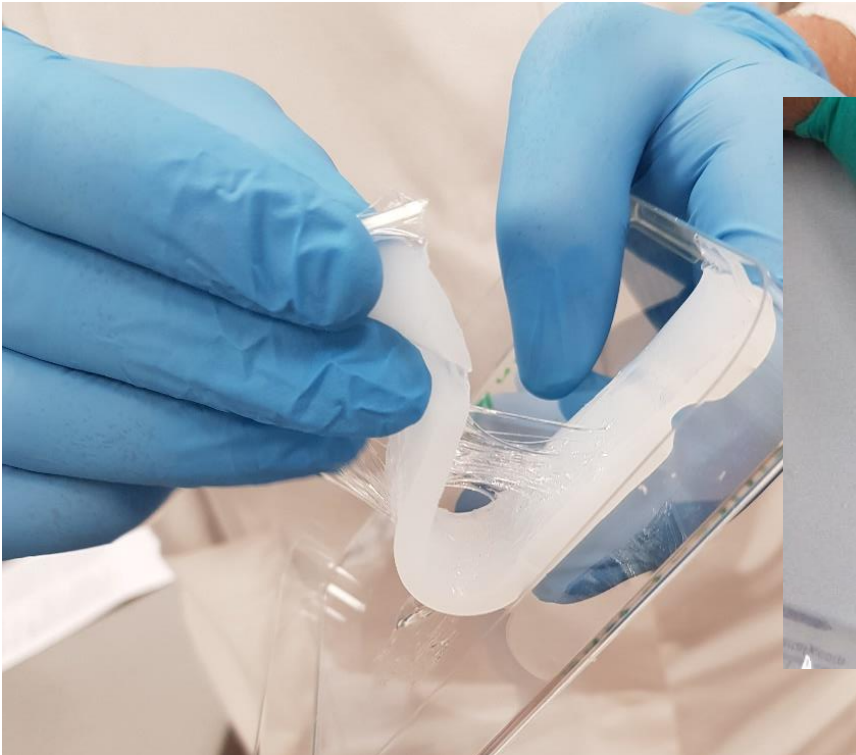
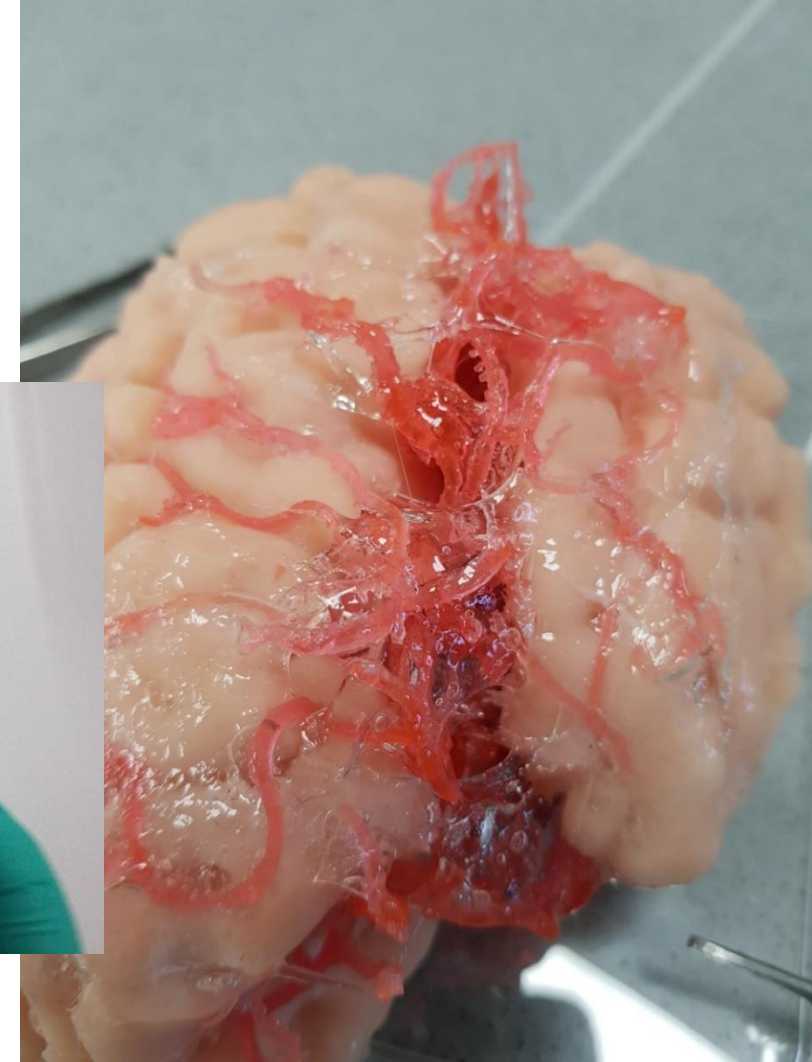
a fine, delicate membrane, the middle one of the three membranes or [meninges](#) that surround the brain and spinal cord, situated between the [dura](#) mater and the [pia](#) mater.

Materialise Mimics, using CT and MR data

ANATOMICAL MODELS – EURYALE - ARACHNOID

- **ARACHNOID**

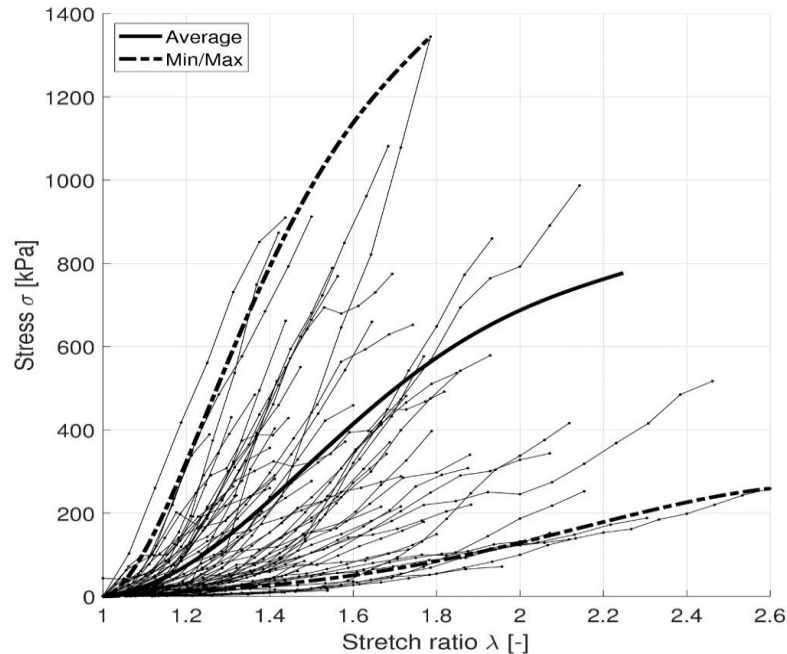
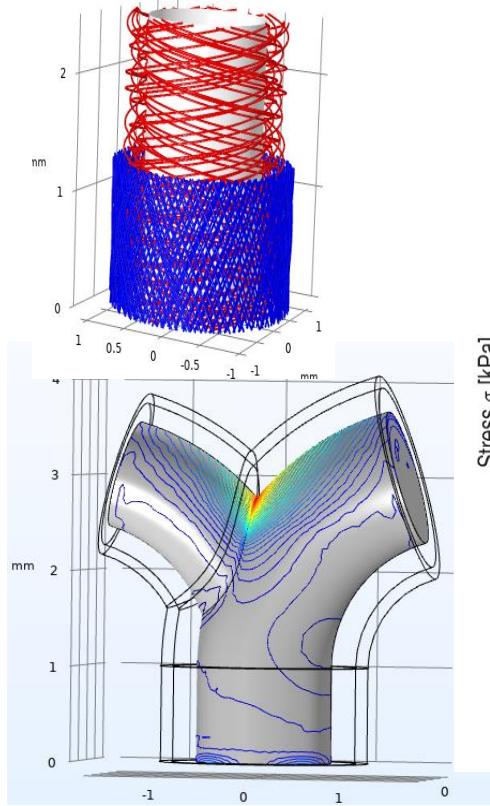
- pHEMA (Poly-(2-hydroxyethyl-methacrylat)) hydrogel as Arachnoid
- Signature mixture for MEDUSA, UV-A crosslinked
 - 1.5 – 2 h preparation time for the surgeon in the simulator before aneurysm can be reached



SIMULATION MODELS

From Continuum Material Models to Molecular Dynamics Models for Biomaterials

Human soft tissues are complex materials that can exhibit **nonlinear**, **time dependent**, **inhomogeneous**, and **anisotropic** behaviors



G. Seebach, JKU, MSc 2021

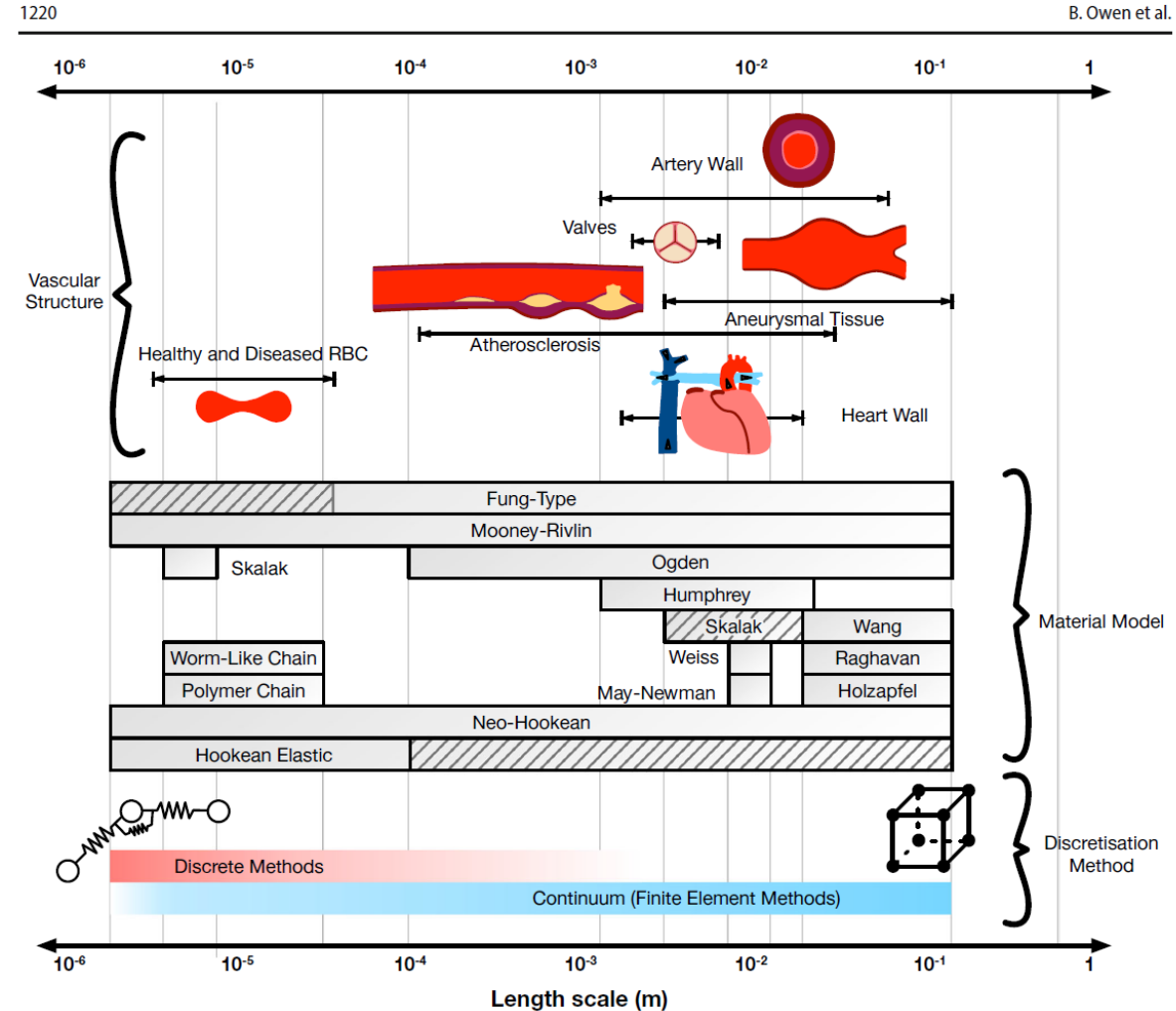


Fig. 1 Structural models used in vascular applications with popular material models and discretisation methods, classified with respect to length scale and the applications to which they have been applied. Hashed lines indicate scales where material models have been used but not commonly

Owen, B, et al, *Biomechanics and Modeling in Mechanobiology* (2018)

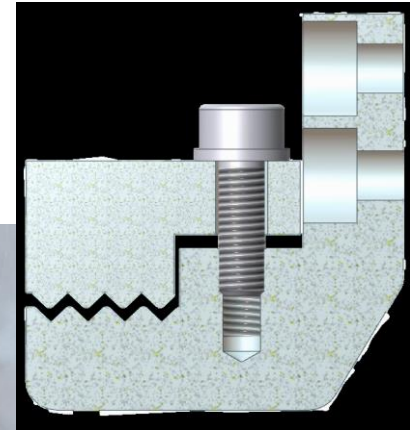
17:1217–1242, <https://doi.org/10.1007/s10237-018-1024-9>

EXPERIMENTS

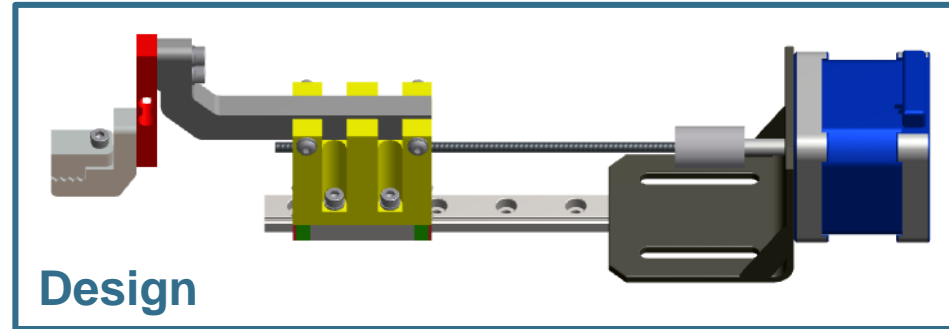
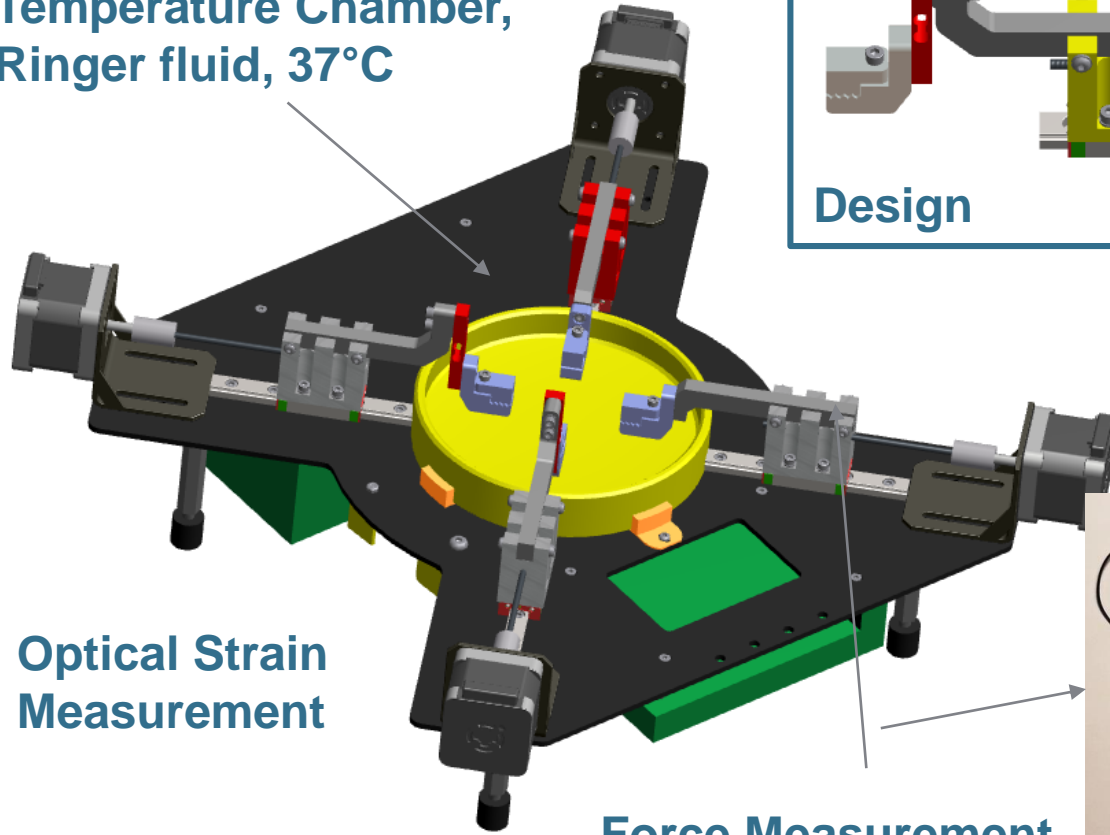
Testing of Biomaterials – Soft tissues, Small Size Specimens

In-plane Biaxial Loading Device, 5mN to 50 N (IPPE Development)

Grip

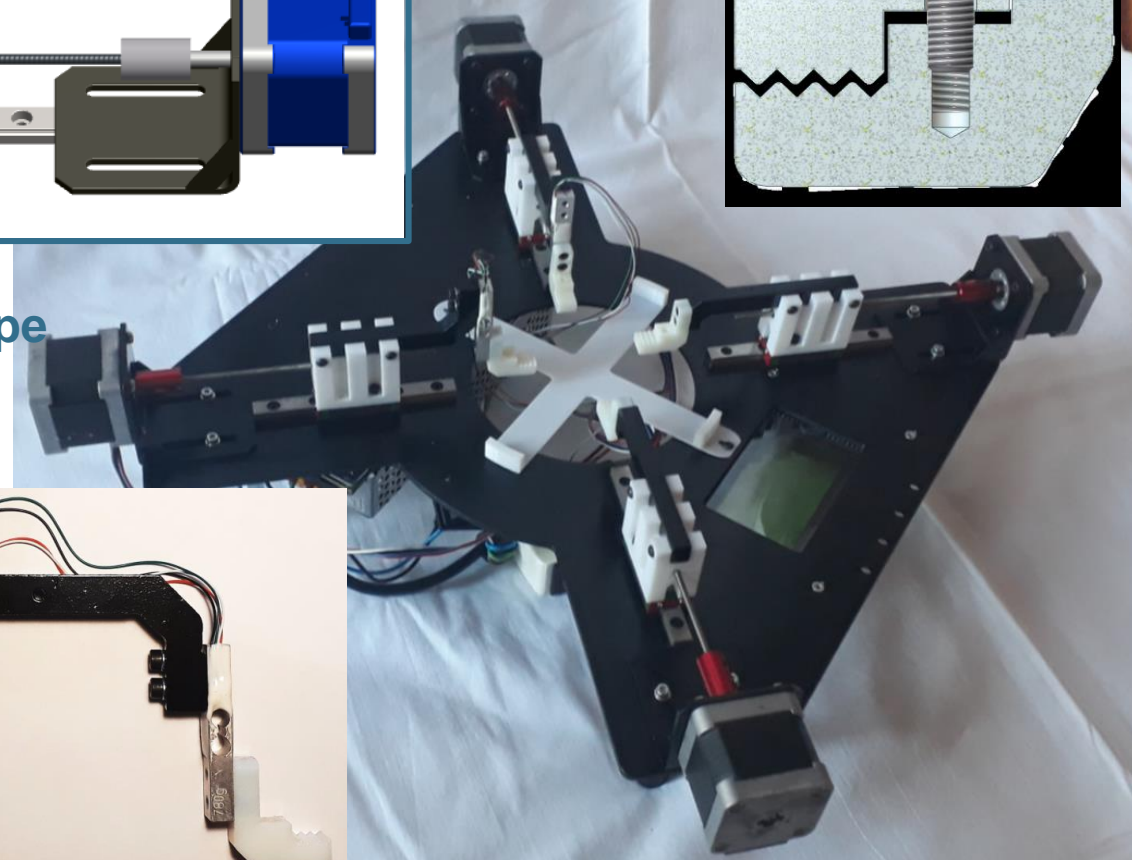


Temperature Chamber,
Ringer fluid, 37°C



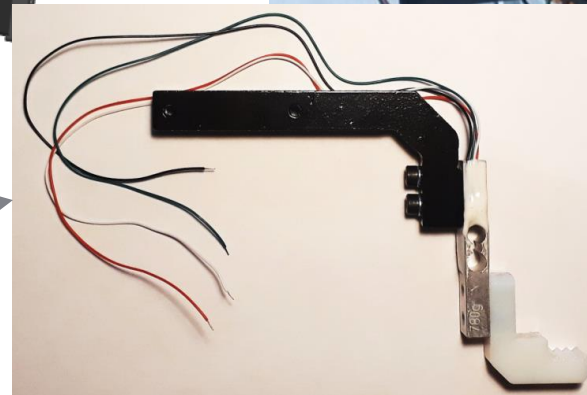
Design

Prototype



Optical Strain
Measurement

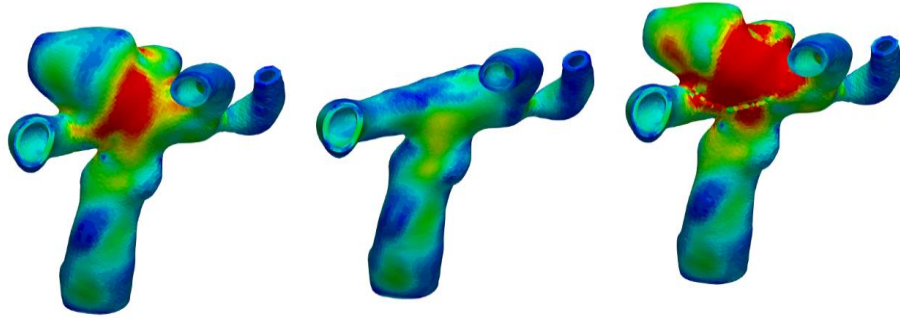
Force Measurement



SIMULATION

- **Finished workflow**

- automatic creation of calculation grid from CAD data
- semi automatic case setup of FSI simulations
- automatic running of simulations



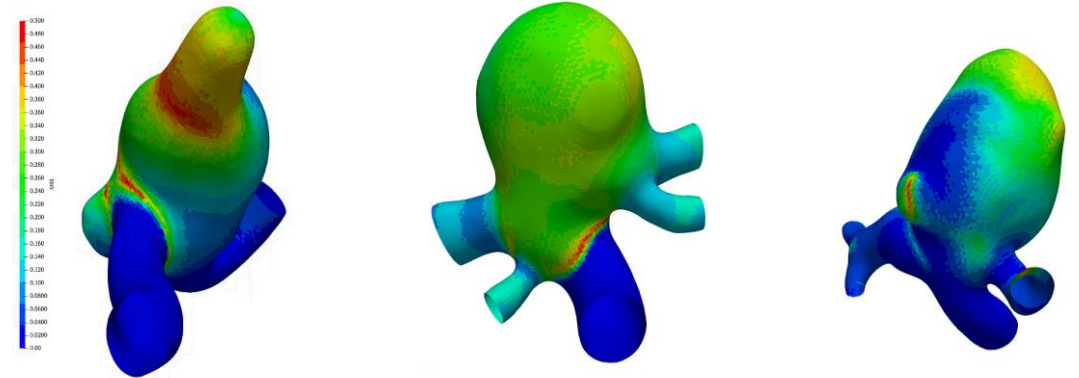
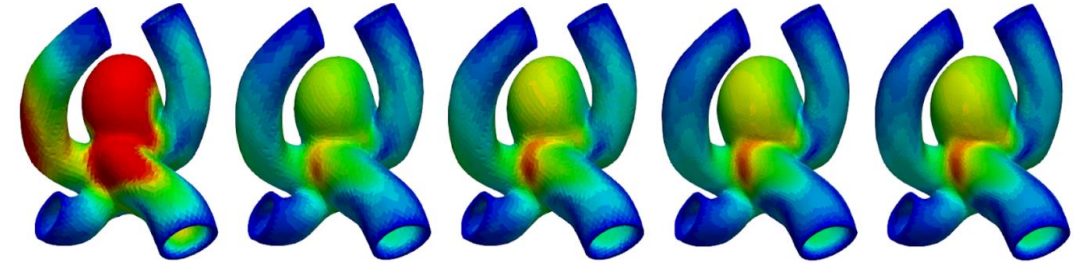
- **Features**

- ⇒ **reduction of wall thickness**
- change of material parameters
- ⇒ **mean / max pressure, mean / max velocity inside aneurysm**



Medusa

linear Ogden red. pol. HGO pHGO

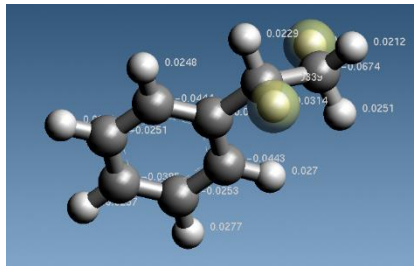


INTEGRATIVE SIMULATION

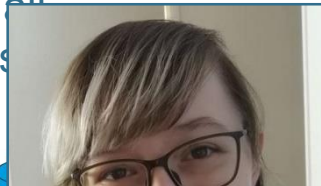
MATERIAL, PROCESS, MICROSTRUCTURE- AND COMPONENT

Molecular Dynamics (CG)

- Rheology, Viscoelasticity
- Fiber/matrix interface
- Diffusivity



➤ Experimental determination of all input data necessary for IM/CM/AM simulations



➤ Experimental determination of all input data necessary for IM/CM/AM simulations



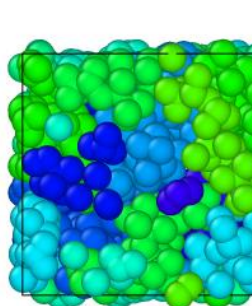
➤ Experimental determination of all input data necessary for IM/CM/AM simulations



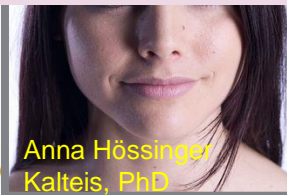
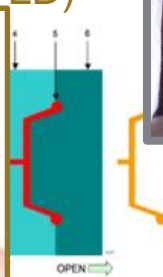
Component characterization simulation experiment

2022

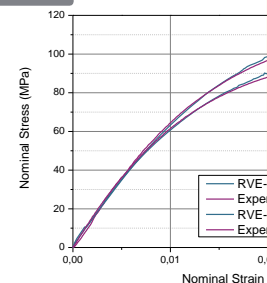
➤ To predict rheological behavior



➤ To predict structure formation (FOD, FLD)



➤ To predict mechanical behavior (stiffness, strength)

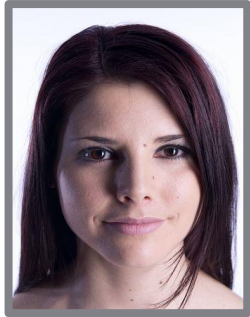


Life Time Analysis
PLM integration
LCA analysis



HOW TO MAKE PRACTICAL (AND SUCCESSFUL) GENDER POLITICS

There will be more woman scientists if they get the chance – habilitation and permanent job



Compu
material

> 2023



Design Methodology and Certification for the
Development of Medical Products (medical engineering)

Public-Private Partnership

- Define and submit research proposals with and without industry partners
- Industry contracts
- Personalized international cooperation
- Support of the collegial bodies and rectorate of the university

Danke für die Aufmerksamkeit



Kontakt:

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+43 732 2468 6591