Individual Optimization of a New 3D-printed Prosthetic Foot
Agenda

1. Mecuris vision
2. Prosthesis development
3. Functional robustness
4. Validation & User testimonial
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1. Mecuris vision

2. Prosthesis development

3. Functional robustness

4. Validation & User testimonial
Mecuris Products and Services

Prosthetics
✓ FirStep
✓ NexStep
✓ ComfyStep
✓ Cover

Orthotics
✓ Night Splints
+ AFO (Ankle Foot Orthotics)

Digital Services
✓ Digital Test Stand
+ Platform Services

German patent pending: DE 10 2019 100 584.1
3D-printed prosthetics
3D-printed prosthetics
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Requirements

- **Medical benefit**
  - Functional parameters
  - User testing

- **Safety**
  - Safety parameters
  - Machine testing
Machine testing

- Durability test - ISO 10328
  - Heel & Forefoot loading (patient weight)
  - 2 million cycles – 1 Hz
- Overload test - ISO 10328
  - Up to 4-5000 N
- Rollover-shape - ISO 16955
  - Full gait cycle
- Energy return
- ...
Finite Element model

- Large deformations
- Plasticity (PA12)
- Non-linear contacts
- Boundary conditions:
  - ISO 10328
Validation - Finite Element model
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Product goals

Design Understanding
Investigate parameter sensitivities, reduce complexity and generate best possible meta models

Model Calibration
Identify important model parameter for the best fit between simulation and measurement

Design Improvement
Optimize design performance

Design Quality
Ensure design robustness and reliability

Robust Design

CAE-Data

Measurement Data
Body weight

Foot size

Patient domain

Existing design
Body weight

Foot size

Patient domain
Product goals

- **Design Understanding**: Investigate parameter sensitivities, reduce complexity and generate best possible meta models.
- **Model Calibration**: Identify important model parameters for the best fit between simulation and measurement.
- **Design Improvement**: Optimize design performance.
- **Design Quality**: Ensure design robustness and reliability.
- **Robust Design**:
Input parameters

- Forefoot thickness
- Toe thickness
- Heel thickness
- Body weight
- Foot size
Design of Experiments

75 samples

150 samples
Sensitivities

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<th>F3</th>
<th>S6</th>
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</table>

Heel deformation

Coefficient of Prognosis (using MOP)
- Full model: CoP = 99%
- INPUT: Forefoot_thickness 6%
- INPUT: Size 17%
- INPUT: Force_Y_Component 36%
- INPUT: Heel_thickness 46%
Optimization constraints

- 2 load cases
  - Same input domains

- 11 safety constraints
  - Max. eq. strain (element sol.)
  - Same areas for 2 load cases
Optimization

- Forefoot stiffness
- Heel stiffness
- Forefoot lowering

- Combined objective
  - 3 functional parameters
- Reference design values
Functional robustness

- Patient parameters
- Free parameters
- Save results
Software

- Solidworks 2017
- Ansys Workbench
- optiSLang (add-in + standalone)

- Simulation time: ~10 days
- Optimization time: 2 hours
  - 56 cases
  - Only once
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Rollover-shape
Finite Element tool
Validation: rollover-shape

Reference - Size 26, 80 kg

Optimised - 80 kg

Size 23
Size 25
Size 28
Proof of concept: expert wearer
“The prosthetic knee harmonizes well with both feet. [...] One foot is a soft variant for usage at home, the other is a stiff variant for outdoor usage and fast walking. My subjective impression confirms the different behaviour of the feet.”

Michael Kramer, Rehatreff, 1 | 2019 (translated from German)
Thank you for your attention!

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