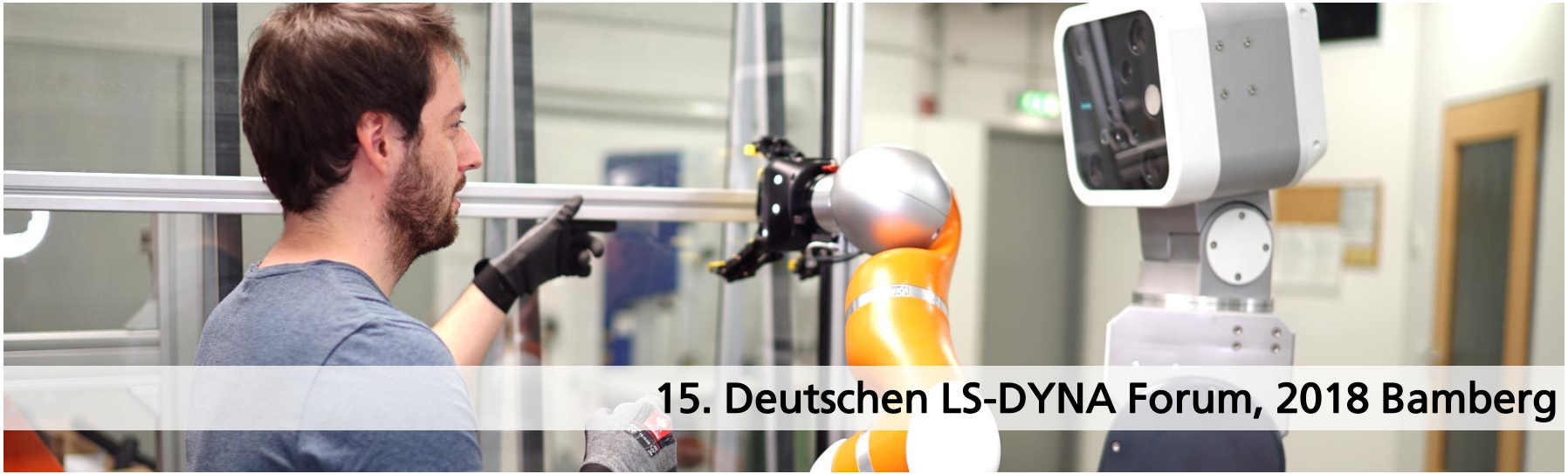
FE-SIMULATION OF IMPACT LOADS ON THE HUMAN BODY: METHODOLOGY FOR THE DEVELOPMENT OF TISSUE MODELS

Zechang Wang, Roland Behrens, Prof. Dr. Norbert Elkmann
Fraunhofer IFF – Robot System



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Motivation

safe human robot collabration with help of FE-methody

safe collabration
- risk of human injury
- limit of pain

human-centered collaboration

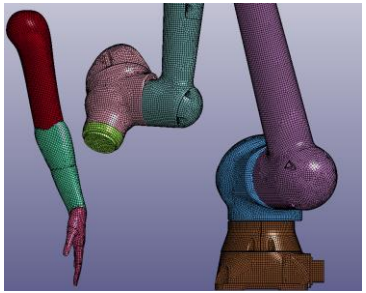
human robot collabration

IFF subjects study

FE-Mode

- 40 subjects
- 21 localization
- force-based limits

ideal for simulating human-robot collisions

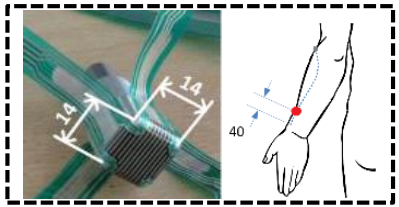


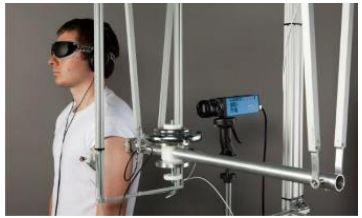
- biomechanics response
- experimental data

Concept

Methodology // develop of a stress tissue model

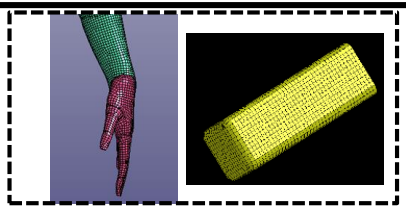
IFF





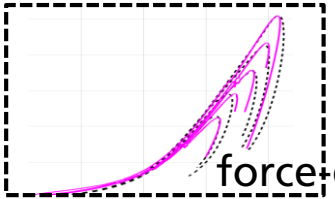
- 40 subjects
- 21 localization

tissue model



$F(N, mm)_{energy}$

validation



force-deformation curve

study

critical data

any contour

- forces
- stress
- energy

collabration

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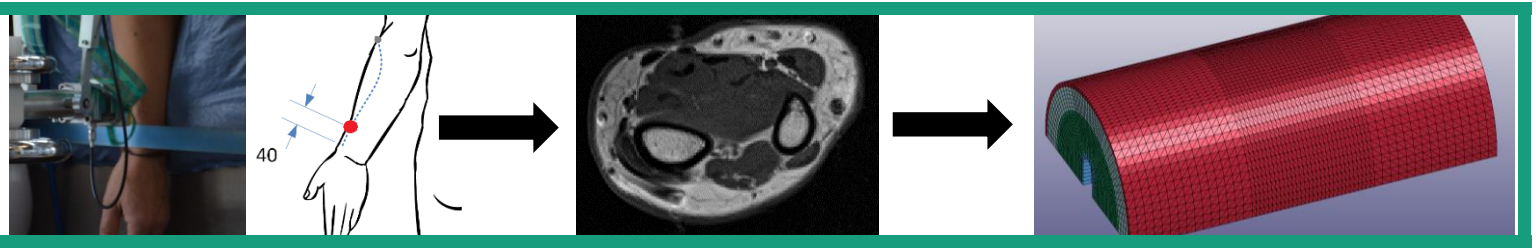
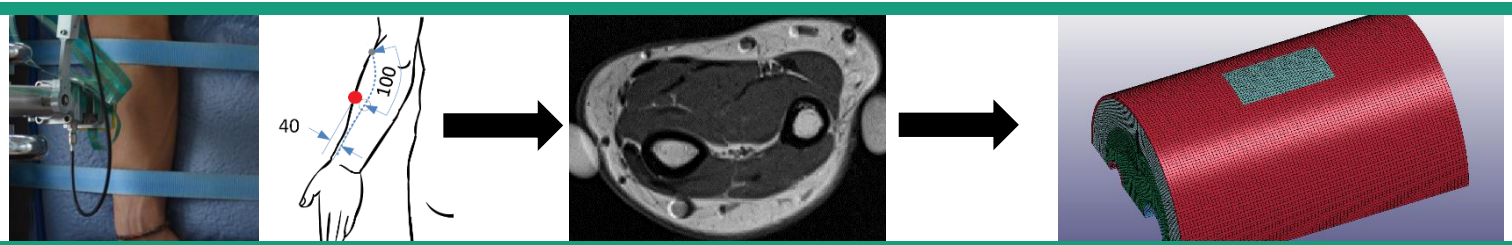
Tissue Model

stress models for the local impact body parts

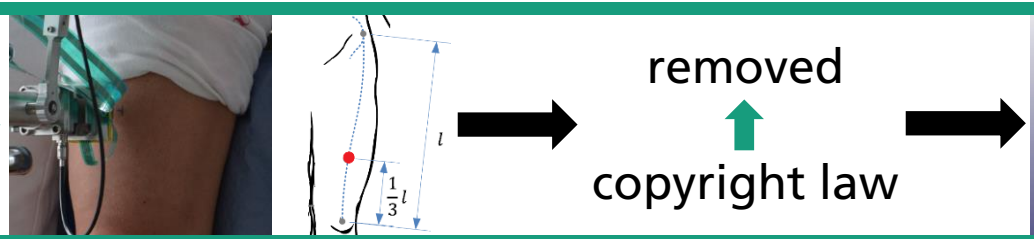
lower arm bone



lower arm muscle



upper leg muscle



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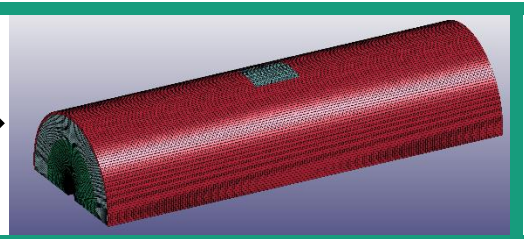
copyright law



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Tissue Model

Tissue models// lower arm muscle

CONTACT

- impactor head and skin

(AUTOMATIC_SURFACE_TO_SURFACE

- skin and fat

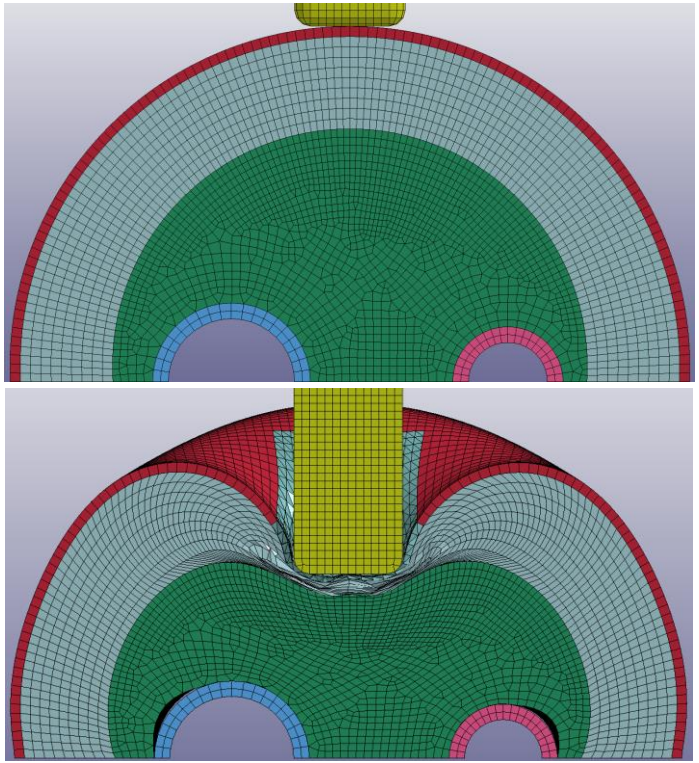
(TIED_SURFACE_TO_SURFACE)

- fat and muscle

(IED_SURFACE_TO_SURFACE)

- muscle and bone

(AUTOMATIC_SURFACE_TO_SURFACE)



Tissue Model

Tissue models// design concept

LIGAMENT

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↑

copyright law

TENDON

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↑

copyright law

MUSCULATURE

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TISSUE MODEL

low energy

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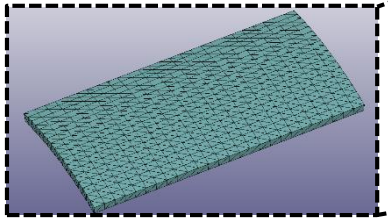
high deformation
low force



tetrahedron

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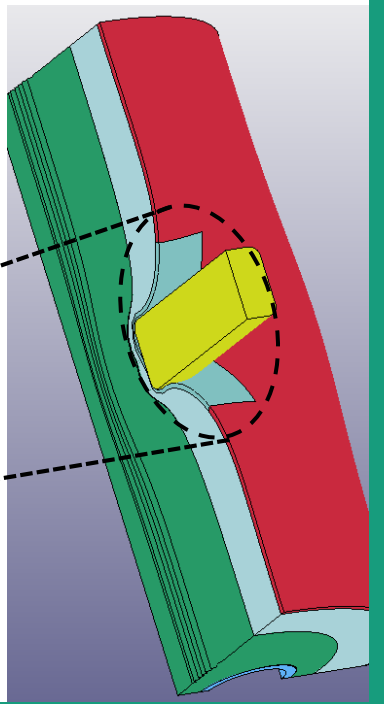
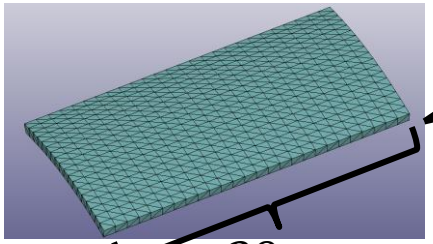
stability



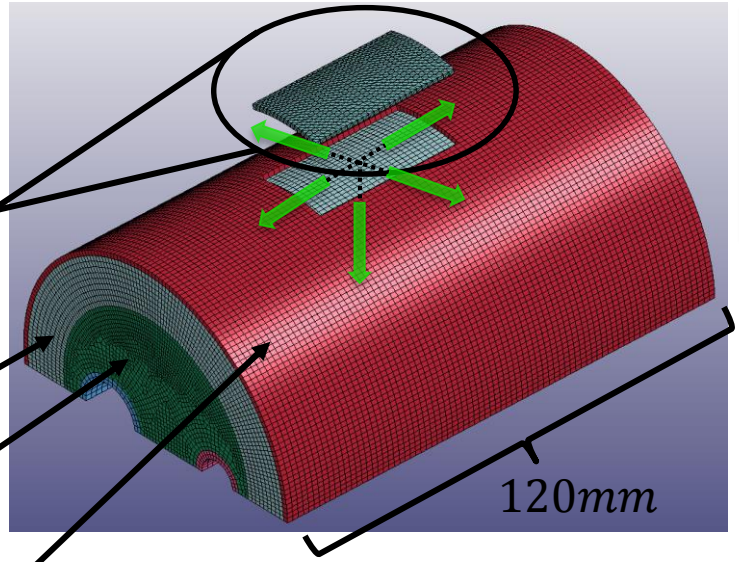
Tissue Model

Tissue models// lower arm muscle

skin contact area
SECTION_SOLID_ERFORM_13



39mm



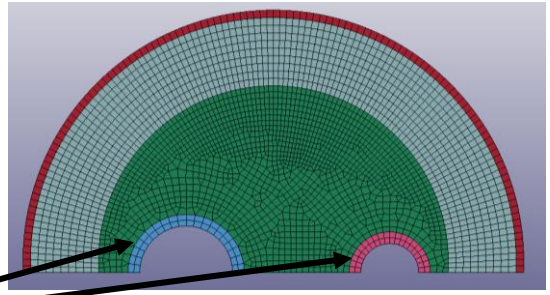
120mm

fat

muscle

skin

soft tissue	bone
ERFORM_-1	ERFORM_1
*MAT_092	*MAT_024



bone

86mm

Tissue Model

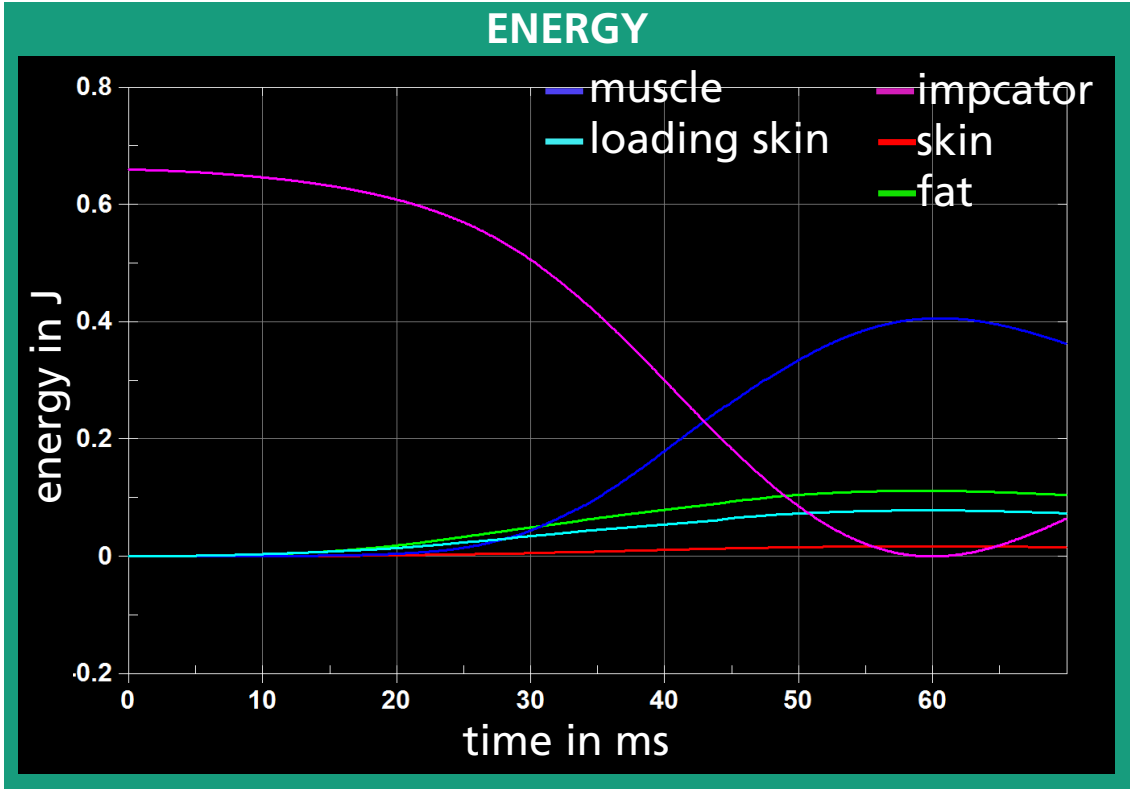
Tissue models// lower arm muscle

- frictionless
- without the heat loss

$$E_{k\_impact}$$

$$\downarrow$$

$$E_{i\_tissue}$$



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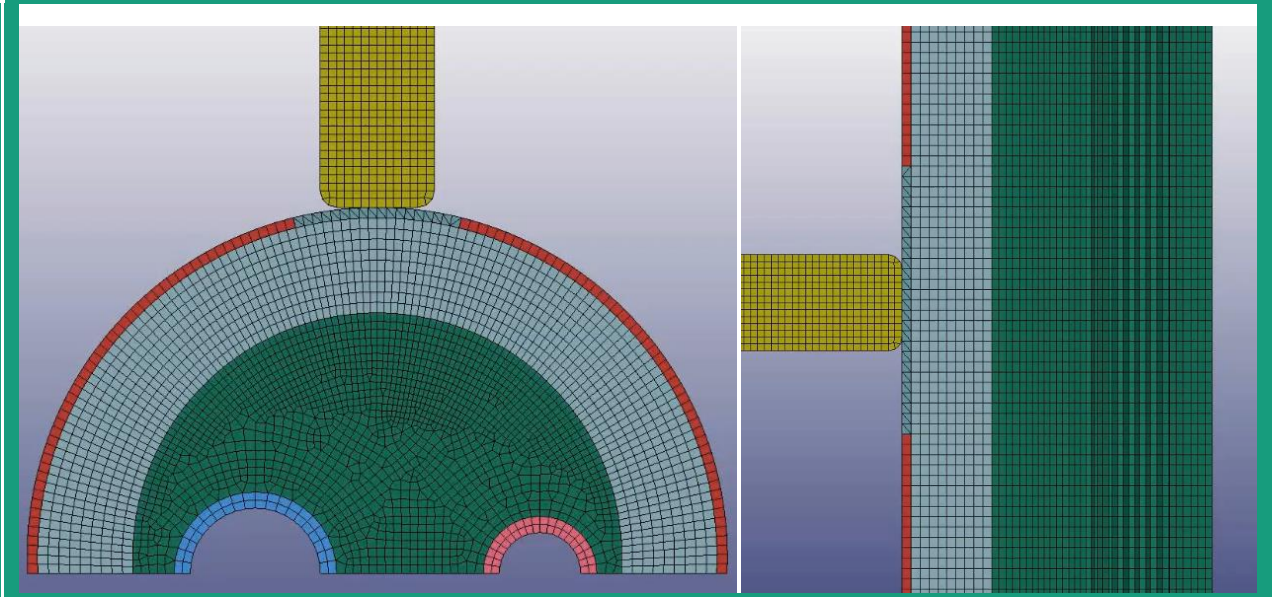
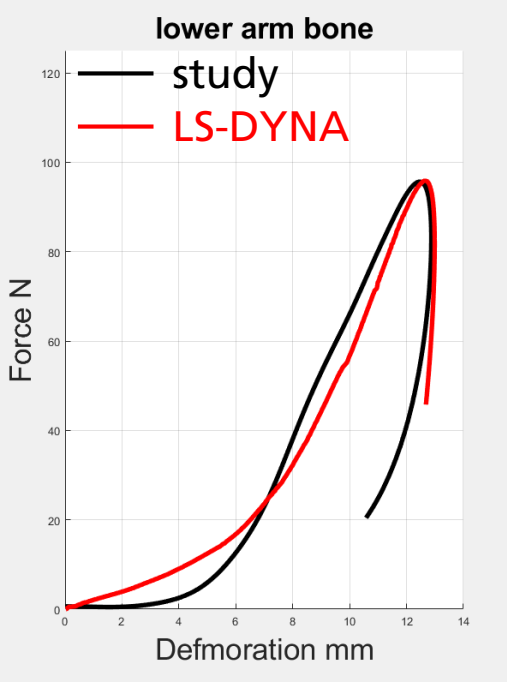
Tissue Model

Video// IFF study and simulation in LS-DYNA

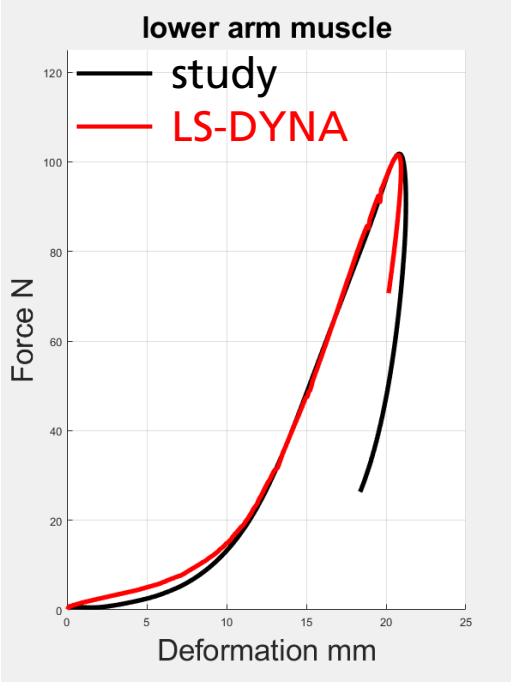
IFF STUDY	SIMULATION IN LS-DYNA
	

Results

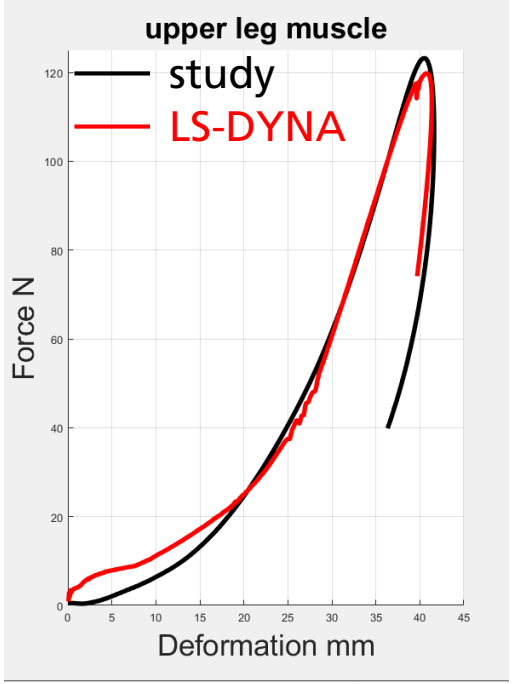
Optimization of tissue model



$Diff < 3\%$



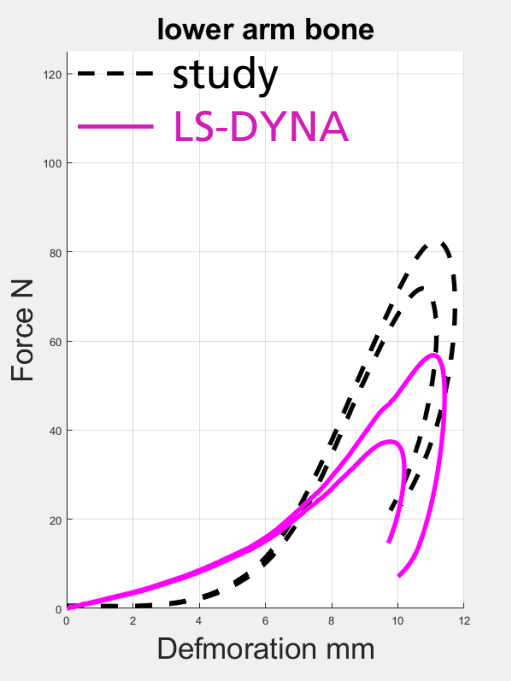
$Diff < 3\%$



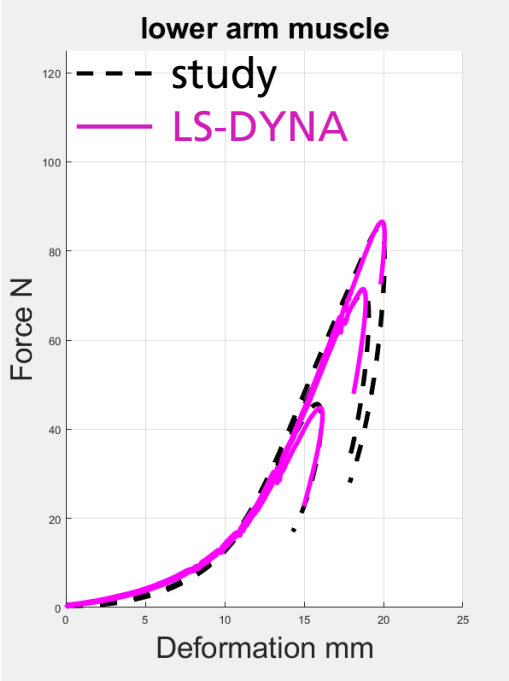
$Diff < 3\%$

Results

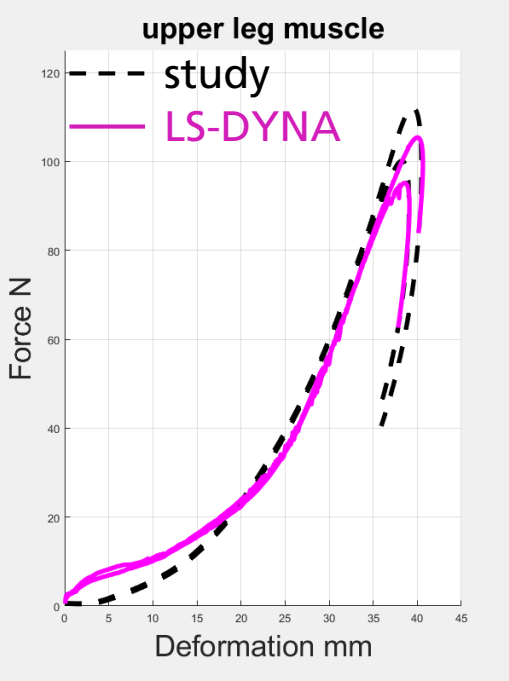
Validation of tissue model



$Diff_N < 30\%$



$< 5\%$



$<\approx 5\%$

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Tissue Model

Tissue models//limitations

1. body information related to each tissue model.

impact body parts	mean stature	mean weight	body mass index
lower arm bone	1.78m	80.7kg	25.46
lower arm muscle	1.76m	78.6kg	25.37
upper leg muscle	1.77m	75.8kg	24.2

body stature
body weight
} change → scale vector { $V_{longitunidal}$, $V_{transversal}$, $V_{sagittal}$

2. range of the impact energy

- research on the threshold for the appearance of pain without injury
- the change of the impactor geometry

Tissue Model

Tissue models//limitations

3. simple model design for local body part with a thick layer of soft tissue
   - geometry in model with higher similarity to the real tissue
   - whole deformation incl. bone

HAND STUDY

ANATOMY

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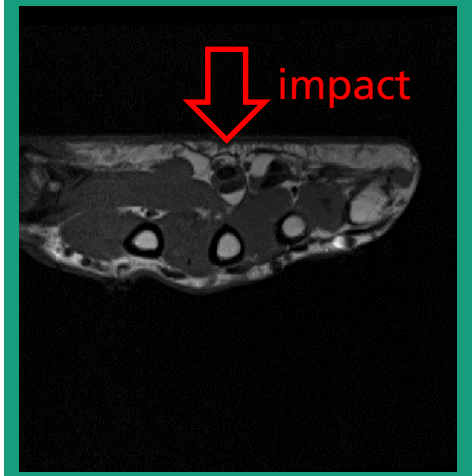
MRI



Tissue Model

Tissue models//hand tissue model

ANATOMY

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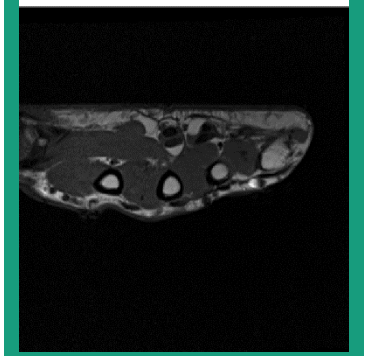
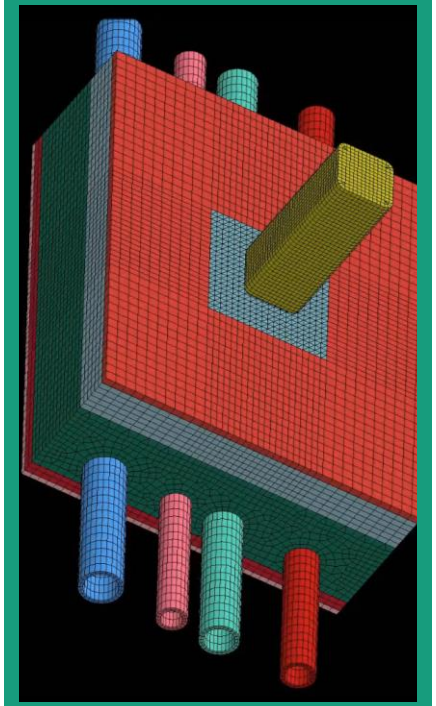
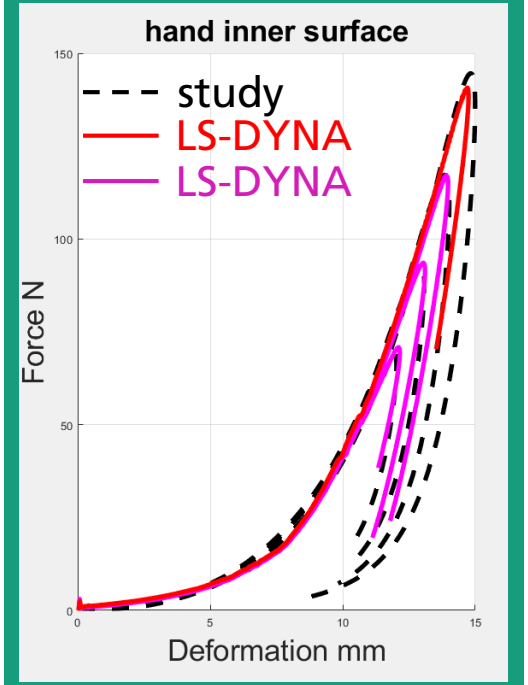


SIMULATION



RESULT



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Fraunhofer IFF
Geschäftsfeld Robotersysteme
Sandtorstr. 22, 39106 Magdeburg
www.iff.fraunhofer.de/rs

Zechang Wang
Wissenschaftlicher Mitarbeiter
zechang.wang@iff.fraunhofer.de

Roland Behrens
Wissenschaftlicher Mitarbeiter
roland.behrens@iff.fraunhofer.de

Prof. Dr. Norbert Elkmann
Geschäftsfeldleiter Robotersysteme
norbert.elkmann@iff.fraunhofer.de

Fraunhofer IFF