# DETERMINATION OF PRESSURE DISTRIBUTION BETWEEN SPORTS BRA AND FEMALE TORSO

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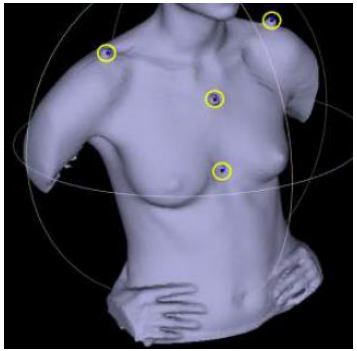
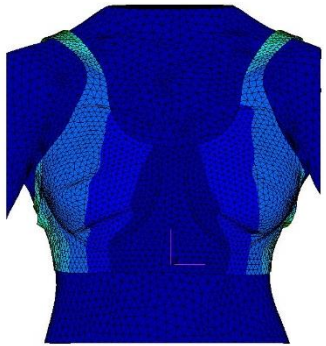
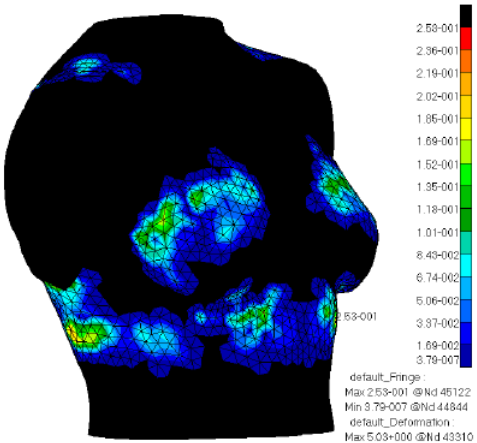
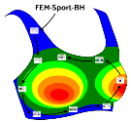






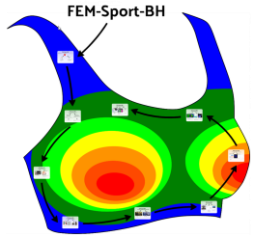


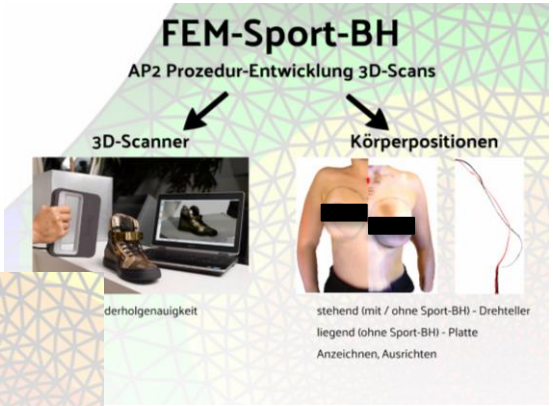

## Research project „FEM Sports Bra“

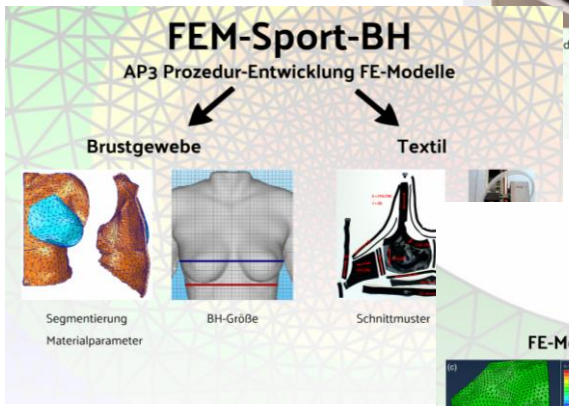
- **Task – investigate**
- **Wear comfort vs. Breast support [1]**
- **Pressure distribution relevant [2]**
- **Up to 85% wear wrong bra size [3]**

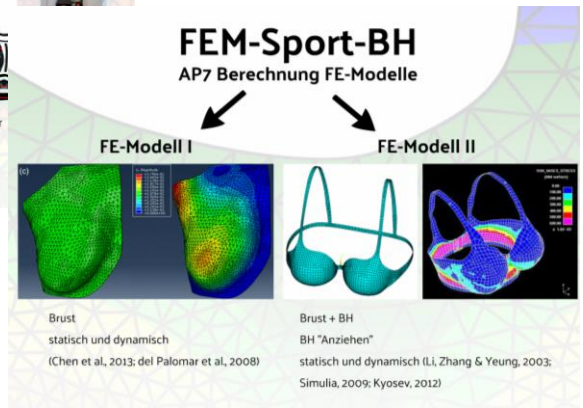
- **Situation:**
- NO geometry data
- NO material data
- neither torso nor bra

- large displacements
- large deformations
- Pretension



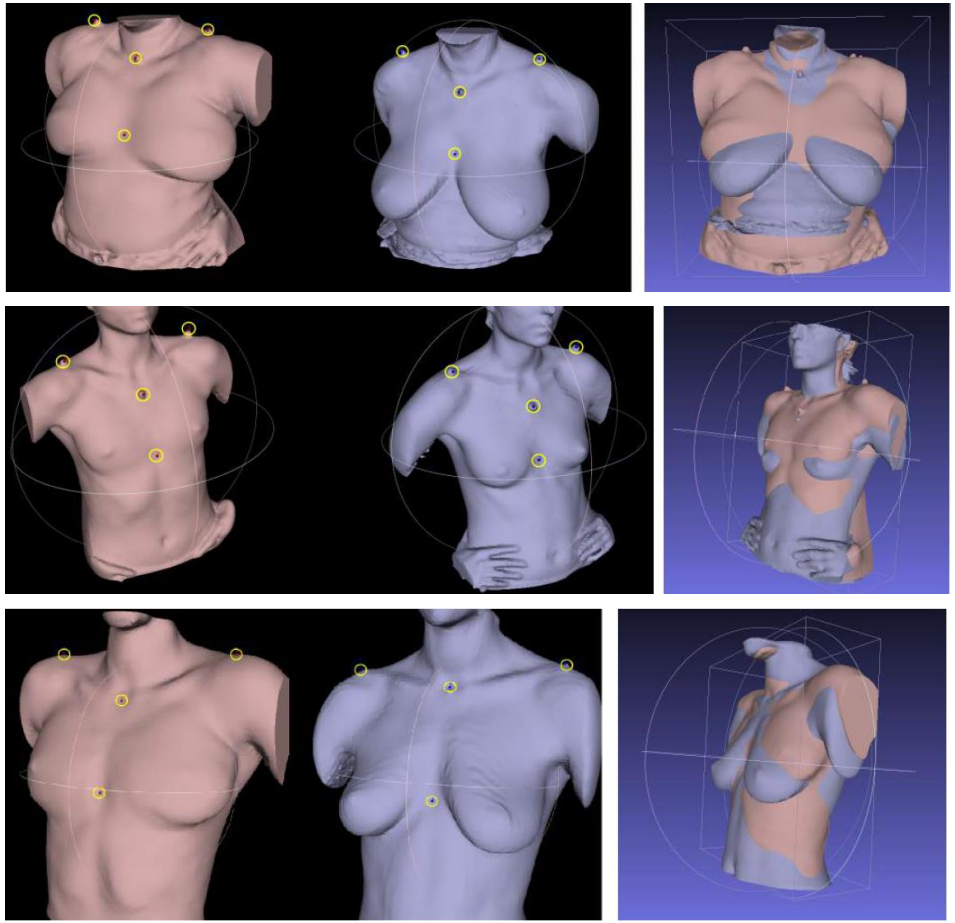



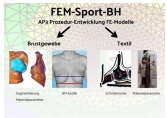



## Scan procedure

- **Scan Setup**
- **Lying down**
- **Standing upright**
- **Markers at breast points**
- **background = Raster**

- **Alignment of Scans lying / standing**
- **PP1 / PP2 / PP3**
- **Clavicula / Sternum**
  - Problem shoulder height
- **Sternum / belly button**
  - Not on Scan

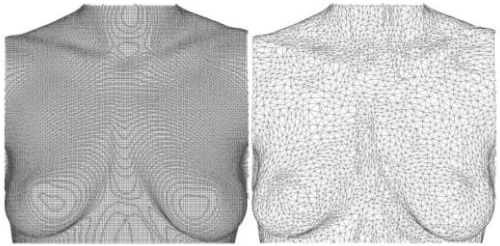


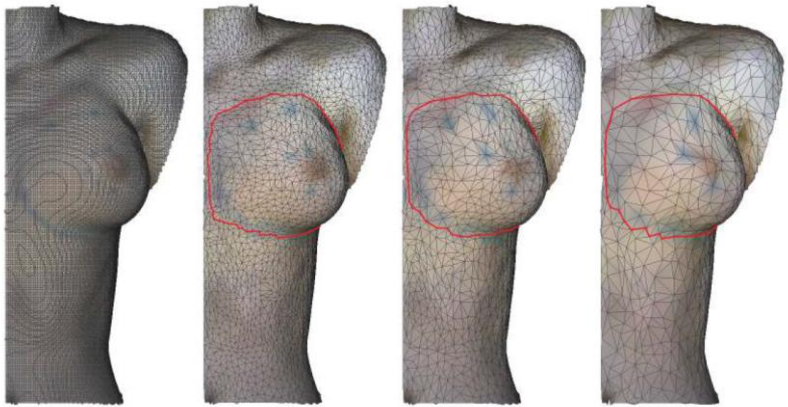



## FE Modell upper body

- Modell from TWO scans
- turning plate und lying down

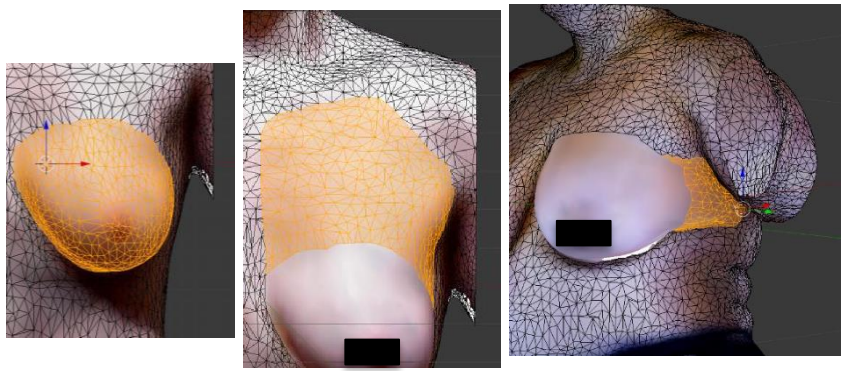
- **Reduction of mesh density**
  - from 190.000 - 250.000 to appr. 20.000 elements





45000 / 6000 / 3000 / 1500

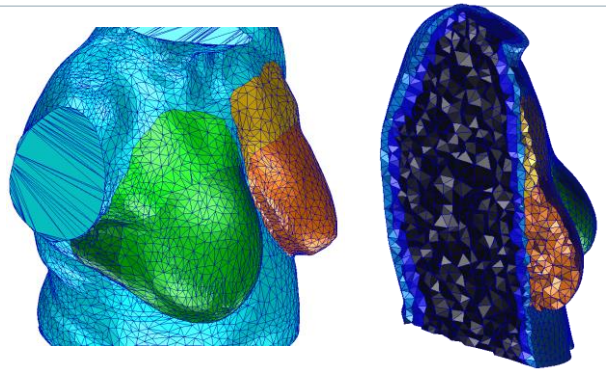
- **Selection of breast tissue / muscle / (fat)**
  - Breast according to marker
  - Muscle according to curvature change
  - Fat according to curvature change
  - Based on evaluators experience (!)

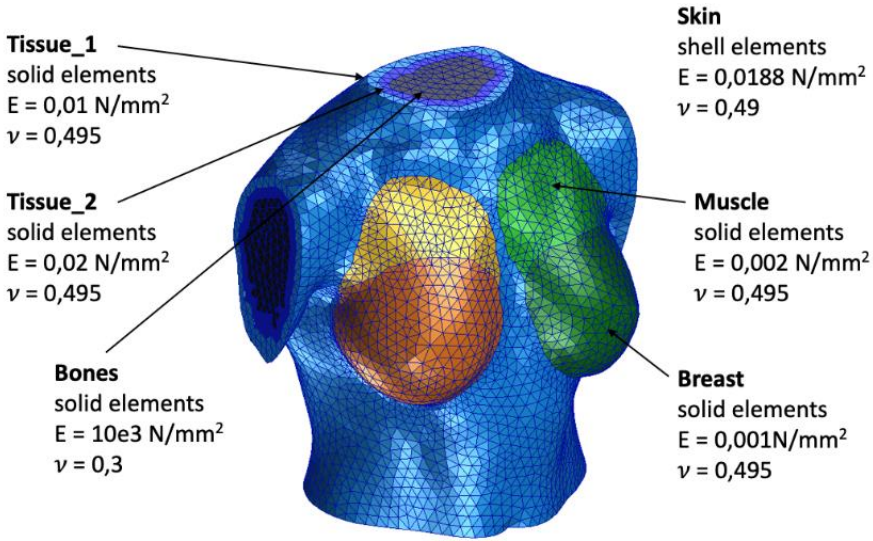


## FE Modell – P1, P4, P6, P18, …

- **Oriented and segmented surface**
  - Triangulated surface
  - Volume meshing by property
  - Contact between torso and breast
    - IMF
- Skin thickness t=2mm
- Density 1e-9 t/mm³ = 1kg/l

| Material | Young's modulus [MPa] |
|---|---|
| Steel | 210 000.000 |
| Aluminum | 70 000.000 |
| Plastics | 2 500.000 |
| Elastomer(techn.) | ~200.000 |
| Silicone | 5.000 |
| Human skin | 0.018 |
| Muscle / Fat tissue | 0.001 |





## FE-Model torso verification

- **Analysis models PP1 – PP4**
- **linear elastic vs. hyperelastic (Ogden 2)**

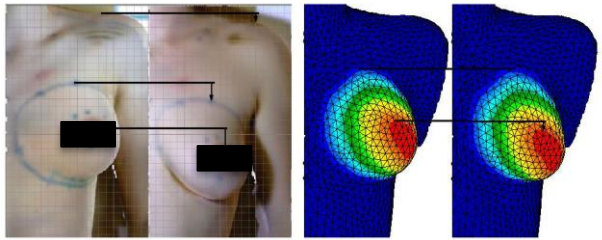
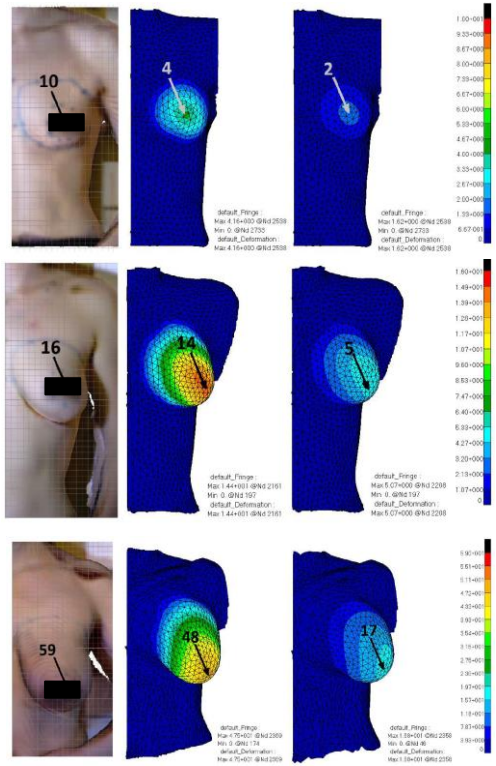


Figure 68: Comparison of the movement of the breast's outlines

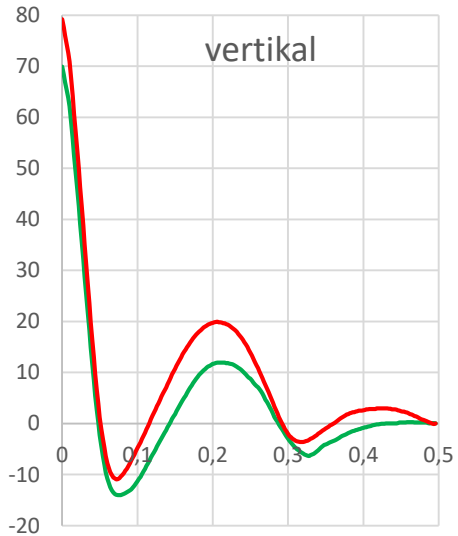



- **Eigen frequency**

| Person | Eigenfrequenz | BH Größe |
|---|---|---|
| PP1 | 3,65 Hz | 85 E |
| PP2 | 7,30 Hz | 75 AA |
| PP3 | 6,16 Hz | 75 B |
| PP4 | 3,28 Hz | 80 C |

## 3D motion analysis

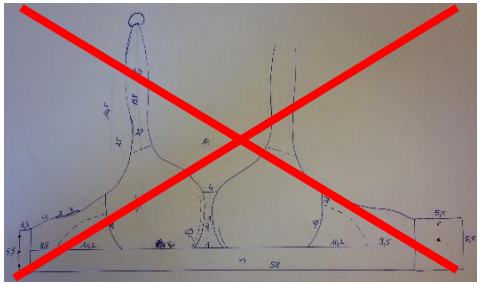
- Evaluation of free oscillation
- Highspeed video
- Amplitude
- Damping

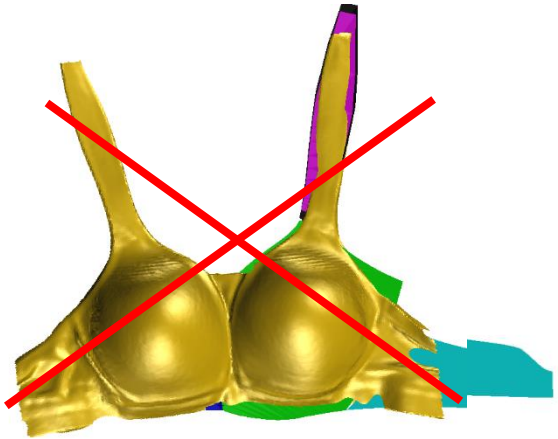


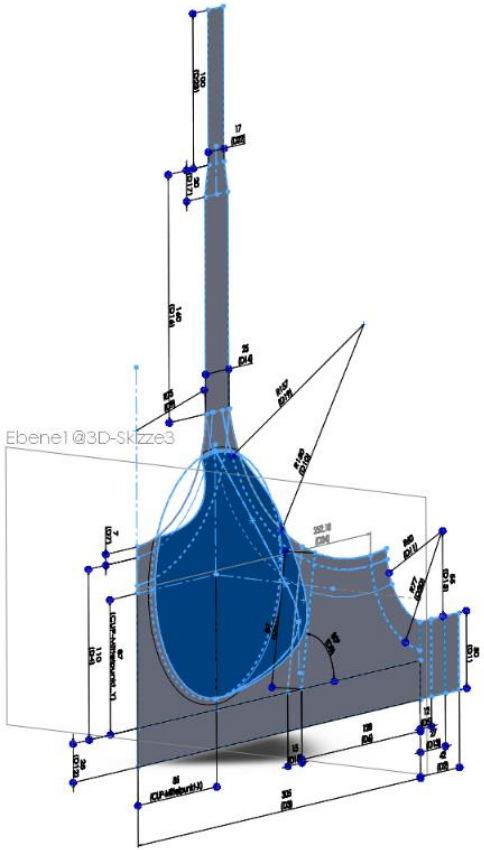
**Poster Session**
**PO.13: Soft tissue / imaging**
**Time: 09/Jul/2019: 3:45pm-4:20pm · Location: Arcade Court**
**MATERIAL PROPERTY EVALUATION OF FEMALE BREAST TISSUE BY FINITE ELEMENT EIGENVALUE ANALYSIS**

## FE-Model BRA

- **Measuring**
- **Cutting pattern**
  - Overlapping
  - Not useful for geometry
- **3D Scan data**
- **3D CAD Modell parameterized**

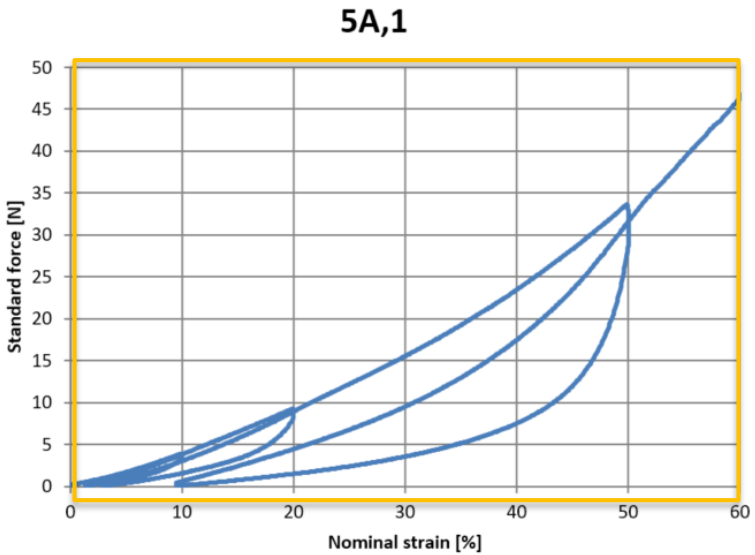


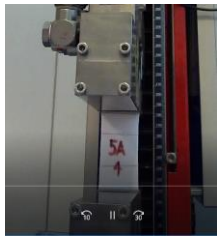


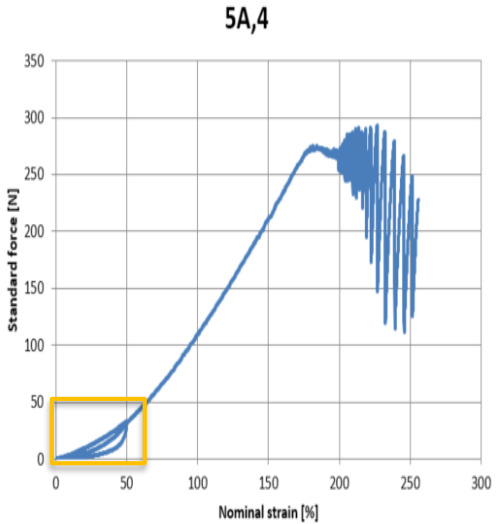


# FE-Model BRA material data

- **Tensile tests**
  - 10% / 20% / 50% Loop
  - Tensile test until failure
  - Sample 5 = CUP



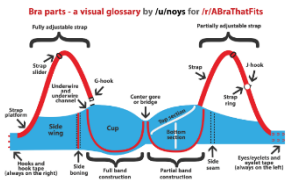



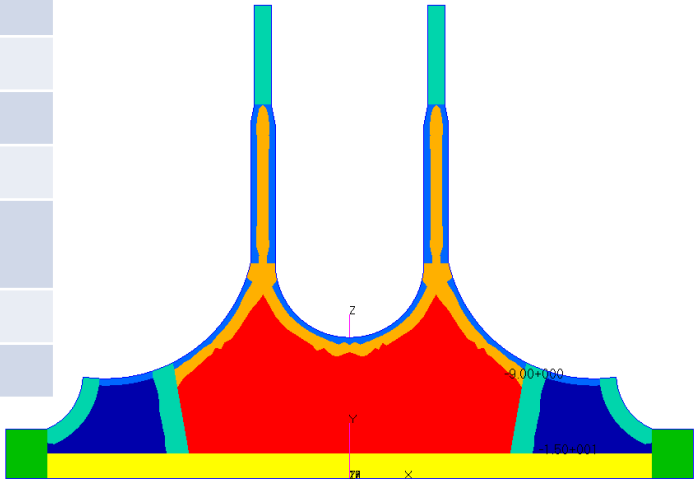


# FE-Model BRA

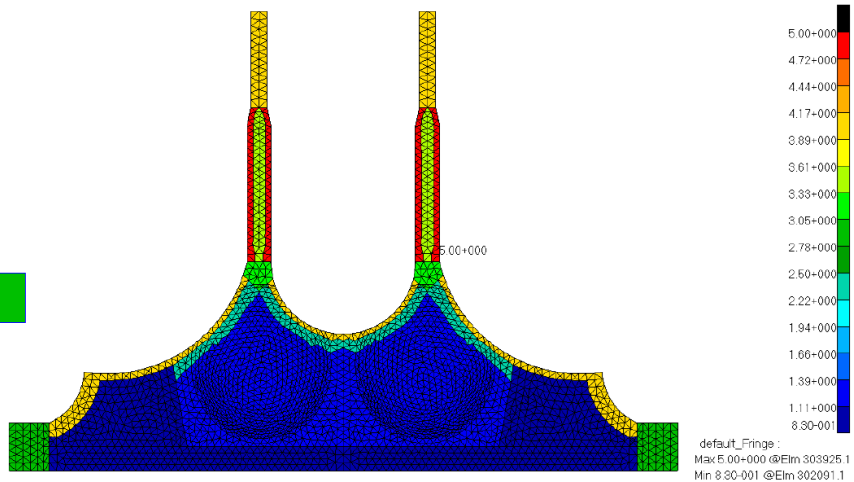
- **Different materials**
  - E = 0.1 to 10 MPa

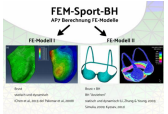
| | |
|---|---|
| | cup |
| | straps |
| | underband |
| | hook/eyelet tape |
| | side boning / strap platform |
| | band hems |
| | wings / net |



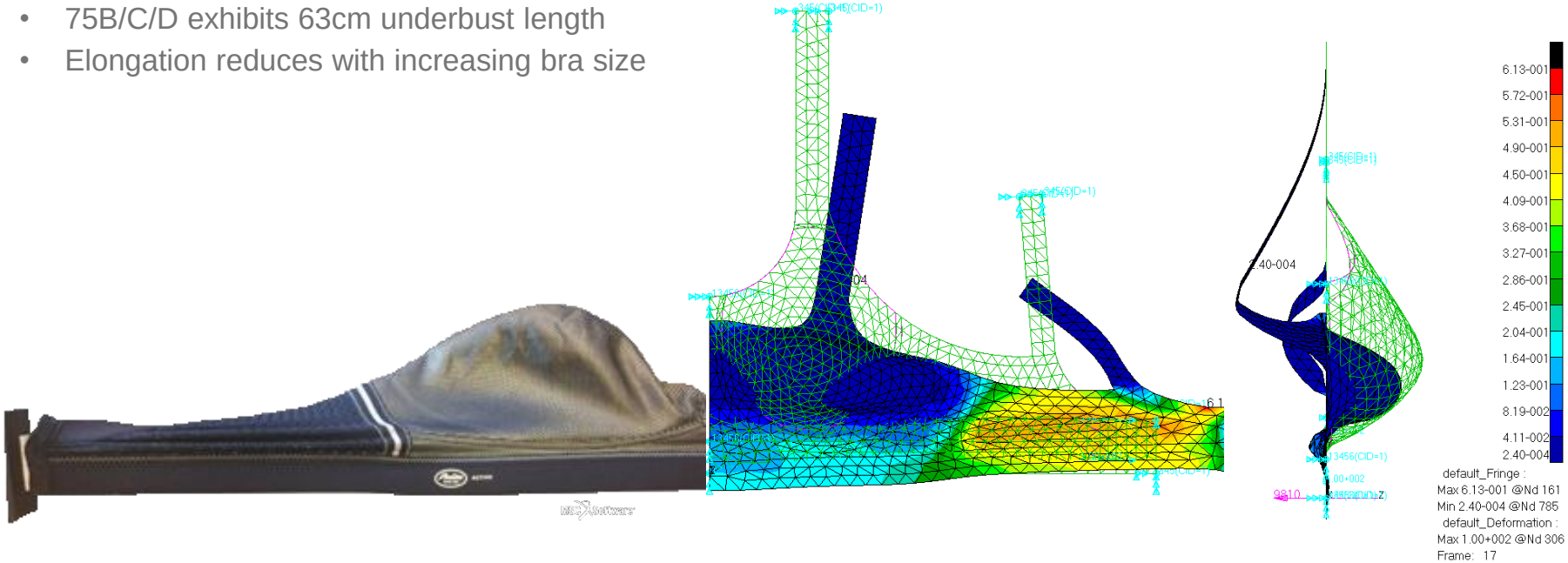

- **Different thicknesses**
  - t = 0.8 to 5.0mm

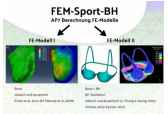





## FE-Model BRA verification

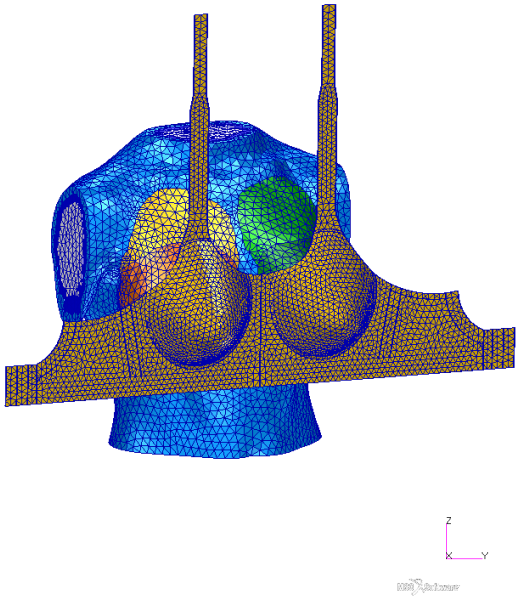
- ~20% elongation of „manufactured“ bra
- Corresponding to getting dressed
  - 75B/C/D exhibits 63cm underbust length
  - Elongation reduces with increasing bra size

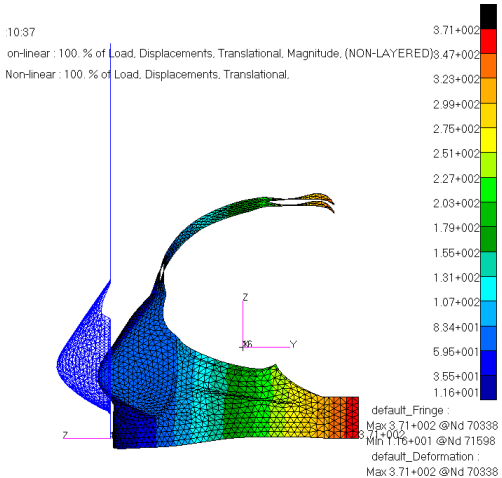


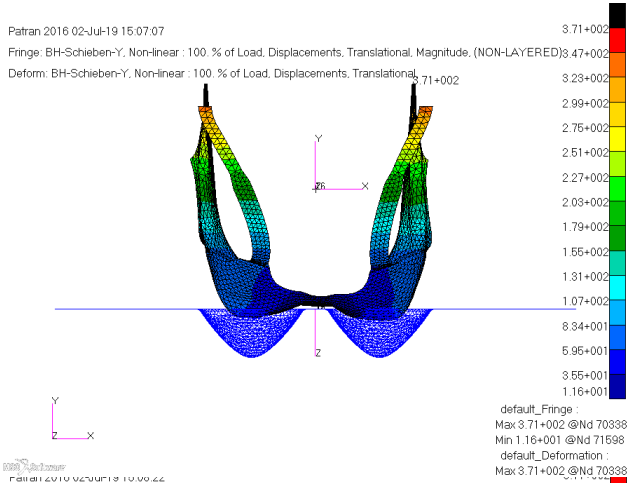


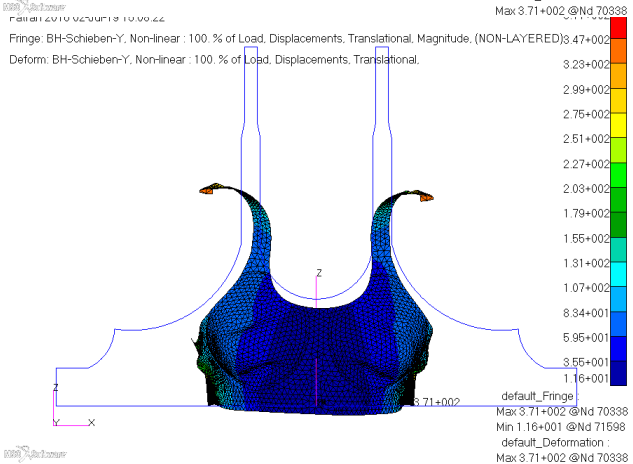

## FE-Model fitting procedure

- „flat“ bra model
- Individual torso model
- „flat“ bra model of bra size according to fitting



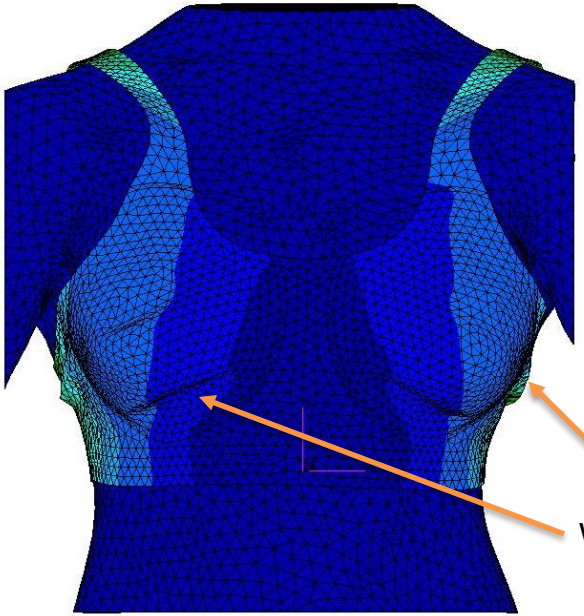


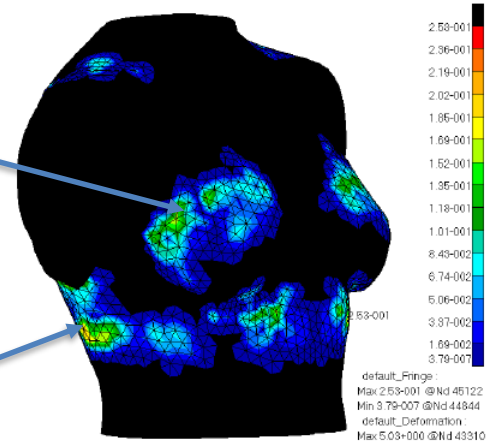



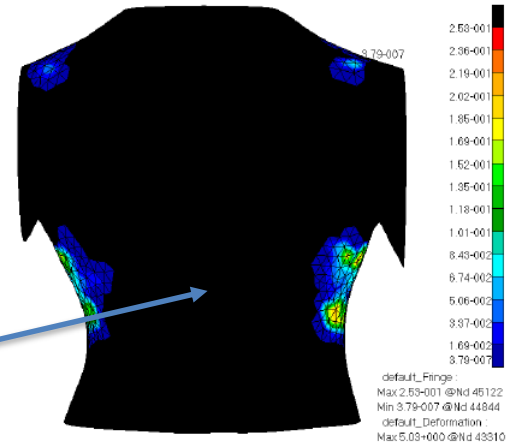



## Results

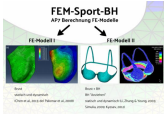
- **Bra shape**
- **Pressure distribution**



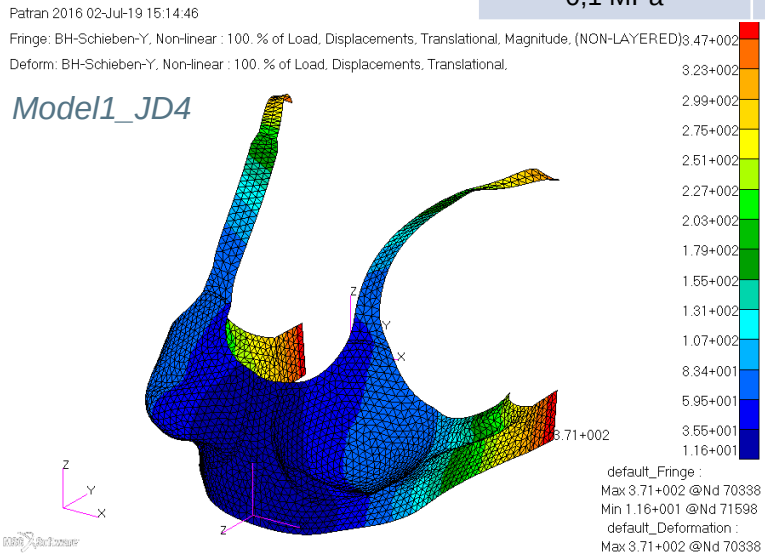
# FEM-Sports-Bra

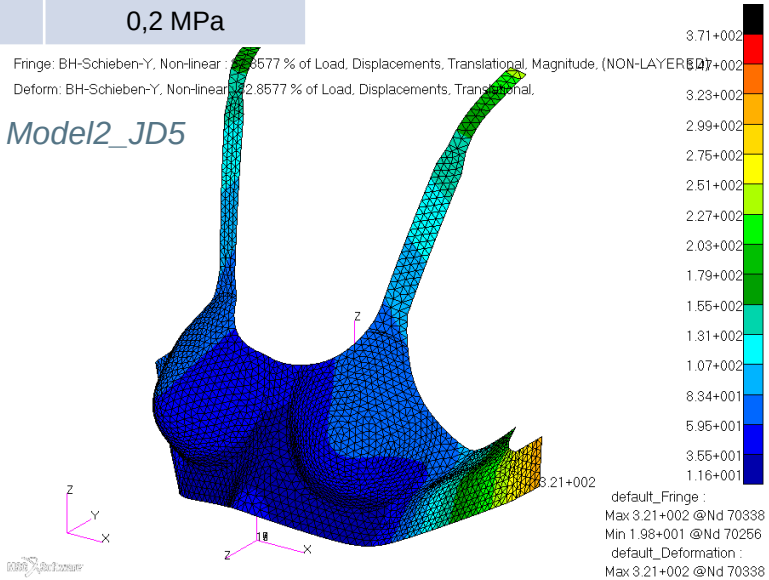



## Results

- **Variation of bra material data by factor 2**

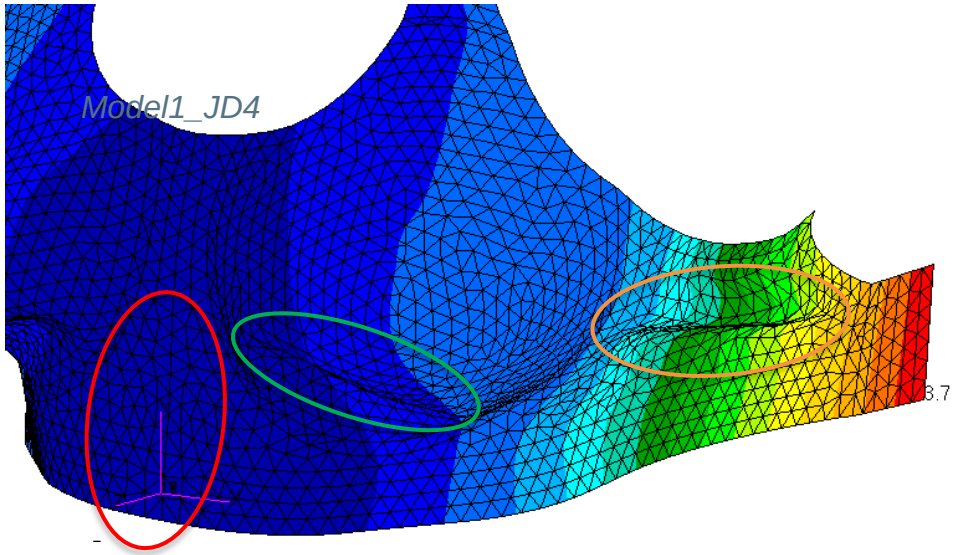
| Model 1 Modulus | Sports bra Anita | Model 2 Modulus |
|---|---|---|
| 1 MPa | cup | 0,5 MPa |
| 5 MPa | straps | 10 MPa |
| 0,5 MPa | underband | 0,25 MPa |
| 10 MPa | hook/eyelet tape | 10 MPa |
| 0,4 MPa | side boning | 0,8 MPa |
| 0,3 MPa | band hems | 0,6 MPa |
| 0,1 MPa | Wings / net | 0,2 MPa |

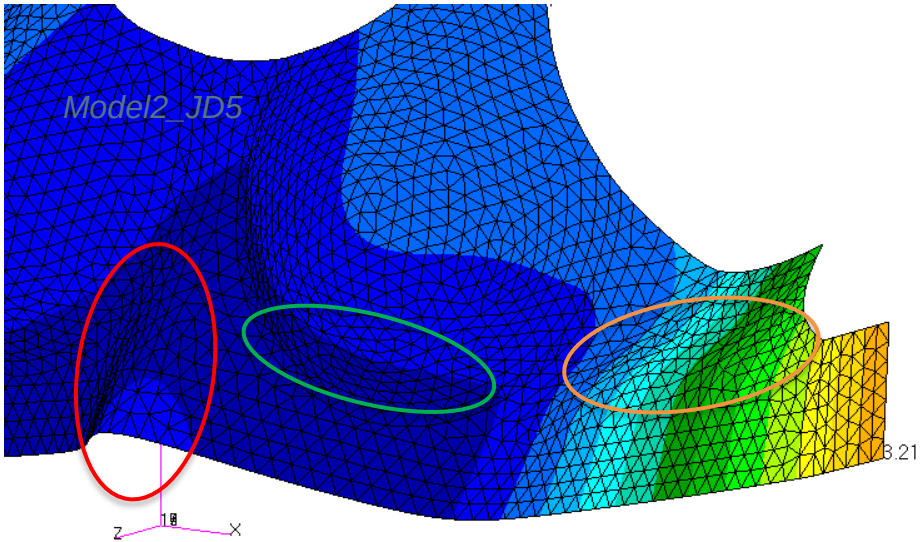


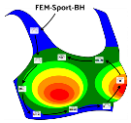



## Results

- **Variation of bra material data**
- **Deformation pattern**

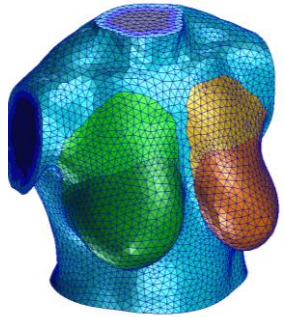


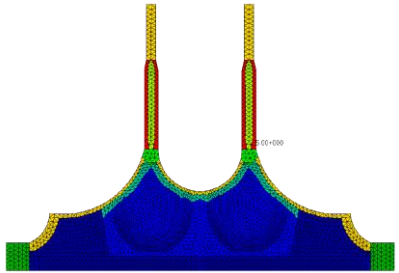



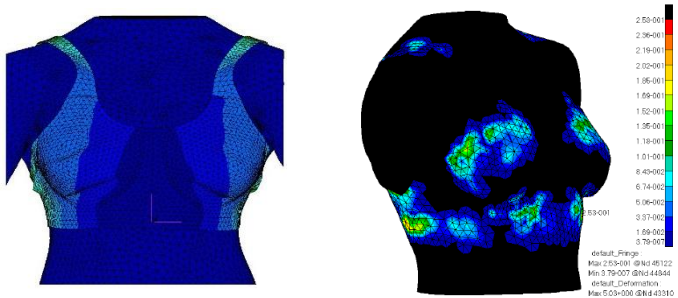



## Summary

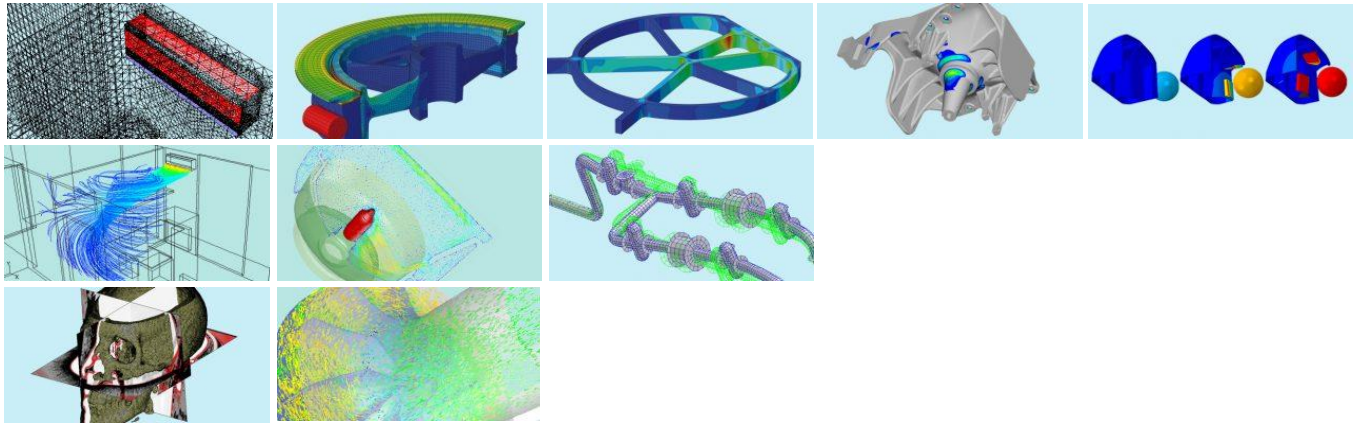
- **Female torso model**
  - 3D-Scan data → geometry
  - Literature data /
    Eigenfrequency analysis → material properties
- **Sports Bra model**
  - 3D CAD reconstruction → geometry / 3D Scan control
  - Uniaxial tension tests → material properties
- **Combined model**
  - Evaluation of Pressure distribution possible
    - Sensitive to textile properties (!)
    - Adjustment of textiles properties to breast properties
  - Numerically challenging
  - Applications
    - Individual sports bra
    - Medical application for post-operative pressure release

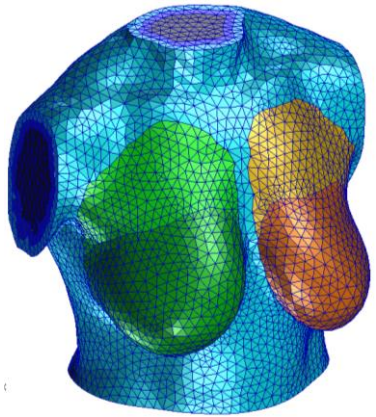






# Thank you for your attention





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