Linking process & product simulation for considering local material properties in crash simulation

Dr. Benedikt ECK, 16.10.2018

Faurecia Composite Technologies
A key part of Faurecia Clean Mobility’s strategic future

Group Key Figures (2017)

€17 Billion
Value-added Sales*

100,000
Employees

35
Countries

Leader in 3 activities

Seating
€7.1 Billion
#1 worldwide in mechanisms & seats structure
#3 worldwide in complete seats

Interiors
€5.3 Billion
#1 worldwide interior vehicle

Clean Mobility
€4.5 Billion
#1 worldwide in emissions control technologies

Building blocks towards Cleaner Solutions

- Emissions Data Analytics & Digital Services
- Powertrain electrification
- **Lightweight composite solutions**
- Energy Efficiency Innovations
- Lightweight & Acoustic Innovations
- Air Quality Innovations: Heated Catalyst, ASDS, Turbo Gas, EGR
- Light Vehicles
- CV on-highway
- CV off-highway
- High Horse-power

Legend: Current business – Traditional portfolio; Innovations; CV off-highway & High Horsepower; Adjacent clean solutions for EV

FCM is driving the transformation of the global Mobility Value Chain towards Cleaner Solutions

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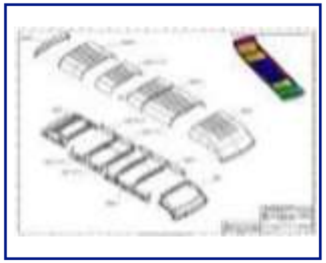
** Value added sales = Total sales w/o Monoliths*

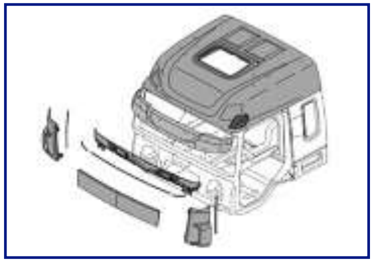
Faurecia Composite Technologies
Focus on Battery Pack, H2 Tank and Lightweight Structures

Current product portfolio


Roof panel


Structural cabin


Load floor


Body panels for trucks


Front end carrier


Body panels for cars

TS: RTM & SMC (BMC…)

Product portfolio extension


Battery pack


H2 Tank


Shock tower


Underbody shielding


Seat structures


CCB

TP: Organosheets, T-RTM…

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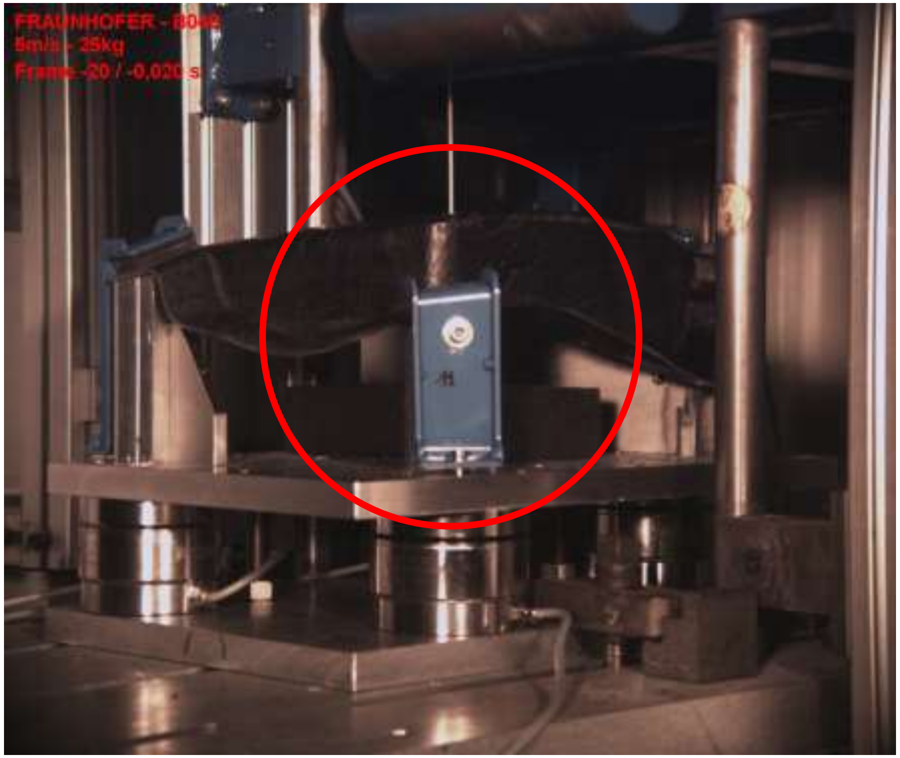
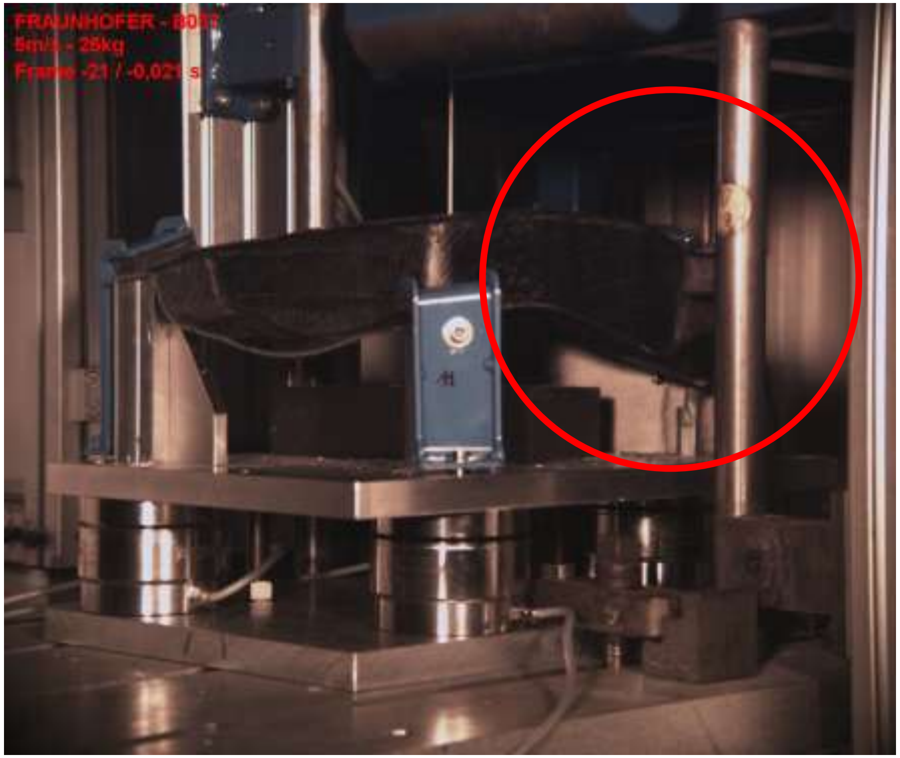
1. Introduction – Composites materials crash behavior

Crash trial on continuous fiber reinforced composites



CF reinforced part type 1



CF reinforced part type 2

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1. Introduction – Composites materials crash behavior

Crash trial on continuous fiber reinforced composites

- **Same parts**
  - Same geometry
  - Same material & lay-up: $[0/90°;\ \pm45°;\ \pm45°; 0/90°]$
- **Repetitive & material independent**
  - Trials on carbon fiber & glass fiber materials

GF reinforced part type 1

GF reinforced part type 2

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1. Introduction – Composites materials crash behavior

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GF reinforced part type 1

GF reinforced part type 2

Only difference: Forming sequence during preforming

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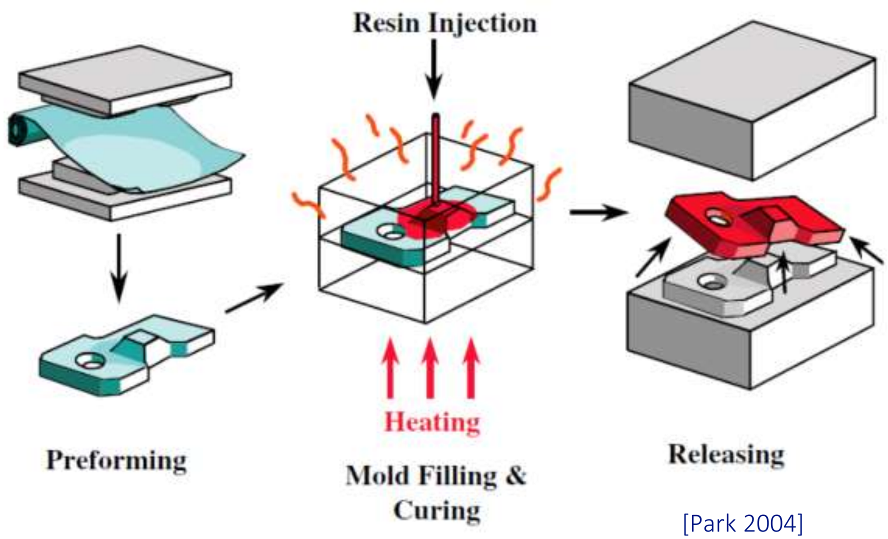
1. Introduction – Manufacturing process

RTM process for manufacturing of TS composites with high lot sizes



[Park 2004]

- **Impacting process step**
  - Preforming of continuous fiber reinforced composite sheets
  - Similar to forming of organosheet materials

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1. Introduction – Manufacturing process

Preforming and forming process

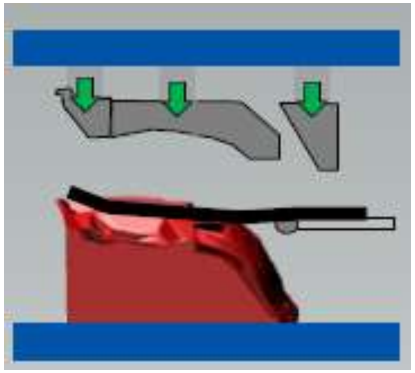
- Waste and defect intensive

Fiber wrinkling

Fiber breakage & thinning

- Important impact on mechanical part properties

+ High repeatability
+ Short cycle time
+ High design freedom



Independent forming stamps

Prof. F. Henning et al., 1st International Composites Congress (ICC) - 2015
"Cost-efficient Preforming as leading process step to achieve a holistic and profitable RTM product development"

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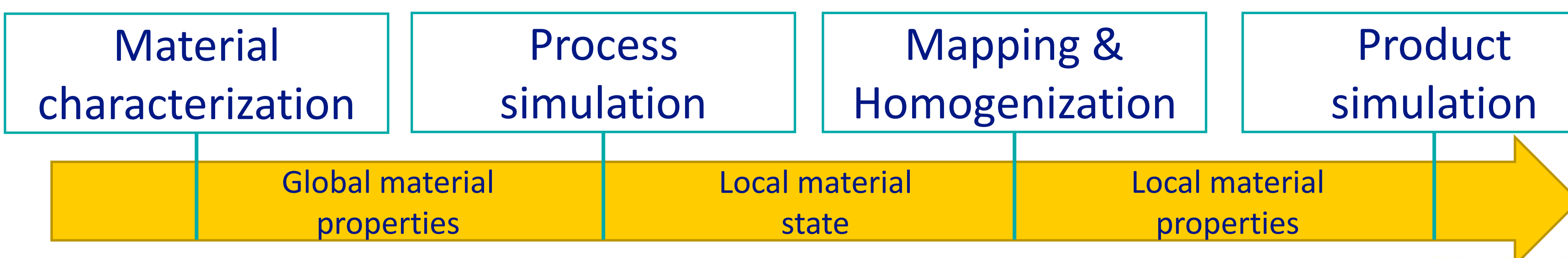
2. FCT Simulation Approach

Complex material behavior

- **Simulation based part design**
  - Avoid costly trial and error
  - High prediction accuracy requested
- **Knowledge of local material state**
  - Induced by manufacturing influence
  - Impact on mechanical performances
  - Prediction and handling by simulation chains



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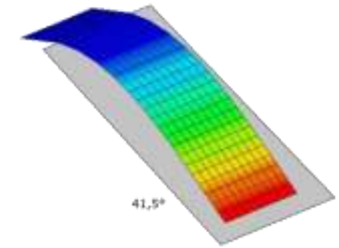
3. Material law characterization & correlation

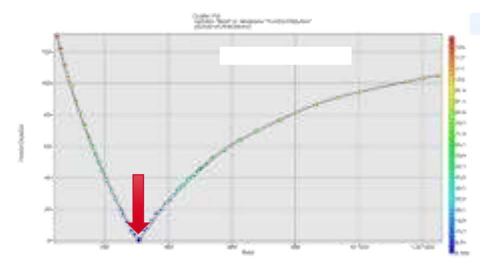
Composites characterization – FCT vision

- **Predict local and global material behavior**
  - At all operating conditions
- **Process simulation material laws**
  - Physical vs. non-physical parameters
  - Direct implementation vs. optimization
- **Product simulation material laws**
  - Iterative process
  - Virtual reconstruction of trials
  - Automation of material law creation & validation

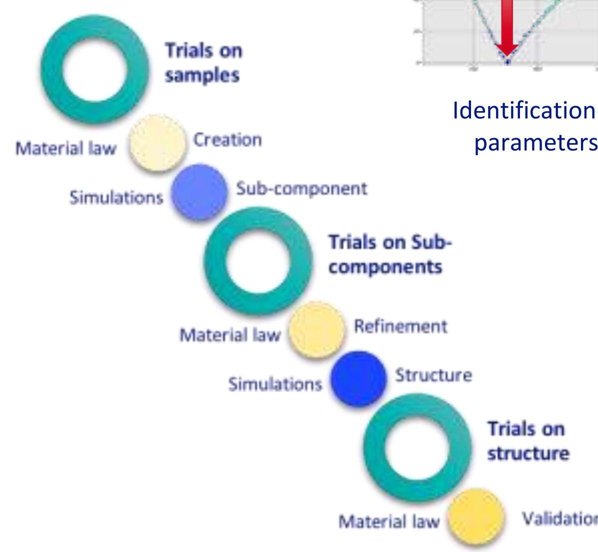
Shear: direct characterization using picture frame test



Bending: Parameter optimization using Cantilever test according to DIN - 53362



Identification of the bending material parameters through optimization



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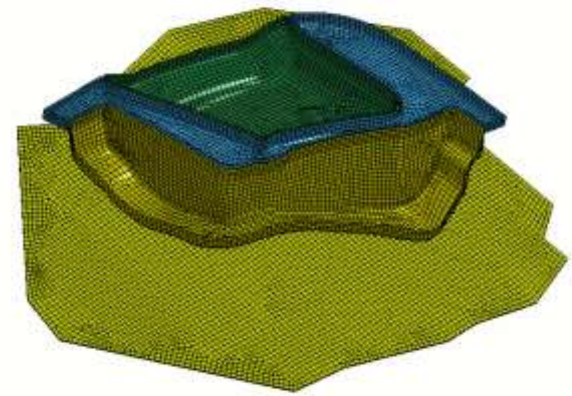
4. Process simulation – Preforming

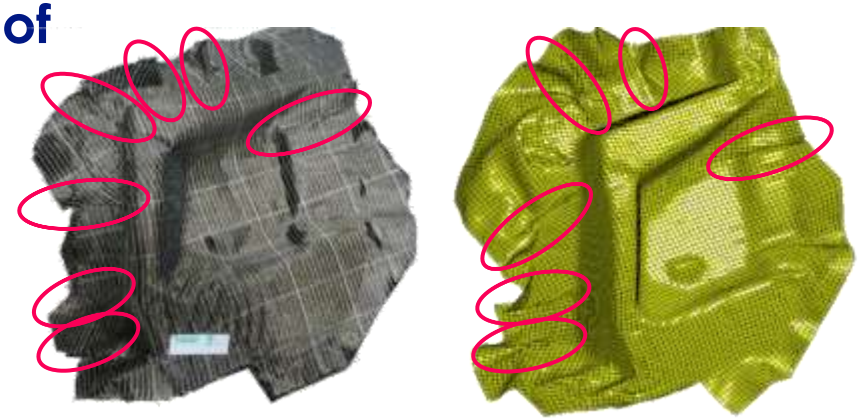
Dry fabrics forming simulation

- **FEA simulation approach implemented**
  - Presented at LS-DYNA Forum 2016
  - Based on material law **MAT_249**
  - Simulate mold, gripper or frame movements



Forming with LS-Dyna

- **Compared to tests, good prediction of**
  - Blank shape
  - Defects (e.g. wrinkles)
  - Local fiber properties (e.g. fiber orientations)



- **High grade of correlation for different materials and forming sequences**

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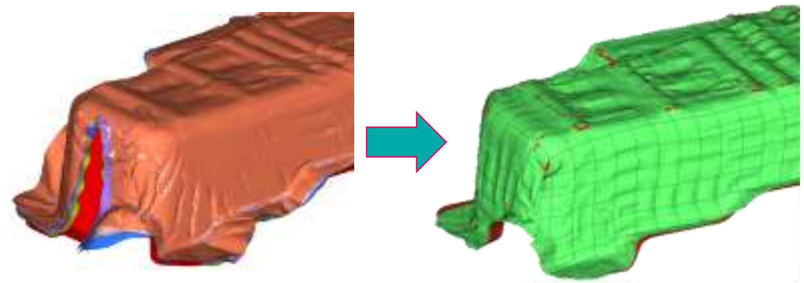
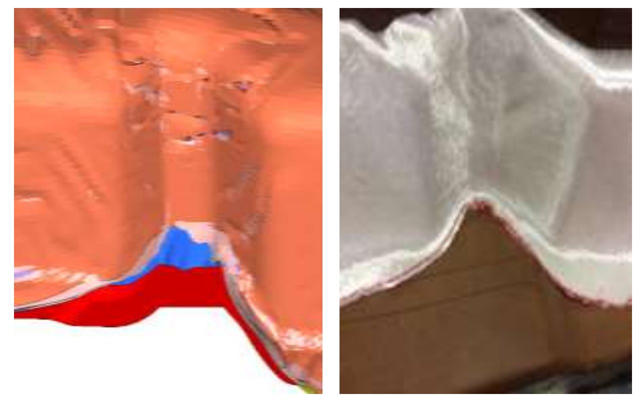
4. Process simulation – Additional advantages

Dry fabrics forming simulation

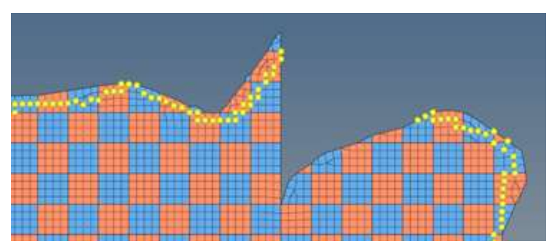
- **Tooling optimization**
  - Assure manufacturability
    - Avoid defects as wrinkles
  - Predict ideal forming kinematics
  - Assure robustness
  - Limited automatization
- **Blank shape prediction and optimization**
  - Predict cutting pattern
  - Reduce scrap
  - Automatization easy



Forming kinematics & cutting optimization



Material lack prediction



Optimization of blanc shape

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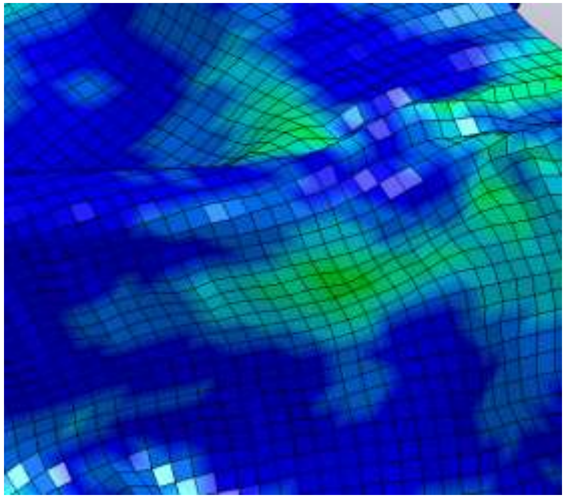
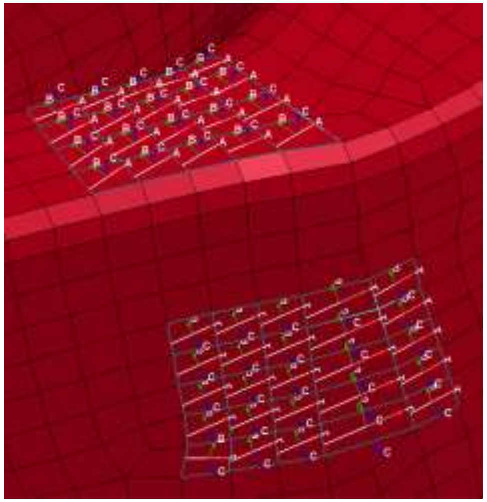
5. Mapping – ENVYO

Fiber orientation mapping

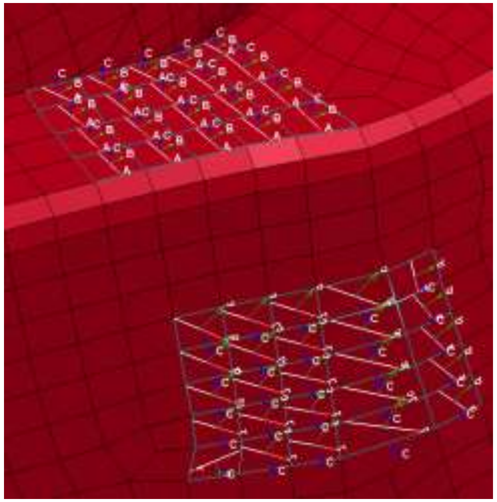
- **Creation of *ELEMENT_SHELL_COMPOSITE**
- **Spatial mapping and smearing of integration points**
  - Forming simulations: 4 integration points including 2 main fiber orientations
  - Mechanical simulations: 2 integration points



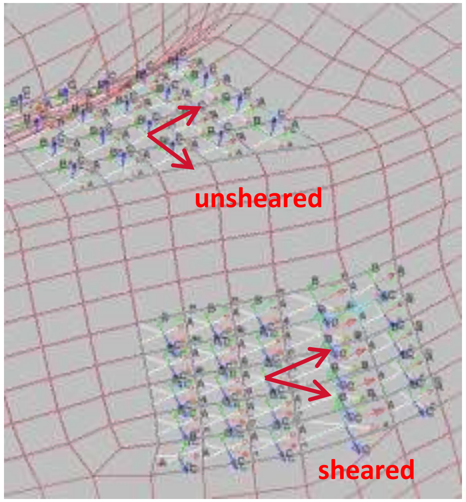
Forming simulation outcome



Mapped first integration point



Mapped second integration point



Shear angle identified with 2 integration points

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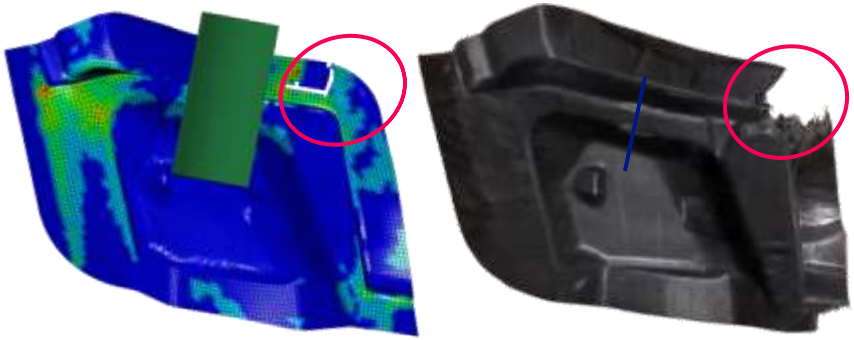
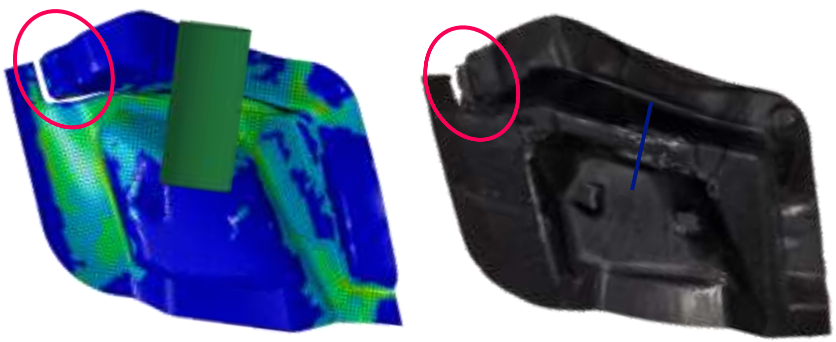
6. Product – Composite part crash behavior

Considering mapped fiber orientations

- **Product simulation using MAT_058**
  - Woven material modeled by two UD-layers
- **Good failure prediction by simulation**



Preforming stamping sequence type 1



Preforming stamping sequence type 2

- **Main impact factors**
  - Fiber orientation (predicted)
  - Local wrinkles (not yet considered)

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7. Conclusions

Resume

- **Considering local material parameters with simulation chains**
  - Methodology for continuous fiber reinforced composites integrated at FCT and applied in programs

Underbody protection (JEC US award)

Lessons Learnt

- **Impact of local material properties on mechanical performances demonstrated**
  - High sensitivity of composites to material and process parameters
  - Simulations allows to address this complex behavior

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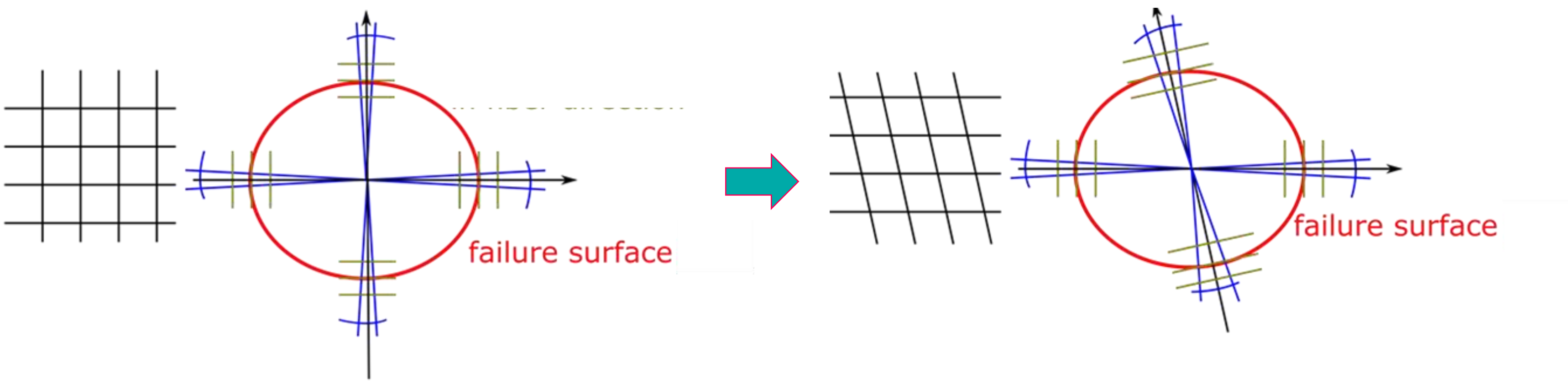
7. Conclusions

Outlook / Next steps

- **Map impact of further material parameters impacting mechanical performances**
  - E.g. wrinkles
- **Woven material laws considering shearing**
  - Evtl. disconnected failure in fibers and matrix



- **Optimizations with coupled product & process simulations**
  - Mandatory to have reasonable computational efforts

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Many thanks to Mr Liebold for enhancing ENVYO