Sebastian Kreissl, Thomas Senner, Arnulf Lipp, Josef Meinhardt.

INDUSTRIAL FORMING SIMULATION OF MULTI-LAYERED UD NON-CRIMP-FABRICS.

13. LS-DYNA FORUM, 07.10.2014, BAMBERG.

BMW
GROUP

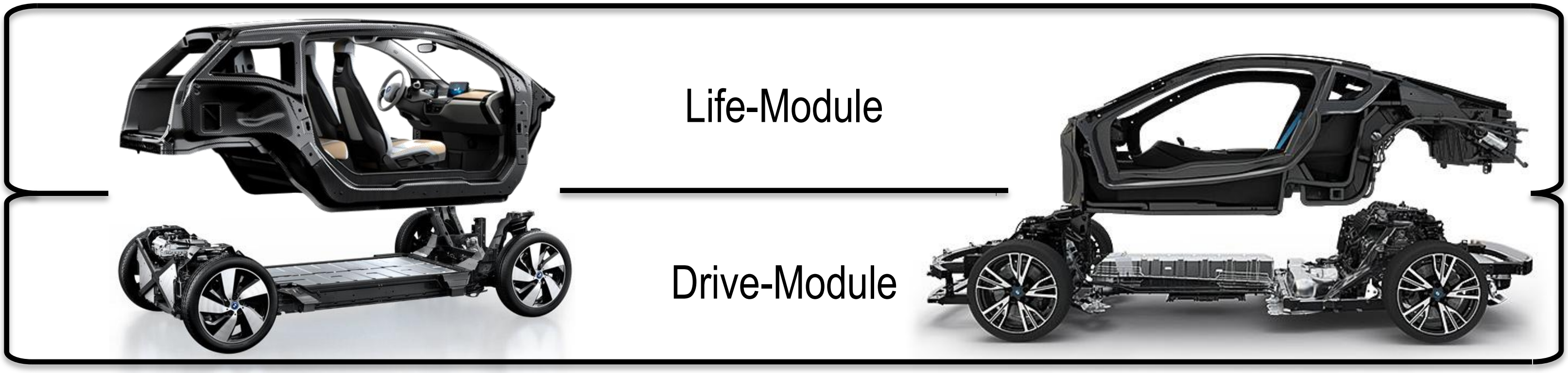
OUTLINE.

- BMW i.
- Production Process of CFRP Shell Structures.
- Large Scale Production of CFRP Parts.
- Semi-finished Carbon Fiber Products.
- Challenges for the Simulation.
- Strategy for Modelling of Unidirectional Non-Crimp-Fabrics.
- Simulation Results for Prototype Part.

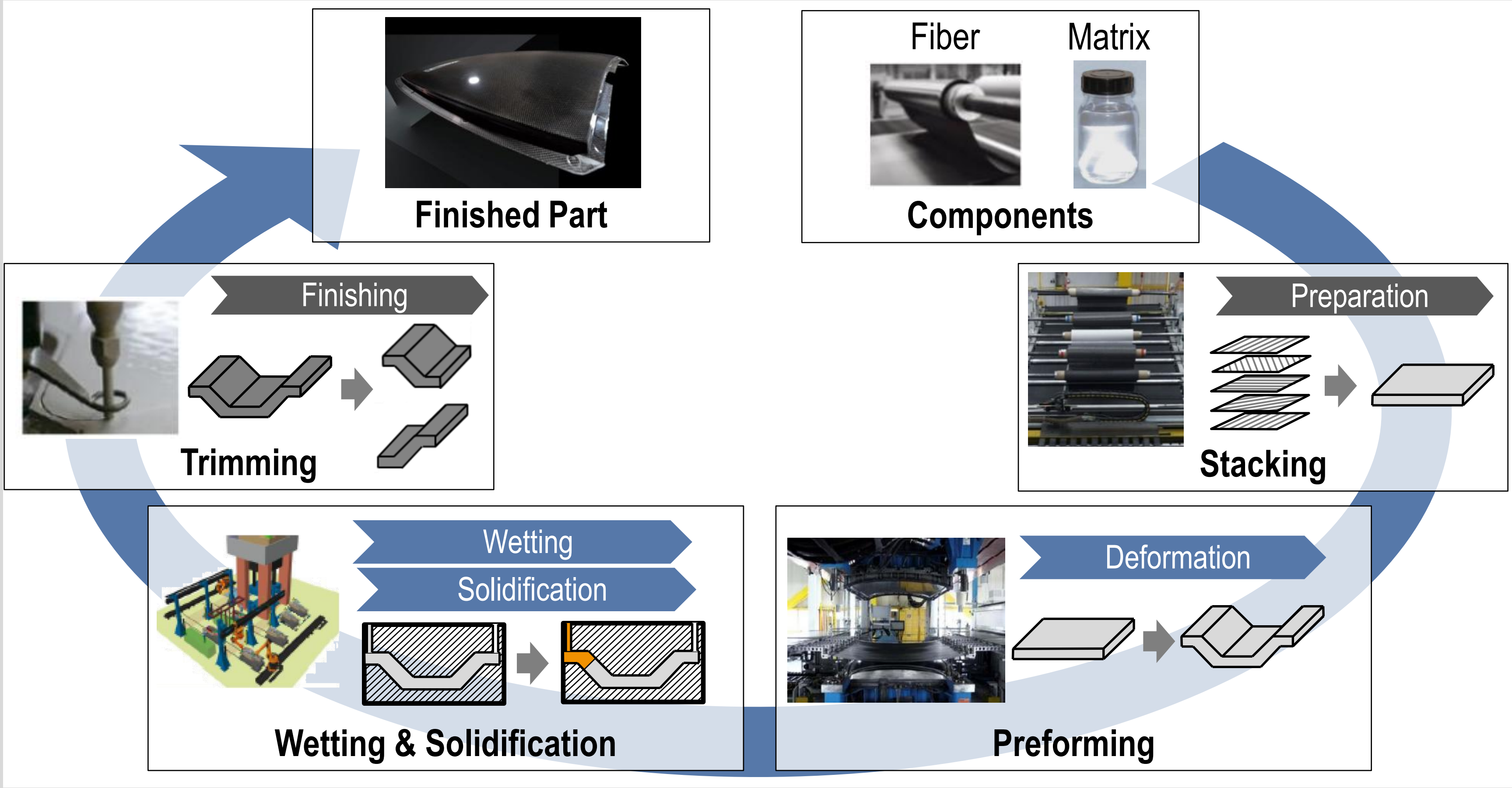
BMW i.
ELECTROMOBILITY & LIGHTWEIGHT CONSTRUCTION.

BMW i3

BMW i8



PRODUCTION PROCESS OF CFRP SHELL STRUCTURES. RESIN TRANSFER MOLDING (RTM) PROCESS.



LARGE-SCALE PRODUCTION OF CFRP PARTS. INDUSTRIAL AUTOMATION.

Single Item Production.

www.boeing.com

- Small number of units.
- Highly flexible.
- Long cycle/process times.

Large-Scale Production.

- Large number of units.
- Highly automated.
- Short cycle/process times.

⇨ Forming simulation to avoid cost and time intensive changes in the tooling /process.

SEMI-FINISHED CARBON FIBER PRODUCTS. EXAMPLES.

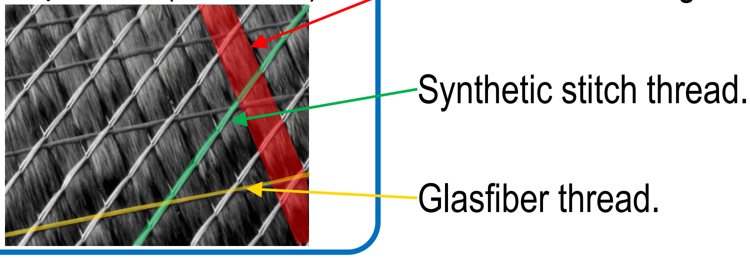
Fiber/Roving:

3K Roving

50K Roving

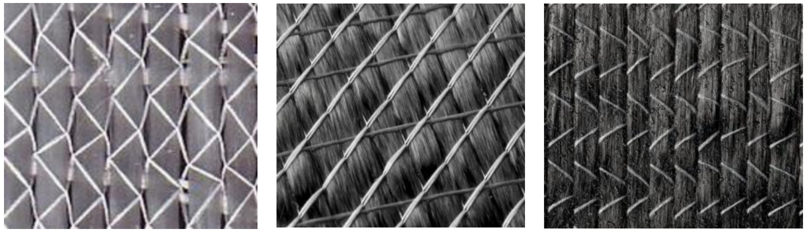
Textile:

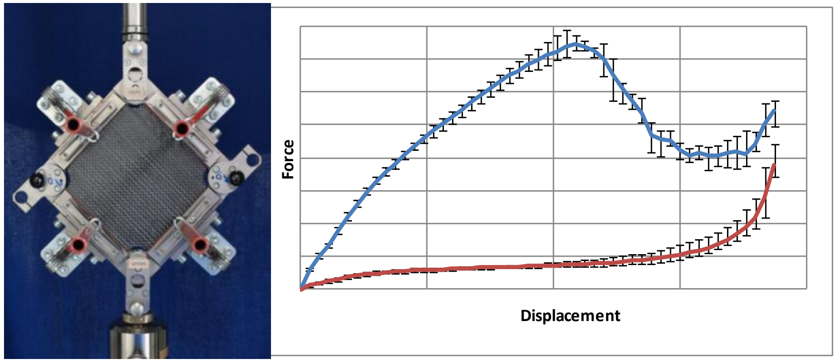
Unidirectional non-crimp-fabric (UD- NCF)



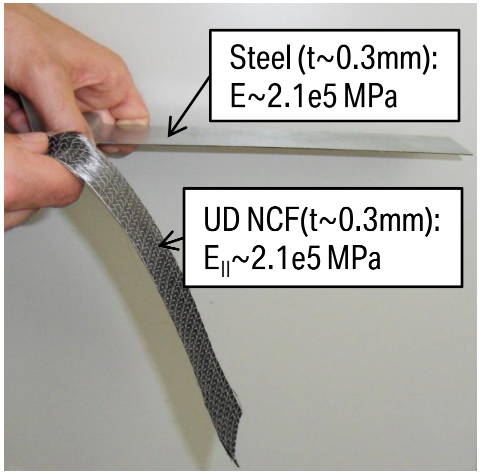
CHALLENGES FOR THE SIMULATION. EXCERPT.

Various Material Types.



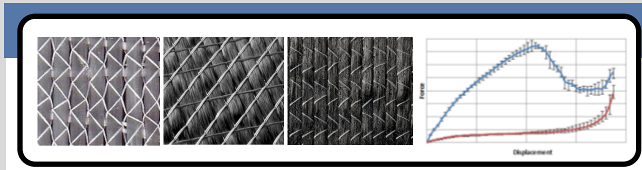


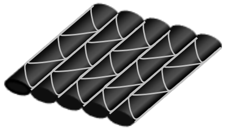
Bending Stiffness.



STRATEGY FOR MODELING UD-NCF. MODULAR APPROACH.

UD-NCF



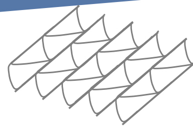


Composition of at least two structures and materials.

Modularization and Characterization

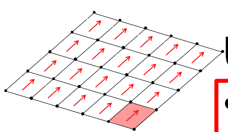
UD fiber structure:
- Compact structure.
- Nonlinear elastic material.

+



Warp-knitted stitch structure:
- Net-like structure.
- Nonlinear elastic material with failure.

Simplified Modeling



UD fiber model:
- Contin. approach (shell elements).
- UD fiber material model.

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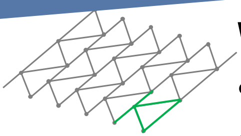
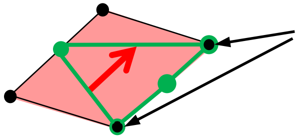


Warp-knitted stitch model:
- Discrete approach (beam elements).
- Cable material model

Representative Unit Cell Model

Resulting macroscopic material behavior by superimposing both models.



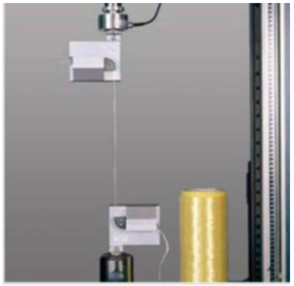
Coincident nodes.

Senner et al.: *A modular modeling approach for describing the in-plane forming behavior of unidirectional non-crimp-fabrics*, Production Engineering Research and Development, DOI 10.1007/s11740-014-0561-z, pp 1-9

STRATEGY FOR MODELING UD-NCF. MODULAR APPROACH.

Calibration:

- Stitching: tensile test of stitch thread.
- UD-NCF: tensile test (⊥ to fibers).



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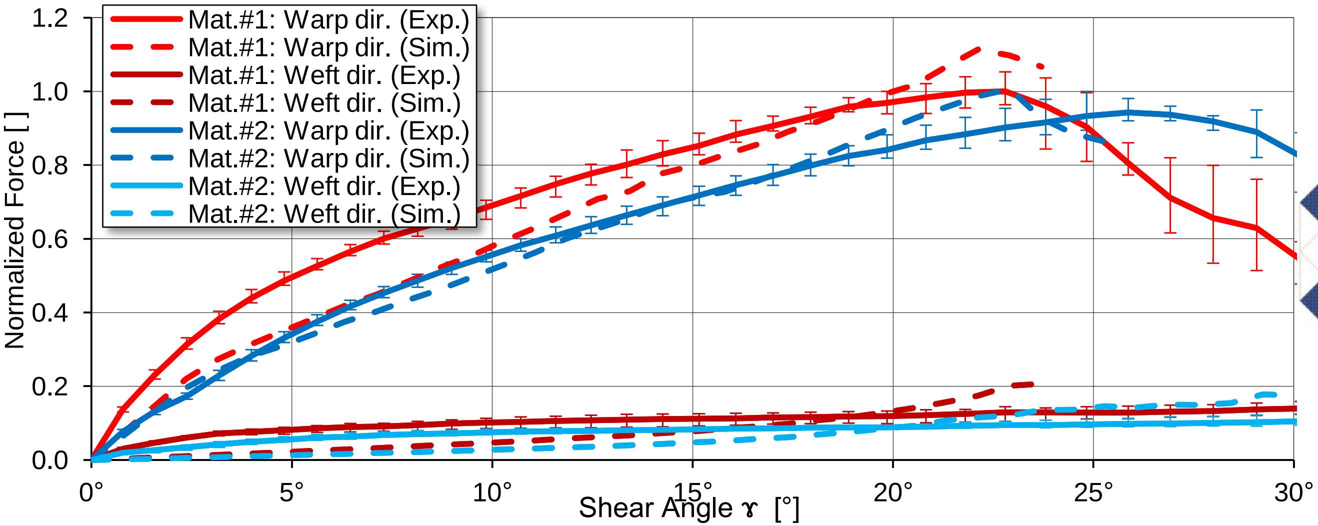
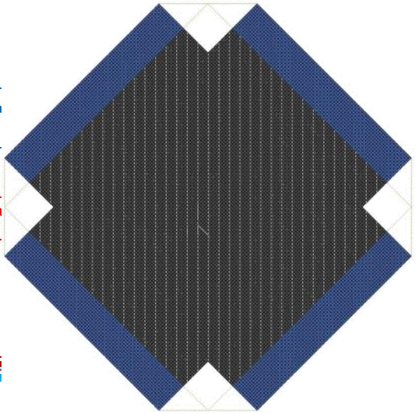
Validation:

Picture-Frame Test.





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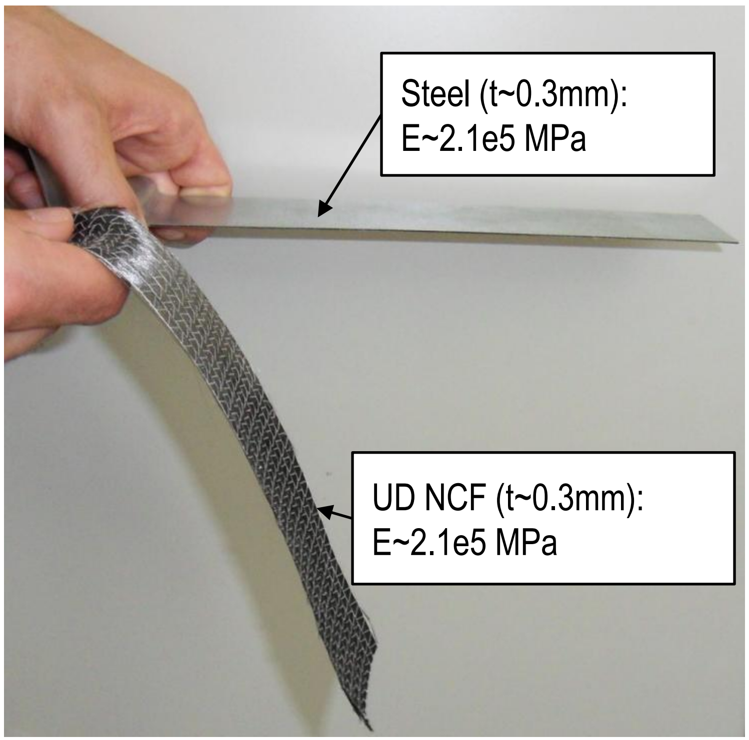
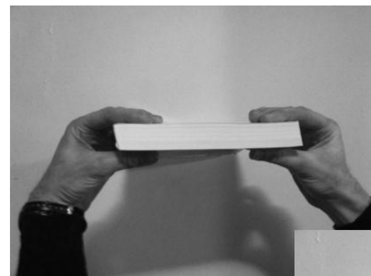
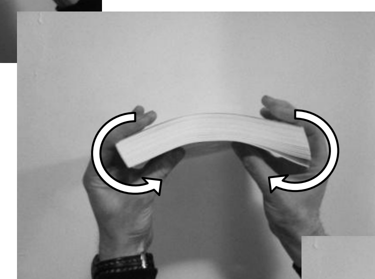
STRATEGY FOR MODELING UD-NCF.
BENDING STIFFNESS.







Discontinuity:
low bending stiffness
due to sliding of fibers.

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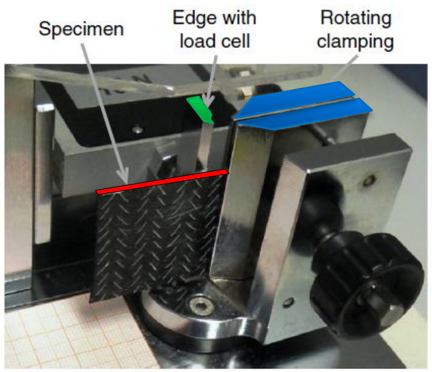

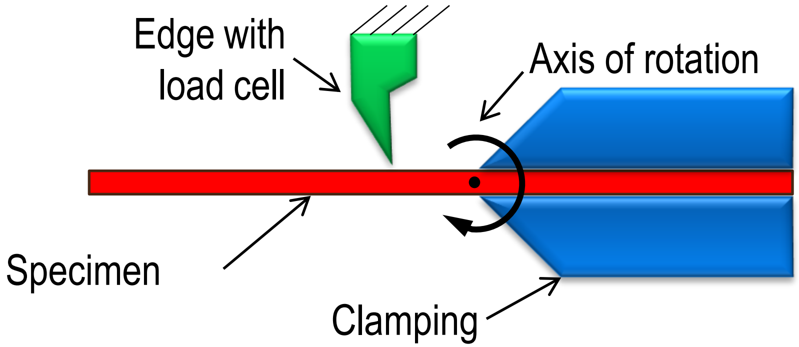

T. Senner et al.: Bending of unidirectional non-crimp-fabrics: experimental characterization, constitutive modeling and application in finite element simulation, Production Engineering Research and Development, DOI 10.1007/s11740-014-0568-5, pp 1-10.

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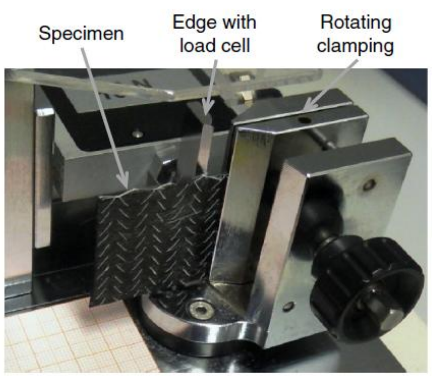

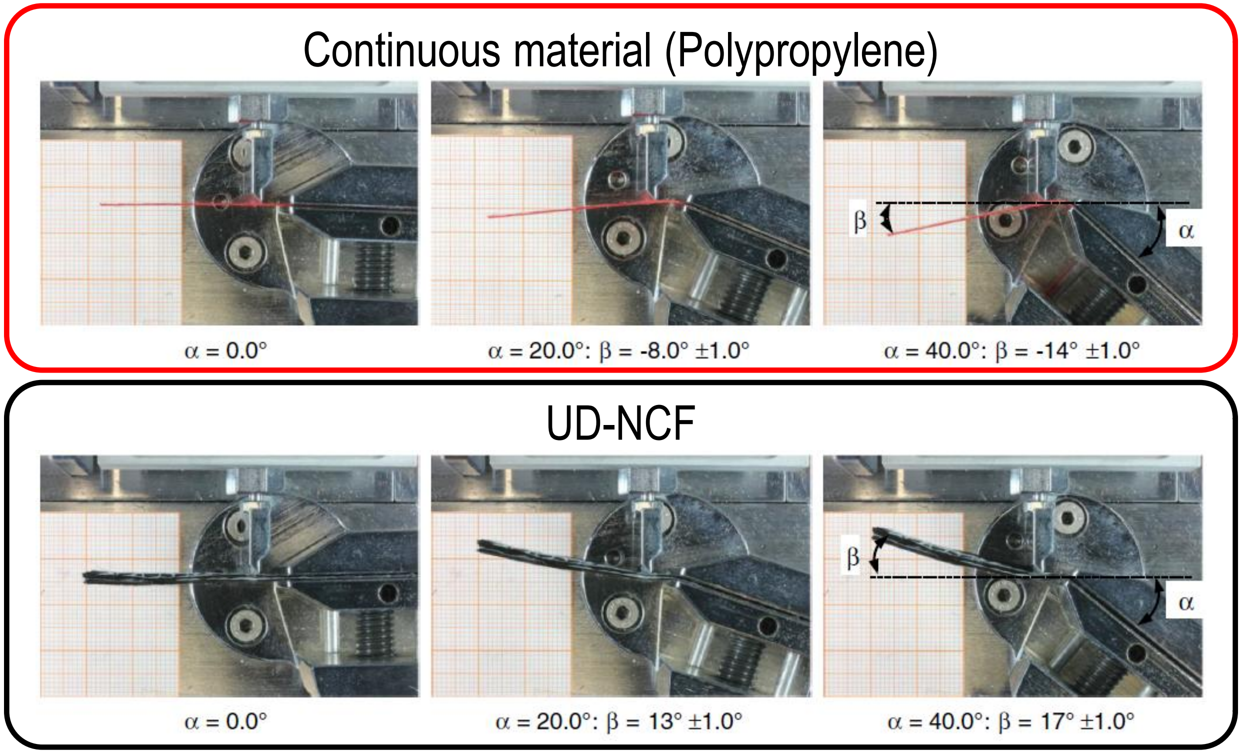

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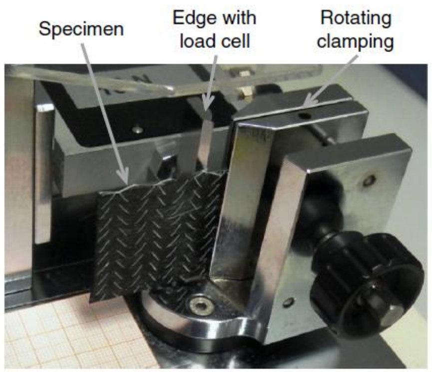
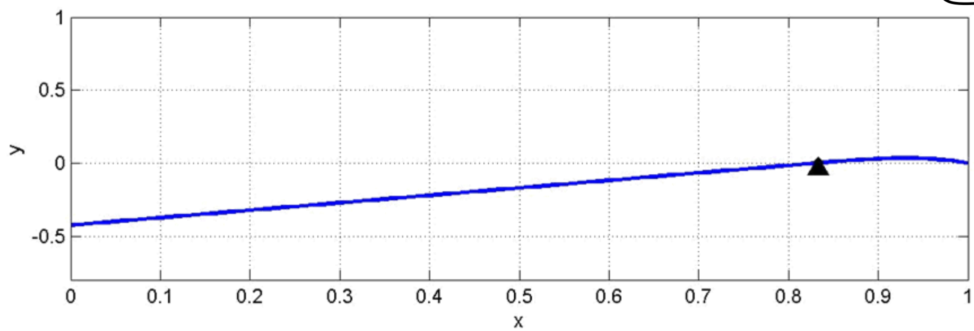


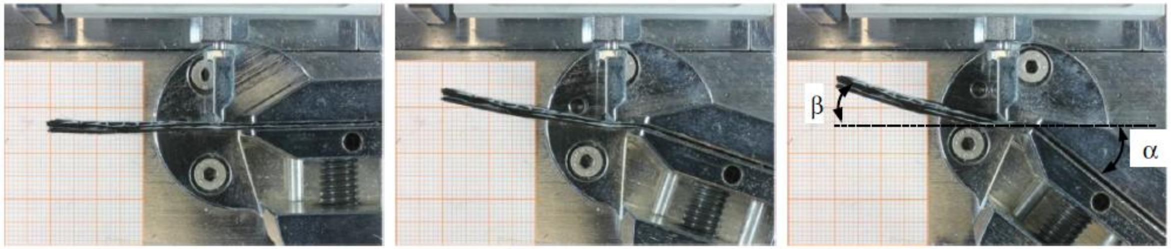
Beam theory (Timoshenko):

$$\frac{dw(x)}{dx^2} = \frac{M(x)}{E \cdot I} - \frac{q(x)}{G^* \cdot A}$$

$$G^* = \boxed{k} \cdot G$$



UD-NCF



α = 0.0° | α = 20.0°: β = 13° ±1.0° | α = 40.0°: β = 17° ±1.0°

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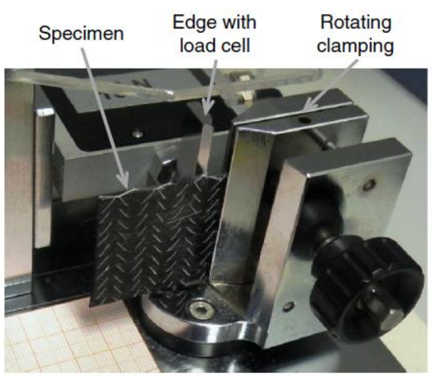

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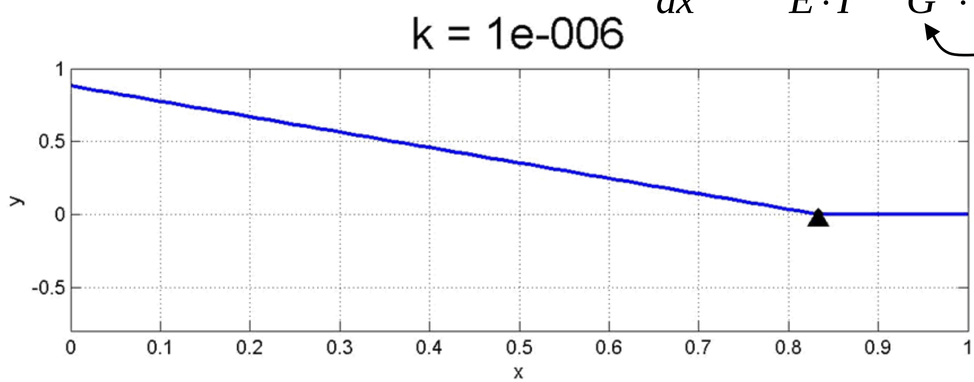
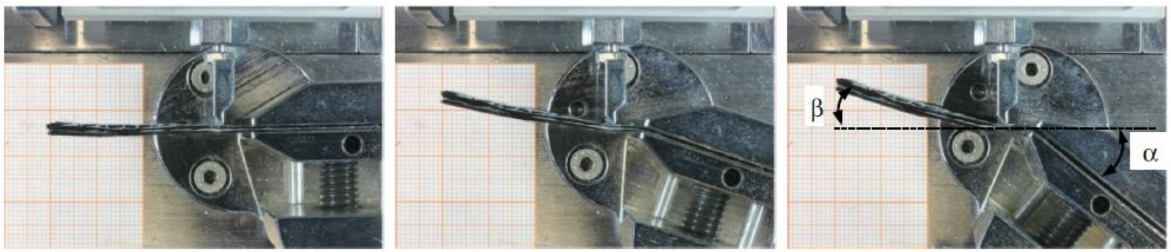


$$G^* = \boxed{k} \cdot G$$

UD-NCF



$\alpha = 0.0°$ | $\alpha = 20.0°$: $\beta = 13° \pm 1.0°$ | $\alpha = 40.0°$: $\beta = 17° \pm 1.0°$

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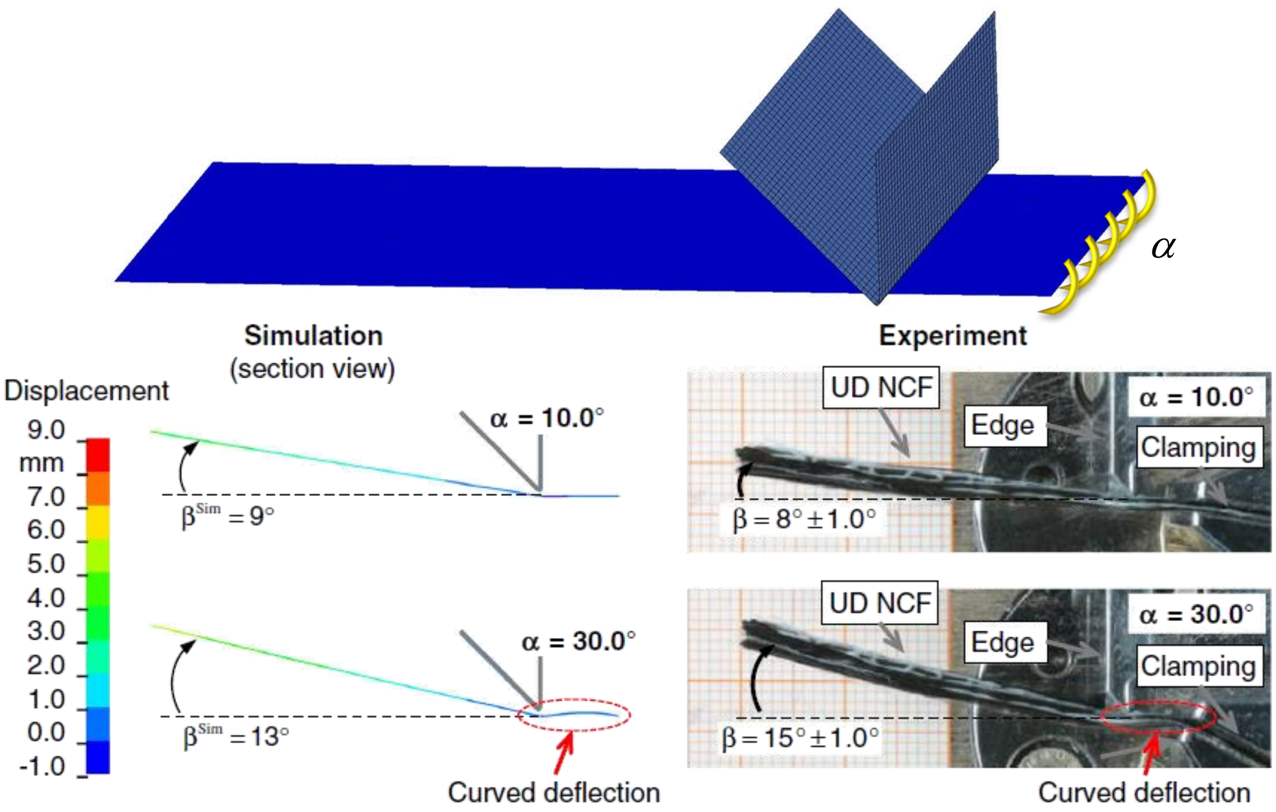
STRATEGY FOR MODELING UD-NCF. BENDING STIFFNESS.

Calibration.



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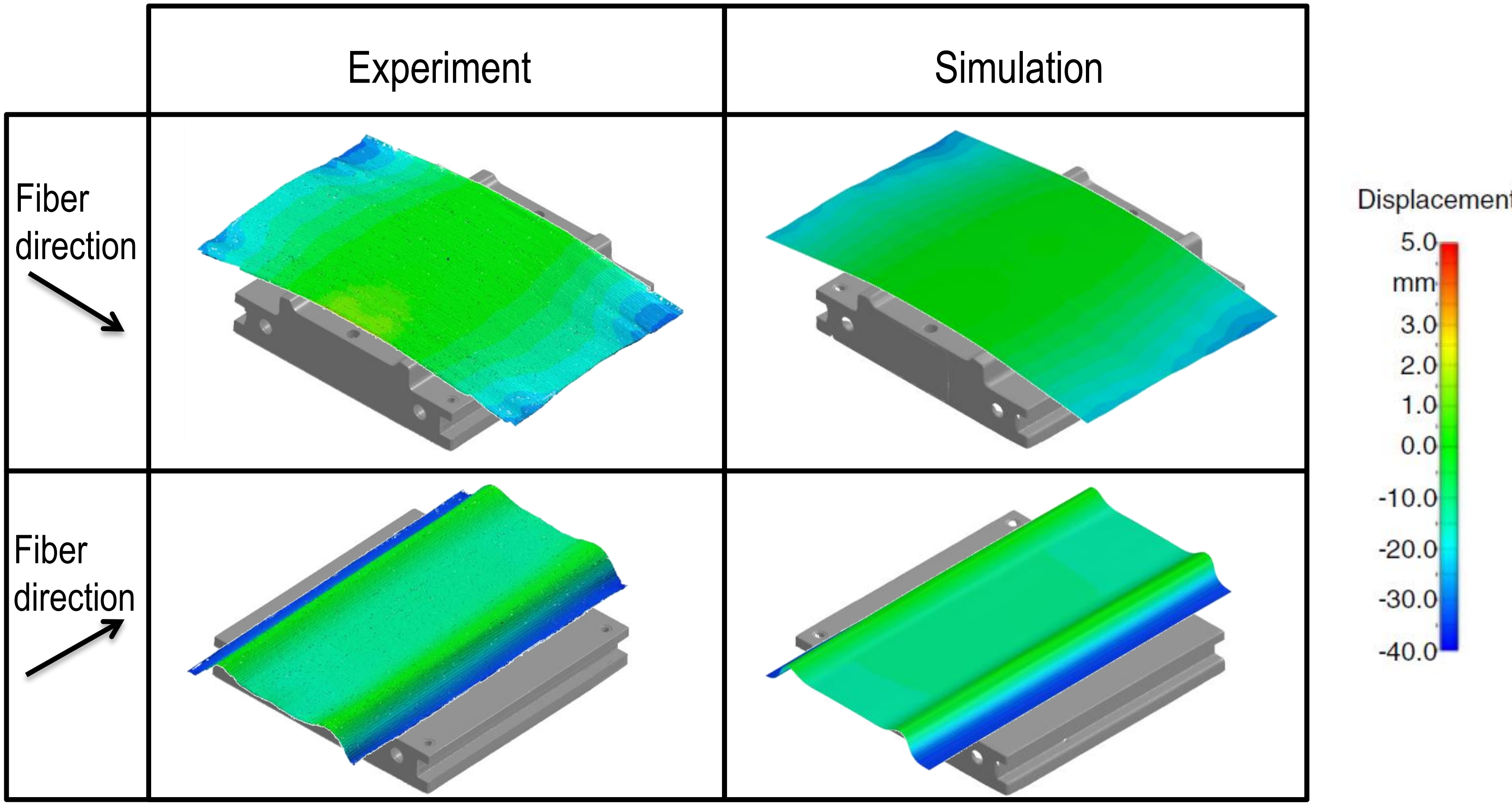

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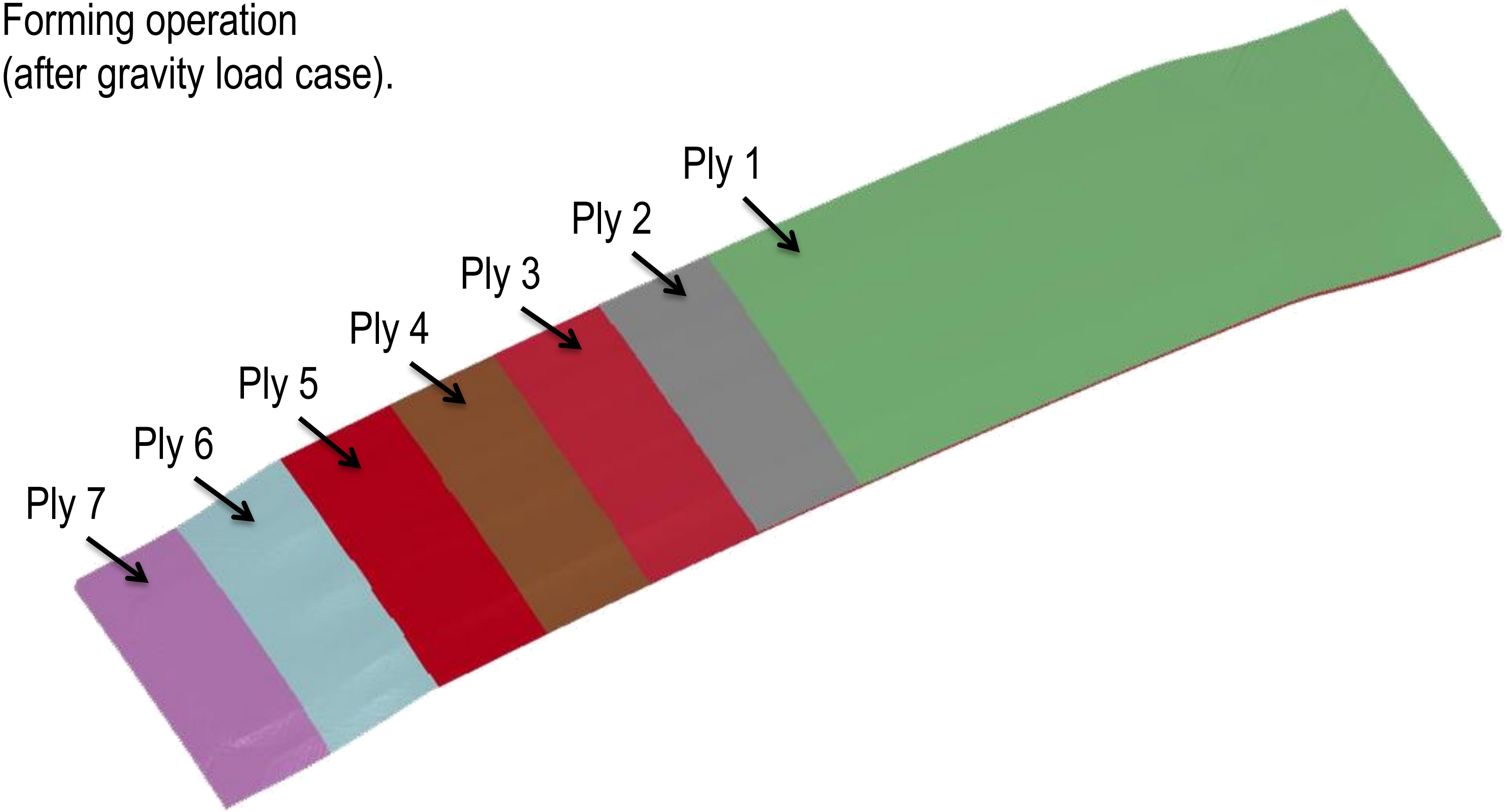
SIMULATION RESULTS FOR PROTOTYPE PART. PLIES 1-7.

Forming operation
(after gravity load case).



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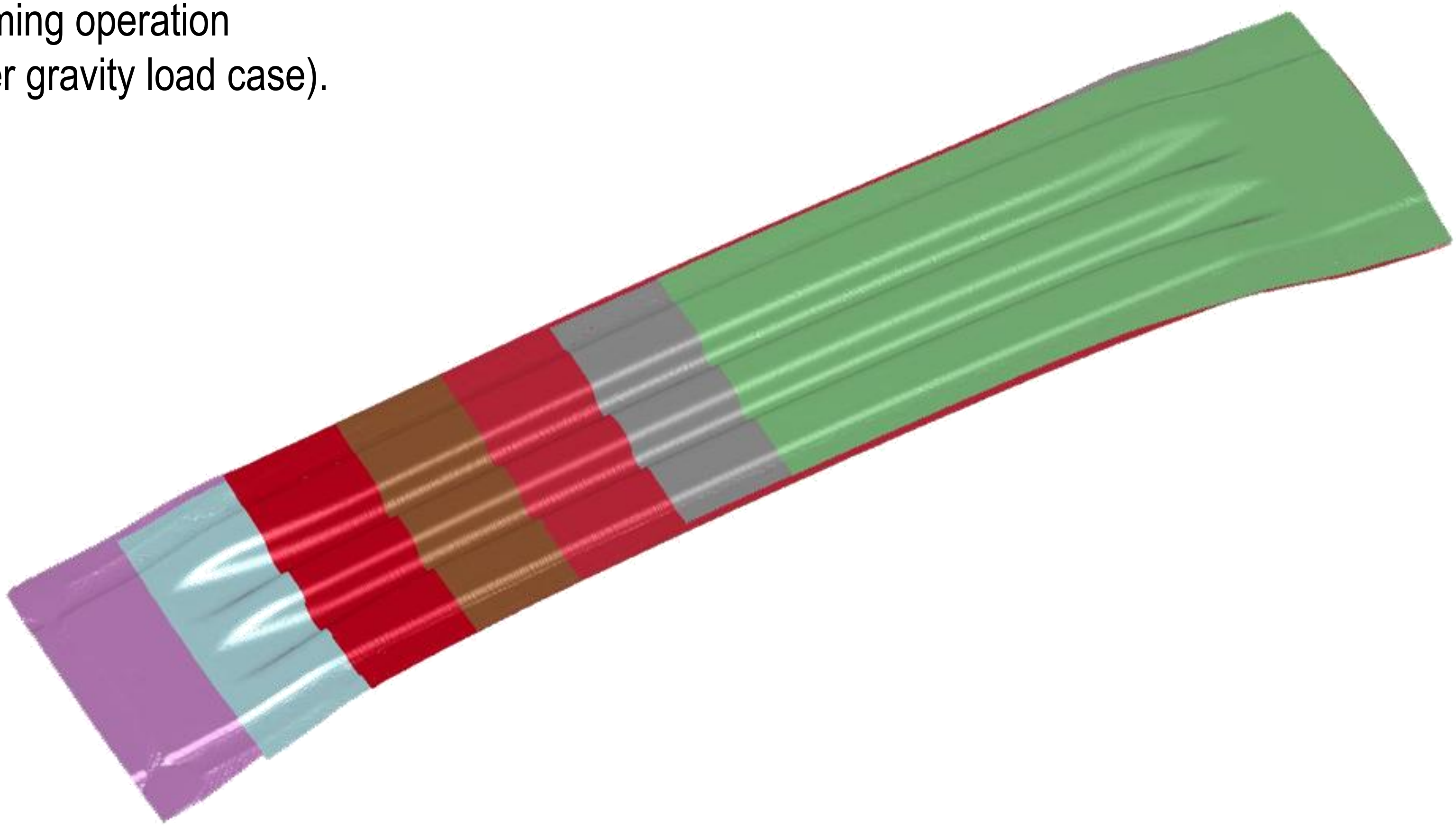
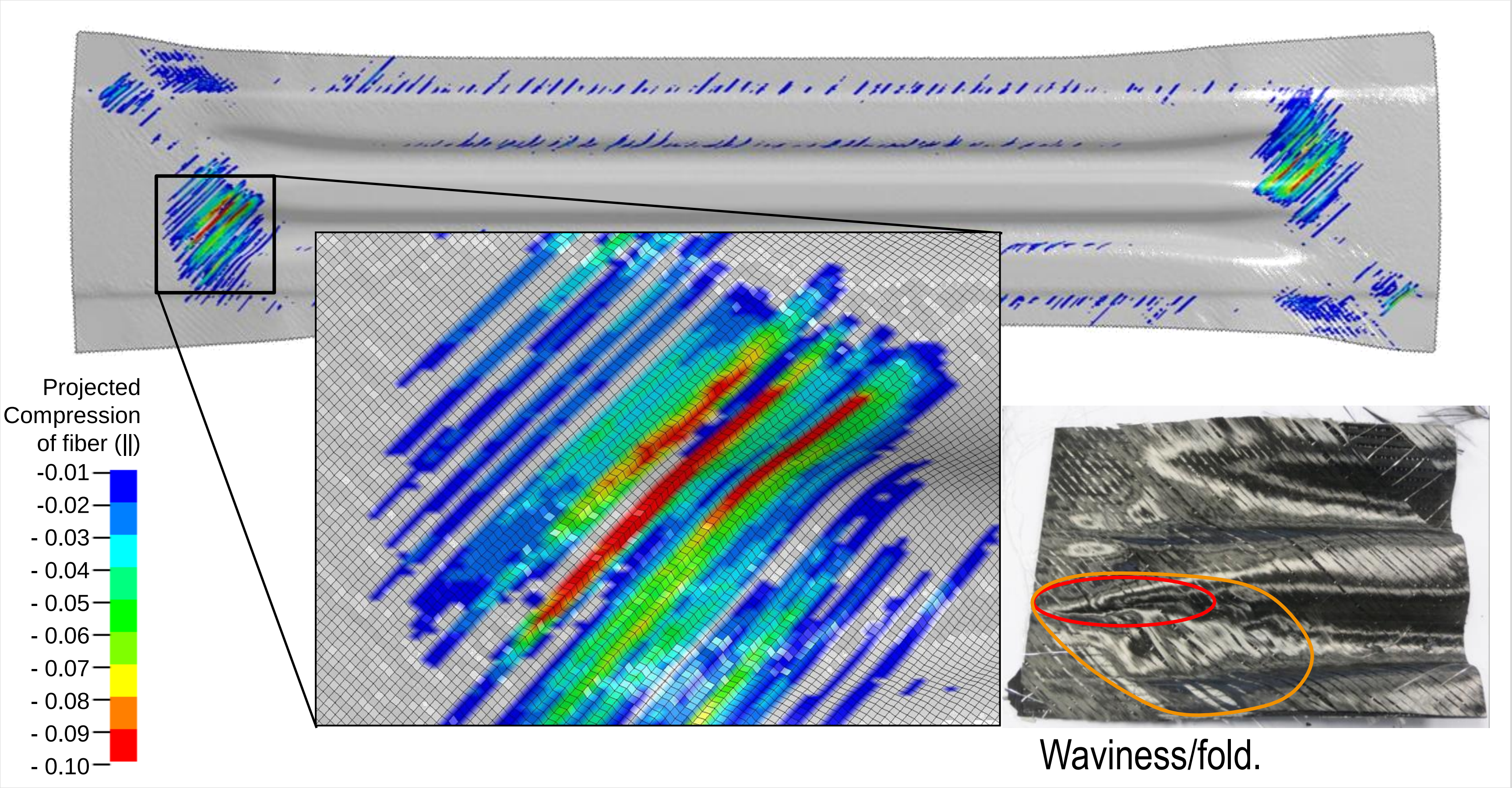


SIMULATION RESULTS FOR PROTOTYPE PART.
DETAIL: -45° PLY.



LITERATURE.

T. Senner, S. Kreissl, M. Merklein, M. Meinhardt, A. Lipp (2014):
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THANK YOU FOR YOUR ATTENTION.