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

13. LS-DYNA FORUM, 07.10.2014, BAMBERG.
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

Life-Module

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

Finished Part

Fiber
Matrix
Components

Preparation
Stacking

Wetting & Solidification

Deformation
Preforming

Trimming

Finishing

Wetting & Solidification

Fiber
Matrix
Components

Preparation
Stacking

Wetting & Solidification

Deformation
Preforming

Trimming

Finishing
LARGE-SCALE PRODUCTION OF CFRP PARTS. INDUSTRIAL AUTOMATION.

Single Item Production.

– 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)

Carbon fiber roving.

Synthetic stitch thread.

Glasfiber thread.
Various Material Types.

Bending Stiffness.

Steel (t~0.3mm): E~2.1e5 MPa

UD NCF(t~0.3mm): E_{||}~2.1e5 MPa
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.

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).

Validation:
Picture-Frame Test.

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STRATEGY FOR MODELING UD-NCF. BENDING STIFFNESS.

Steel (t~0.3mm): E~2.1e5 MPa

UD NCF (t~0.3mm): E~2.1e5 MPa

Discontinuity: low bending stiffness due to sliding of fibers.
STRATEGY FOR MODELING UD-NCF. BENDING STIFFNESS.

STRATEGY FOR MODELING UD-NCF. BENDING STIFFNESS.

Continuous material (Polypropylene)

α = 0.0°  α = 20.0°: β = -8.0° ± 1.0°  α = 40.0°: β = -14° ± 1.0°

UD-NCF

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

**STRATEGY FOR MODELING UD-NCF. BENDING STIFFNESS.**

Beam theory (Timoshenko):

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

\[
k = 1
\]

\[
G^* = k \cdot G
\]

STRATEGY FOR MODELING UD-NCF. BENDING STIFFNESS.

Beam theory (Timoshenko):

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

\[ G^* = k \cdot G \]

STRATEGY FOR MODELING UD-NCF. BENDING STIFFNESS.

Calibration.

STRATEGY FOR MODELING UD-NCF. BENDING STIFFNESS.

Experiment | Simulation
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Fiber direction

SIMULATION RESULTS FOR PROTOTYPE PART. PLIES 1-7.

Forming operation (after gravity load case).
SIMULATION RESULTS FOR PROTOTYPE PART. PLIES 1-7.

Forming operation (after gravity load case).
SIMULATION RESULTS FOR PROTOTYPE PART. DETAIL: -45° PLY.

Projected Compression of fiber (||)
-0.01
-0.02
-0.03
-0.04
-0.05
-0.06
-0.07
-0.08
-0.09
-0.10

Waviness/fold.

THANK YOU FOR YOUR ATTENTION.