A Multiscale Strategy for the Simulation of Braided Composites with ENVY0

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- closed, numerical process chain
- from the presizing to the final product
- simulation on the meso and macroscale
- various simulation tools
- HDF5 format

- braided structures
- Open-Reed-Weaving parts

-50% development time min. -10% weight
Investigation of a braided reinforcement structure under quasistatic 3-point bending

- complex structure geometry $\rightarrow$ potential defects due to manufacturing conditions
- use as reference for the investigation of different modelling approaches

- transfer of test condition in the simulation (impactor and support displacement, testing speed etc.)
1 – Standard approach
Reference approach

Principle of the approach

1. Modelling with UD-plies

2. Calculation of yarns stiffness and strength
   - Use of material properties from datasheets

   Matrix
   Fibre
   FVC
   Yarn

Analytical calculation according to Chamis „Mechanics of composite materials: past, present, and future, NASA TM-100793, 1984“

3. Structure simulation **without tuning**

   → **Overprediction** of structural strength

4. Changes of material parameters → try-and-error → no predictive simulation, only a post-test simulation
Reference approach

Principle of the approach

1. Modelling with UD-plies

2. Calculation of yarns stiffness and strength
   - Use of material properties from datasheets

3. Structure simulation

   - local effects are not considered
   - fibre architecture is not reproduced
   - adjustment cycles necessary
   - overpredictive if not tuned

Advantages

- "universal" approach (weave / UD...)
- fast model generation
- low computing time

Analytical calculation according to Chamis „Mechanics of composite materials: past, present, and future, NASA TM-100793, 1984“
2 – Multiscale approach
Example of a 30°-triaxially braided laminate – compaction simulation

CT-Scan

Braiding angle
Braiding core diameter
Breite = \( f_1(\theta, d, k, \eta) \)
Länge = \( f_2(\theta, d, k, \eta) \)
Lücke = \( f_3(\theta, d, k, \eta) \)
FVC
Size of yarn

Parametric model of the dry textile
Simulation on the mesoscale

Example of a 30°-triaxially braided laminate – tension simulation

Data for generation of a material card (E_{11}, E_{22}, S_{11}, S_{22}...)
Structure simulation of the reinforcement structure

- automatic postprocessing of unit cell results with ENVYO
- generation of material cards for the different textile types

Virtual material data

MAT_187_SAMP-1

MAT_262_LAMINATED_FRACTURE_DAIMLER_CAMANHO

CONTACT_SURFACE_TO_SURFACE_TIEBREAK
Predictive structure simulation of the reinforcement structure

Simulation on the mesoscale

- Stiffness prediction
- Strength prediction
- Prediction of residual strength

Delayed failure of axial yarns

![Graph showing force vs. displacement for different experiments and methods.](image-url)
Simulation on the mesoscale

Structure simulation of the reinforcement structure

**Advantages**
- consideration of textile architecture
- realistic textile behaviour in simulation
- automatisation possible
- predictive simulation, no tuning

**Drawbacks**
- increased computing times
- more complex model generation
3 – Process chain approach
Process chain approach

Braiding simulation

Machine parameters
- Number of bobbins
  - Fibre type
- Yarn pretension
- Braiding Speed
- Robot path

Simulation model
- Manufacturing effects
  - Orientation
  - Ondulation
  - Dry spots
  - Gaps to core
- Opt. machine parameters

Digital Twin

Original textile architecture after braiding simulation

Gaps in the braided textile

Gap between yarn and braiding core → matrix-rich zones
Braiding simulation

Machine parameters
- Number of bobbins
  - Fibre typ
- Yarn pretension
- Braiding Speed
  - Robot path

Simulation model
- Manufacturing effects
  - Orientation
  - Ondulation
  - Dry spots
  - Gaps to core
- Opt. machine parameters

Closing of the gaps

Upper movable mould

Lower fixed mould

Braided textile with closed gaps
Process chain approach

Information mapping to structure mesh

Mapping of:
- Yarn orientations
- Ondulation
- Dry spots
- Yarn geometry (width/thickness)

Model from the braiding simulation
Process chain approach

Structure simulation with mapped information

- Stiffness prediction
- Strength prediction
- Prediction of residual strength
- Prediction of yarn influence on local strain field

![Graph showing force vs. displacement](image1)

- Shear-loaded braiding yarns
- Tension-loaded axial yarns (compression-loaded on the lower side)
- Plastic deformation of the structural foam
Process chain approach

Structure simulation with mapped information

- Stiffness prediction
- Strength prediction
- Prediction of residual strength
- Prediction of yarn influence on local strain field

Advantages
- consideration of textile architecture
- realistic textile behaviour in simulation
- automatisation possible
- local strain field can be predicted

Drawbacks
- increased computing times
- more complex model generation
- investigation of information mapping with ENVYO is necessary
Conclusion

- mapping tool as link between process simulations and structure simulations
- transfer and simplification of information from the mesoscale to the macroscale
- a sensitivity analysis have to be performed before starting the structure simulation
- increase of prediction capabilities of structure simulation

**Mesoscale**
- process simulation
- reduction of experimental effort
- increased structure quality through optimisation loops

**Macroscale**
- structure simulation
- consideration of manufacturing effects
- relative low CPU time

Envyo

HDF5 format
Thank you very much for your attention.