3D Fabrics for Composites

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Contents

- Characteristics and types of 3D-textiles
  - Braids
  - Warp Knits
  - Woven Fabrics
- Invitation for partnership
- Summary
Characteristics and applications of 3D textiles

Specific characteristics of 3D textiles

- Near net-shape
- High material efficiency
- Very good mechanical properties
  - Delamination and impact resistance
  - Tensile strain-to-failure values etc.
- Complex manufacturing techniques
- Higher production costs
Characteristics and applications of 3D-textiles

Enabler to further enhance manufacturing of 3D textiles

Design tools
- Fabric designing using TexGen [ITA]

Automation
- Automated preforming [ITA]

Quality management and control
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3D braiding – biomimetic structures

- Natural paragon
  - Deep sea sponge Euplectella aspergillum
  - Calcified skeleton
  - Hierarchical fibrous structure with 7 levels
- Technological imitation
  - 3D rotary braid
  - Hierarchical structure with 5 levels
- Advantage
  - Material efficient
  - Damage tolerant

Sampe Innovation Award

Sponge Euplectella (left) und 3D braid (right)
3D hexagonal braiding - prototype 2nd generation
Selection of simulated hexagonal braids

Hexagonal  
Diamond  
Triangle  
Linear

Source: Ko et al.
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Warp knitting - tailored NCF

- Applying steel manufacturing methods for textile preform processes
  - Multi-step preforming: converting "Tailored-NCF" and "Tailored Braid" into near-net-shape preforms in a sequence of automated process steps

![Diagram showing steel processing, single-step preforming, tailored blank, tailored tube, assembly line, and multi-step preforming processes.](image-url)
Warp knitting - tailored NCF

- State of the art NCFs:
  - Constant width, thickness and stacking
  - Constant knitting pattern
  - Constant drapability
  - Rollable good

- Tailored NCFs provide:
  - Tailored (individual) stacking
  - Up to 34 individual layers
  - Local reinforcements
  - Locally adjustable drapability
  - Stackable tailored sheets
Warp knitting - tailored NCF

- ITA technology for tailored NCF production
  - Feeding module for local reinforcements and patches
  - Adaptive pillar-thread bar for knitting of thickness steps
  - Electromechanically driven guide bar
    - locally adjustable drapability
  - Cutting and stacking module

Cutting and stacking module

Electromechanical guide bar

Adaptive pillar-thread bar
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Applications of 3D woven fabrics

Specific advantages for different applications

- High energy absorption
- Low crack propagation
- Good impact behavior
- High tensile strength

Development of composite share in aviation [1]
3D woven fabrics for stiffener structures

Current deficits

- Multistep preforming processes necessary for conventional skin-stiffeners
- High risk of delamination after impact

Advantages of woven stiffener profiles

- Weaving of complex profiles in a single step
- High resistance against delamination
- Automated producing, also for curved stiffeners

Economic assessment

Assumptions:

- Always the same stringer dimensions, length of 2 m
- Same weight of carbon fibre material for all techniques
- 5000 curved stringers are to be produced in one lot
- Salary of 34 €/h, interest rate 3,67 %
- All other information is gathered from machine producers and manufactures

Significant values in the economical comparison are

- Production rate [kg/h]
- Capital consumption over usage time [€/year]
- Cut-off [%]
- Deficient products/scrap [%]
- Consumable material [€/kg]
- Labour costs [person hours/machine/h]
Production cost (without material) for one m stringer in €/m:

<table>
<thead>
<tr>
<th>Process Description</th>
<th>Capital Consumption</th>
<th>Deficient Products</th>
<th>Costs of Labour</th>
<th>Consumption</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prepreg-Layup with foam core</td>
<td>46.65 €/m</td>
<td>0.45 €/m</td>
<td>15.99 €/m</td>
<td>0.41 €/m</td>
</tr>
<tr>
<td>Braiding and RTM core</td>
<td>30.09 €/m</td>
<td>8.04 €/m</td>
<td>28.84 €/m</td>
<td>0.14 €/m</td>
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<tr>
<td>3D woven preform with RTM impregnation</td>
<td>15.05 €/m</td>
<td>1.34 €/m</td>
<td>21.32 €/m</td>
<td>0.00 €/m</td>
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<tr>
<td>3D woven preform with RTM impregnation</td>
<td>36.65 €/m</td>
<td>0.14 €/m</td>
<td>0.00 €/m</td>
<td>0.00 €/m</td>
</tr>
<tr>
<td>3D woven preform with pultrusion impregnation</td>
<td>0.82 €/m</td>
<td>0.00 €/m</td>
<td>0.00 €/m</td>
<td>0.00 €/m</td>
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<tr>
<td>3D woven preform with compression moulding</td>
<td>0.60 €/m</td>
<td>1.13 €/m</td>
<td>0.14 €/m</td>
<td>0.00 €/m</td>
</tr>
</tbody>
</table>

Economic assessment and production costs.
Open Reed Weaving

Current work

- With the new and worldwide unique Dornier „Open Reed Weaving“ loom multiaxial woven fabrics can be produced by adding an additional yarn system
- Right now the loom is modified at ITA to weave 12k rovings in 4 directions
- Focus for future projects lies on local reinforcements and reinforcements of holes
Partial reinforcements

Basefabric

Partial Reinforcement
Characteristics and types of 3D-textiles

Braids

Warp Knits

Woven Fabrics

Invitation for partnership

Summary
Reasons for companies to cooperate with us …

- Reasons to cooperate with us or to join our team at RWTH Aachen University:
  - Top international position in polymer, production and automotive research
  - Ranked No. 1 university for technology in Germany
  - Several sources of research funding

- All relevant textile production chains present in competencies and facilities
- Role model of ITA – process upscaling and product development close-to-market
Reasons for exchanging people with RWTH Aachen…

- Infrastructure
  - Analytics
  - Computational Engineering
  - Machinery from lab to industrial scale
  - All relevant textile processes

- Several funding possibilities
  - DAAD, DFG, Humboldt, …

- Research language is **English**,
- Language courses in German provided
- Assistance in accommodation, etc.
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Summary

3D textiles offer unique properties such as high material efficiency
Depending on the application there are specific requirements for 3D textiles
Because of their properties 3D textiles are most suitable for composite applications

What we provide in the field of 3D textiles

- Devolvement of machines, processes and process chains
- Design of 3D fabrics for different applications
- Cooperation within our RWTH Aachen University network
Thank you very much for your attention!

You are invited to visit us in Aachen!

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