High performance textile structures for composites through open reed weaving

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Overview

• Introduction
• Principle and potential of open reed weaving
• Integral reinforced fabrics
• Triaxial fabrics
• Shear reinforced fabrics for stringer elements
• Summary
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Textile design according to load paths

- Fiber properties highly direction depend
- Best mechanical properties in fiber direction
- Small angle deviation leads to significant performance drop

→ **Approach: Tailored textiles**
- Fiber placement along load paths
- High material and weight efficiency
- Suitable for large scale production

**Mechanical properties depending on angle deviation**

Reference: Cherif
Introduction

Examples: Tailored textiles technologies

- Most common: Placement technologies
- Example: Tailored Fiber Placement

References: ITA, Laystitch
Introduction

Examples: Tailored textiles technologies

- Most common: Placement technologies
- Example: Fiber Patch Placement

References: Geßler, Coqswell
Introduction

Examples: Tailored textiles technologies

• Most common: Placement technologies
• Example: Dry Fiber Placement

• Main limitation: Low production rate due to additive principle

References: Dell'Anno, Geßler
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Principle and potential of open reed weaving

Open Reed Weaving (ORW)

- Principle of function integration
  - Introduction of two additional yarn systems
  - Angle of additional yarns adjustable

Reference: ITA
Principle and potential of open reed weaving

ORW process
Principle and potential of open reed weaving

Application in composites

• High potential for efficient preform production
  – Saving of production steps and waste in preforming
  – Reinforcement yarns can be placed according to load paths

• Product examples
  – Local reinforcements
  – Triaxial fabric
  – Multiaxial profile reinforcement

Reference: ITA
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Integral reinforced fabrics

Potential and need for research

- Single step production of integral reinforced fabrics
  - Load tapes
  - Hole reinforcements
  - Force transmission points
- Reducing expensive waste and productions steps
- Lack of research: new textile structure to be considered in product design processes
  - Component design
  - Weave design
  - Process technology
  - Production planning
Product design

- No design standards for locally reinforced textiles
- Limited design possibilities

→ Development of product design tool
  - Identification of possible part designs
  - Economical comparison to conventional preform design

Reference preform

Definition of suitable reference

ORW-concept

Identification of possible ORW-concepts

Complex example part

Reference: ITA
Integral reinforced fabrics

Mechanical evaluation

• Notching
  – Reducing of local load peaks
  – Improvement in strength of up to 60 %

• Local force transmission point
  – Elimination weakness point at insert
  – Improvement of up to 36 %

• Hole bearing
  – Occurring at screws and bolts
  – Improvement of maximum strength up to 80 %

Reference: ITA
Integral reinforced fabrics

Further research demand

- Reinforcement design
  - Derivation of general design rules
  - Determination of “engineer’s formulas”
  - Establishing of FEA model

- Process technology
  - Tribological adaption of guiding elements
  - Improvement of yarn length tensioning

- Economical evaluation
  - Determination of profound knowledge regarding productivity
  - Evaluation of economic potential for industrial applications

Reference: ITA
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Triaxial fabrics

Motivation and approach

- Due to limited needle shifting, only small areas of multiaxial fabric possible
- Load path interrupted

- **Approach:** realizing an overlapping of two yarn systems

Reference: ITA
Triaxial fabrics

Product potential

• “Triaxial” fabric:
  – Continues load path in bias direction
  – Angle of additional reinforcement direction adjustable

• Possible application: multilayer laminates
  – Quasi-isotropic laminates such as [0/90/+45/-45/90/0°]
  – Saving of waste and preforming cost by saving +/-45 fabric layer

Reference: ITA
Triaxial fabrics

Experimental verification

• Well-known principle
  – Adhesive joints
  – Repairing of FRP
  – Short fibre reinforcements

• Calculated necessary overlapping length: 16.28 mm

• Conducting three-point-bending tests
  – Varying overlapping length
  – Carbon and glass tested
  – Reference samples
    ▪ [0/90°] fabrics
    ▪ [0/90/45°] fabric with continuous reinforcement

\[ F = \frac{\tau_K \times b}{\sqrt{\frac{1}{2} \times \frac{1}{E_t} \times \frac{G_K}{t_K}}} \]

Formula for calculation overlapping length of adhesive joints [Schuermann]

References: Schuermann, ITA
Experimental verification

• Results

![Graph showing bending strength vs. overlapping length for different materials including Carbon, Glass, Reference, and Reinforced Reference. The Y-axis represents bending strength in MPa, ranging from 0 to 500, and the X-axis represents overlapping length in millimeters, ranging from 0 to 40. The graph includes error bars for each data point.](graph.png)
Further research demand

- Fabric design
  - Determination of necessary overlapping lengths
  - Rules for weave design
- Process technology
  - Challenging yarn tension control
  - Tribological improvement of yarn guidance
- Application
  - Detailed mechanical evaluation
  - Economic evaluation
  - Comparison to reference materials

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Shear reinforced stringer elements

Motivation

- Application of stringers
  - Stiffening of shell elements
  - Mostly used for airplane and train shell elements
- Conventional production of stringers
  - Pultrusion → Limitation in fibre angle
  - Braiding → Limitation in productivity
  - Weaving → Limitation in fibre angle

References: Boeing, Vom Baur
Shear reinforced stringer elements

Potential of using ORW for stringer elements

• Using multiaxial reinforcement yarns to introduce a shear reinforcement
• Due to small component width, high yarn shifts not necessary
→ ORW suitable for producing stringer elements up to 2 m length

Reference: ITA
Shear reinforced stringer elements

Experimental study

- Design of reinforcement stringer
- Establishing production process

Fabric production

Introducing reinforcement yarns

Reference: ITA
Shear reinforced stringer elements

Experimental study

- Infusion of samples in RTM process
- Testing in 4-point-bending
- Economical evaluation
- Comparison to stringer made of conventional fabric

Reference: ITA
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High performance composite structures through ORW

• ORW offers combination of fabric production and fiber placement
• Design flexibility of ORW allows placement along load paths
• High potential for highly integrated parts
• Potential shown for different application cases
  – Local reinforcements
  – Triaxial fabrics
  – Stringer elements
• Further steps necessary for industrial application
  – Improved fabric design
  – Proof of economical advantages
Thank you for your kind attention

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