Novel Fiber Placement Technologies for Composite Applications
SPE ACCE 2012

Tailored Fiber Placement
Enabling Machine Solutions for Production and R&D

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Novel Fiber Placement Technologies for Composite Applications

• **Automated Tailored Fiber Placement (TFP)**
  – Introduction to TFP
  – TFP design example

• **Lower Cost & Improved Characteristics**
  – Comparison of Characteristics of a TFP design versus traditional designs.

• **3-D Preform Examples**
  – 3-dimensional TFP application examples showing simple as well as fairly complex 3D preforms.

• **Dispelling the myths**
  – Modern Automated TFP Made Easy for High Production Volume
Mechanical properties of a FRP depend on:
Fiber type; Matrix; Fiber volume fraction; Fiber Orientation

Source: Hightex Verstärkungsstrukturen GmbH
Fiber Orientation and Geometry depend on Textile Type

Felt/Veil  Woven Fabric  Knitted Fabric  Non Crimp Fabric (NCF)

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Fiber Orientation
Tailored Fiber Placement

Tailored Fiber Placement

Fiber Orientation and Geometry depend on Desired Product Properties

Used by courtesy of Hightex Verstärkungsstrukturen GmbH
Biomimetics or Bionics

“a relative new term for a process as old as humankind -- borrowing ideas from nature for shaping and creating our surroundings.”

Tailored Fiber Placement (TFP)
FiberPrinter™ Technology

FiberPrinter™ Automated Fiber Placement

R&D setup with a head-mounted bobbin – SLOW MOTION
Tailored Fiber Placement

Free Fiber Orientation

Local Reinforcements

Eliminating Production Waste

Circles, Arcs, Angles

Precise Layers

Mixed Materials

Near Net Shape Preforms

Example: Carbon & Glass
Tailored Fiber Placement

Selective Stitching
Laying out dry fibers with a minimum of stitch points

Enabling creative preform designs
TFP Design Example

Mountain Bike Brake Booster

Fiber Placement  Dry Preform  Composite Part

IFB Institute of Aircraft Design, Stuttgart, Germany
TFP Design Example
Mountain Bike Brake Booster

Design Considerations:

Design driven by the profile requirements:

- Outer Shape
- Material Distribution
- Material Orientation
Preform Design:

- Near Net Shape
- Preform in two symmetrical half’s on glass fiber fabric
- I-shaped Cross Section
- Fiber Orientation aligned with main Stress Directions:
  - 0° Reinforcement along outer contour
  - ±45° around Neutral Axis

IFB Institute of Aircraft Design, Stuttgart, Germany
TFP Design Example
Mountain Bike Brake Booster

**Stiffness:**

**Aluminum**
- Weight: 71g
- Stiffness absolute: 235N/mm
- Stiffness specific: 3.3 N/mm/g

**Tailored Fiber Placement**
- Weight: 24g
- Stiffness absolute: 220N/mm
- Stiffness specific: 9.1N/mm/g

**Woven Prepreg**
- Weight: 29g
- Stiffness absolute: 65N/mm
- Stiffness specific: 2.3n/mm/g

IFB Institute of Aircraft Design, Stuttgart, Germany
TFP Design Example
Mountain Bike Brake Booster

Comparison Summary

<table>
<thead>
<tr>
<th>Weight (gram)</th>
<th>Stiffness (N/mm)</th>
<th>Preform Cost (USD)</th>
</tr>
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<tbody>
<tr>
<td>TFP</td>
<td>Woven Prepreg</td>
<td>TFP</td>
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<tr>
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TFP - TFP Prepreg
NCF - Woven Fabric

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3-D Preform Example

*Light Weight Robot Arm*

**TFP Parts:**
- Four Robot arm link modules
- Wrist module

**Main Benefits:**
- Very Low Weight; High Stiffness
- Less moving energy
- Speed and acceleration

**Preform Design:**
- TFP Preform parts stitched together
- Creative lay & stitch pattern makes preform stretchable
- Integrated heating for improved curing

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3-D Preform Example
*KUKA Robot arm*

**TFP Parts:**
- Robot arm and Parallel arm

**Main Benefits:**
- Shorter cycle time
- Less moving energy
- Speed and acceleration

**Preform Design:**
- TFP Preform parts
- Preform wrapped around foam kernel

RTM molded with foam kernel inside

*KR40 In series production since 2005
KR180 In series production since 2001*

Used by courtesy of Hightex Verstärkungsstrukturen GmbH
3-D Preform Example

Airbus Carbon Window Frame

TFP Part:
- Carbon Window Frame

Main Benefits:
- Low weight
- Lower cost

Preform Design:
- TFP Preform parts
- Creative lay & stitch pattern makes preform stretchable
- L-structure design
- Selective stitching
- Structural stitching

In series production since 2010

Used by courtesy of Hightex Verstärkungsstrukturen GmbH
3-D Preform Example
Helicopter Longerons

TFP Parts:
- Longeron parts

Main Benefits:
- Low weight
- Preform mass variation less than +/-0.3 %.
- Range of breaking load lower than +/-1 %.
  (four point bending test)
- Considerable cost reduction compared to Prepreg.

Preform Design:
- Several TFP Preform parts stitched together

RTM molded
In Series production

Used by courtesy of Hightex Verstärkungsstrukturen GmbH
3-D Preform Example
Airbus Omega Frame Parts

TFP Part:
- Omega Frame Parts

Main Benefits:
- Low weight
- Lower cost

Preform Design:
- TFP Preform parts
- Selective stitching & Creative lay stitch pattern makes preform stretchable to be shaped.
- U-structure design

Used by courtesy of Hightex Verstärkungsstrukturen GmbH
3-D Preform Example

Boat Propeller

TFP Part:
- Boat Propeller

Main Benefits:
- Increased Strength & Stiffness
- Thin blades
- Low cost compared to prepreg

Preform Design:
- 3 TFP Preform parts joined
- Continuous fibers from blade to blade improving strength and stiffness

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Tailored Fiber Reinforcement

Spread Tow Fabric With Tailored Fiber Reinforcements
Characteristics of Spread Tow Fabric

1. The Spread Tow structure makes it possible to achieve thinner and lighter laminates.
2. Straighter fibers with reduced crimp result in improved performance.
3. Fewer and smaller crimps reduce the amount of excess resin, thereby minimizing weight (High Vf).

Used by permission from Oxeon AB
Combining Benefits:

Spread Tow Fabrics:
- Improved Mechanical Performance:
  - Strength, Stiffness, Impact resistance
- Ultra light and ultra thin
- Improved surface smoothness
- Enables high fiber volume fraction

Tailored Fiber Reinforcements:
- Tailored Reinforcements Around Holes & Edges
- Local Reinforcements up to 10 mm thick
- Improving stiffness and strength locally - in any direction
- Structural stitching in select areas
Integrating Wires, Tubes and Optic Fibers

- Wire on Fabric
- Recessed Laid Wire
- Wire on Nonwoven
- Wire on Foam
- Heating Element
- Heavy Gauge Wire on Net
Tailored Fiber Placement
Dispelling the myths

Complicated? New Design Tools makes TFP easy
  - *New Automated Stitch Design Software* and *Machine Technologies* makes TFP structures easy to design and produce.

Slow? High Production Capacity
  - New multi lay-head machines with fast stitching have high production capacity. (Annual capacity of 100K – 2,000K parts per machine)

Expensive? Considerable Cost Reduction
  - New Automated Stitch Design Tools minimize design costs.
  - *Fiber Tow/Roving is a lower cost material* than Woven fabrics or NCF. Using Less of a Lower Cost Material (Tow) and avoiding scrap saves cost.

To Stitch? Stitching is Reliable & Gentle
  - *Modern machines with Thin stitching needles* using Thin stitching threads are well proven to be Precise, Reliable and Gentle to the laid out fiber.
  - *Fiber Direction complying with Force Direction* enable High Fiber Volume Fraction and Improvements of Part Characteristics.

2-D? TFP is a 3-Dimensional Technology
  - Modern Draping Methods and Techniques enable 3-Dimensional parts
  - Precise fiber placement & selective stitching enable repeatable draping
Special Thanks

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