Automated 3D fiber layup concepts based on Fiber Patch Placement technology

Dr. Neven Majic, Executive Vice President and Co-Founder

**ADVANCED ENGINEERING**, Birmingham, UK 31 Oct. - 1 Nov., 2018
Complex composites still manufactured by hand!

- Long production cycles
- No effective quality control
- High scrap rate
- High cost

Need for automation solutions?
Fiber Patch Placement
Additive 3D fiber lay-up technology for complex composites

SAMBA Series
Automated production cells

Benefits
- Digitized, automated process chain
- 100% input material control
- Multi-material layup capability
- up to 50% material and cost savings

www.cevotec.com/en/fpp-technology/
Key enabler: the Cevotec patch process

Only the patch process enables high-complexity parts with cost-efficiency and volume capabilities.

- Automated complex direct 3D layup
- Processing multiple materials in parallel
- Customizing local fiber orientations
- 100% in-process raw material control
The Cevotec patch gripper
Adapting to complexity

Controlled fiber deposition on concave & convex surfaces

Example: Patch Placement onto a core of a sandwich structure

Key for automated fiber placement on complex surfaces
Focus industries and applications

Focus industries:
- Aerospace
- Automotive
- Medical, industrial
- Sports
- Additional

Primary applications:
- Multi-material components
- Complex geometries
- Tailored reinforcements
SAMBA Series
Additive 3D fiber lay-up systems.
Tailored to your requirements.

Modular, scalable components
- Material feeding & cutting e.g. laser, ultrasonic, mechanical
- Quality control cameras incl. image processing computer
- Robot with patch gripper e.g. 4-axis pick & place, 6-axis robot
- Tool manipulator e.g. 6-axis robot, tilting rotator, linear table

SAMBA Pro
flexible series production

SAMBA Scale
high-throughput production

SAMBA Multi
carbon, glass and other fibers

SAMBA Step
entry to patch technology

All systems available in dry fiber and thermoset-prepreg configurations
SAMBA Pro
High-volume, flexible (batch) series production

Specs
- 10 robot axes for highest degree of product complexity
- Laser cutting for individual patch geometry
- High-res cameras for maximum placing precision
- Fiber throughput ~ 2-3 kg/h
- Fast and easy tool change system

Application areas
- Volume series production of medium to small parts
- Flexible batch series production
SAMBA Scale
High volume, high throughput series production

Specs
- Scaled patch placement system for high fiber throughput
- Robust, durable components for 24/7 production settings
- Integration into industrial composites lines possible
- Fiber throughput ~ 15 kg/h per patch unit
- Fiber throughput > 100 kg/h through combination of units

Application areas
- Volume series production of large to medium-sized parts
- Optimized for continuous, high-throughput production
SAMBA *Multi*

High volume series production for multi-material processing

**Specs**
- Processing different materials (carbon fiber, glass fiber, …)
- 6-axis robot on a linear moving unit
- Varying gripper sizes within the process
- Fiber throughput ~ 15 kg/h

**Application areas**
- Volume series production of large to medium-sized parts / sandwich structures – ideal for aerospace parts
Industry 4.0 automation with Fiber Patch Placement
Continuous process & quality control with a multitude of integrated sensor for key process parameters

- Real-time production data analysis and comparison with a database of previously processed patches
- Controlled deposition process
  - Temperature
  - Pressure
  - Compaction time
  - Contact time from pick-up to deposition
- Station for in-process gripper exchange
  - Automated detection for contamination
- Interfaces for integration into existing process control landscapes
- Controlled tape feeding
  - Temperature for material storage
  - Controlled tape pull-off
  - Automatic tape positioning to centricity
- Vision control patch
  - Position
  - Orientation
  - Self-correction process for precise deposition
  - Width
  - Length
  - Cutting edge
  - Waviness
- Global parameters:
  - Temperature & humidity in manufacturing cell
  - Frequency of patch deposition
  - Cycle time
  - Mass throughput

Objective: Replace individual unit tests by continuous process monitoring
SAMBA **Step 3D**
Low-volume, direct 3D production & product development

**Specs**
- Low-investment entry to patch placement technology
- Flexible degree of automation, here: 9 robot axes
- High precision fiber placement
- Fiber throughput ~ 500 g/h
- Fast and easy tool change system

**Application areas**
- Flexible, low-volume series production of 3D components
- Prototyping and product development
- Research and development
Integration of SAMBA in industrial composites lines

Patch technology: decrease cost and improve product performance
Comprehensive CAE software suite for Fiber Patch Placement

Enabling a continuous virtual process chain

**CAD – PATCH ARTIST**

- Patch-based laminate generation

**FEA – Artist Studio Plug-in**

for commercial FE-Software

- Modeling & Simulation of mechanical behaviour (stiffness, strength)

**CAM – MOTION ARTIST**

- Offline robot programming

October 2018
The Cevotec portfolio
Your one-stop partner for patch-based production equipment & software

Production systems
SAMBA Series

- Direct 3D fiber lay-up systems
- Tailored configurations
- Full automation incl. laminate handling

CAE software
ARTIST STUDIO

- CAD-CAM for patch technology
- Export of laminate for FEM
- Perfectly matches SAMBA systems

Patch technology services & products
Development, production, spread tow, gripper

- Product development, prototyping & series production
- CAE analysis & FEM-based optimization
- Customized fiber spread tow and patch grippers
We enable manufacturers to produce complex composites in high volume and superior quality.

For a lighter, more sustainable future.

Dr. Neven Majic  Executive Vice President
Phone:  +49 89 2314 165 31
Email:  neven.majic@cevotec.com

Summary

· Smart automation based on Fiber Patch Placement Technology for serial production & research activities

· Different machine configuration depending on requirements

· Continuous process & quality control

· Integration-friendly in existing production lines

· Virtual process chain available (CAD-CAM-FEM)
Product details:
SAMBA Series & ARTIST STUDIO
Automated handling of SAMBA fiber laminates
End-to-end automation for complex fiber laminates in series production

- Automated removal from mold
- Innovative tooling concept for first ply release
- Standard gripper equipment for lifting and transport

Increase output and maximize productivity of the SAMBA systems
SAMBA *Step 2.5D*
Low-volume, 2.5D production & product development

**Specs**
- Low-investment entry to patch placement technology
- Flexible degree of automation, here: automated layup table
- High precision fiber placement
- Fiber throughput ~ 500 g/h
- Fast and easy tool change system

**Application areas**
- Flexible, low-volume series production of 2D reinforcements
- Prototyping and product development
- Research and development
milestones in composites

Case Study: Operating box cover with Premium Aerotec
Results from BMBF-supported project IMPULS

Challenge: Automated layup of operating box cover
Material: Hexcel M21E preg tow (1/2 inch width)
virgin residuals from M-Torres AFP machine

Results: Weight -70%, Cost -75% (to actual version of the part)

Looking forward:
· Continuous, automated process – blueprint for high complexity parts
· New options for manufacturers already using AFP / ATL systems
· Significant material cost savings from re-purposing AFP “left overs”

Material cost savings

<table>
<thead>
<tr>
<th>Throughput AFP: 25 kg/h</th>
<th>Material: 100 €/kg</th>
</tr>
</thead>
<tbody>
<tr>
<td>Daily production: 18 h</td>
<td>Yearly production: 250 days</td>
</tr>
<tr>
<td>OEE: 80%</td>
<td>Note: figures only illustrative.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Volume p.a. [kg]</th>
<th>AFP residual material</th>
</tr>
</thead>
<tbody>
<tr>
<td>% FPP repurposing</td>
<td>2,5%</td>
</tr>
<tr>
<td>60%</td>
<td>1.350</td>
</tr>
<tr>
<td>70%</td>
<td>1.575</td>
</tr>
<tr>
<td>80%</td>
<td>1.800</td>
</tr>
<tr>
<td>90%</td>
<td>2.025</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Value p.a. [€]</th>
<th>AFP residual material</th>
</tr>
</thead>
<tbody>
<tr>
<td>% FPP repurposing</td>
<td>2,5%</td>
</tr>
<tr>
<td>60%</td>
<td>135.000 €</td>
</tr>
<tr>
<td>70%</td>
<td>157.500 €</td>
</tr>
<tr>
<td>80%</td>
<td>180.000 €</td>
</tr>
<tr>
<td>90%</td>
<td>202.500 €</td>
</tr>
</tbody>
</table>
ARTIST STUDIO

CAD-CAM software for patch technology

Standalone software platform for a continuous process from CAD to machine data. Adjusted to match every SAMBA system.

Patch Artist
- Generates high-performance laminates
- Enables complex and curvilinear fiber orientations
- Optimizes patch overlaps and positions
- Works with all standard CAD file formats
- Export of patch laminate for FEM simulation

Motion Artist
- Generates machine data for SAMBA
- Optimizes robot movements
- Simulates the production process, incl. collision detection
- Performs offline programming of SAMBA robots
Patch laminate architecture for optimized strength
Laminate optimization with comprehensive CAE software suite for Fiber Patch Placement

**Fact**

Composite materials have a lot of parameters which can be optimized:
- Fiber direction
- Thickness
- Layer order
- Overlap

**FPP:** Main performance driver is a load-path oriented fiber direction and the patch overlap pattern.

- Patch layup enables high lightweight design potential
- >50% better mechanical properties than conventional laminates!

> Optimized patch layup is increasing the strength*

*tested based on ASTM norm
Beyond application:
The theory, principles and scientific results of patch placement technology
Bionics lightweight design
Motivation for Fiber Patch Placement technology

Natural Fibrous Structures
- Leaf
- Tree trunk
- Human bone

Technical Structures
- Airport hall
- Curvilinear carbon fiber orientation
- Topology optimized chassis

Fibers follow curved paths
- Transferring the principle to lightweight construction
- New curvilinear textile technologies
- Fiber Patch Placement
  - Direct fiber patch placement on
  - 3D geometry or along 3D load paths
Massive drop in strength of classical laminates
Average fiber-to-load deviation is significantly reduced with Fiber Patch Placement

Fact
Multiaxial non-crimp fabrics such as quasi-isotropic lay-ups cannot exploit the full potential of the material.

Example
Only 15° deviation to a tension-based load path leads to an extremely reduced strength (>80%)

Patch layup supports optimal lightweight design
2.5x stiffness increase with load-optimized patch laminate
High performance lightweight design with Fiber Patch Placement

Mass-specific stiffness [kN/(mm·g)]

Quasi-isotropic lay-up  Optimized patch lay-up

Source: Cevotec and Technische Universität München
2.2x strength increase through curvilinear fiber orientation

Demonstration at an open hole specimen

Biaxial non-crimp fabrics

Load path oriented fibers (patch basis)

20% weight decrease with patch reinforcements
Load-path-oriented reinforcements reduce material, weight and cost

Quasi-isotropic lay-up

Lay-up with patch layers

8 unidirectional layers

4 unidirectional layers + 2 patch layers

20% weight reduction