Closing the Gap in Lay-up Automation

for High-performance, Multi-material Aerostructures

Thorsten Groene, CEO & Co-Founder

Cevotec GmbH

www.cevotec.com

Agenda

Introduction to Fiber Patch Placement

Multi-material lay-up

Load-optimized laminate design

New FPP R&D opportunities at NIAR

Introduction

Fiber Patch Placement (FPP) technology

Complex aerostructures still manufactured by hand!

- Long production cycles
- No effective quality control
- High scrap rates >30%
- High cost

Image: FACC

Image: Liberty Aerospace

Next generation technology?

Fiber Patch Placement

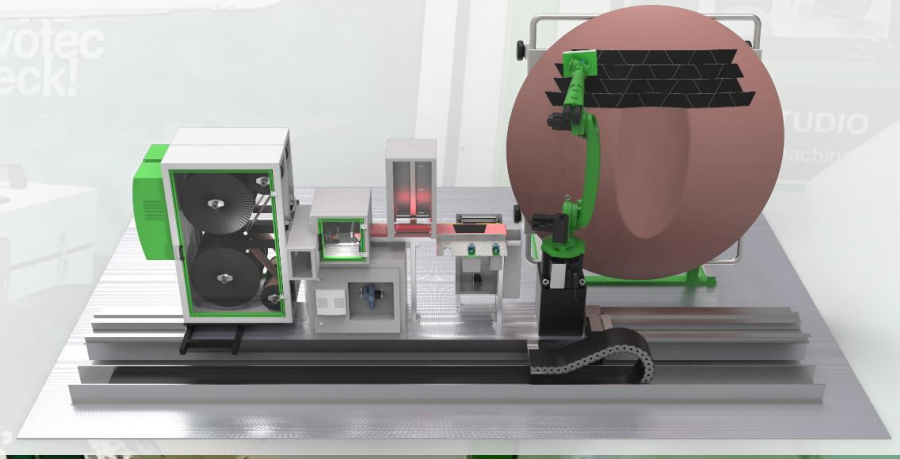
Additive 3D fiber lay-up technology for complex composites

Benefits

- Digitized, automated process chain
- 100% in-process raw material control
- Multi-material lay-up capability
- 20% - 60% cost & time savings

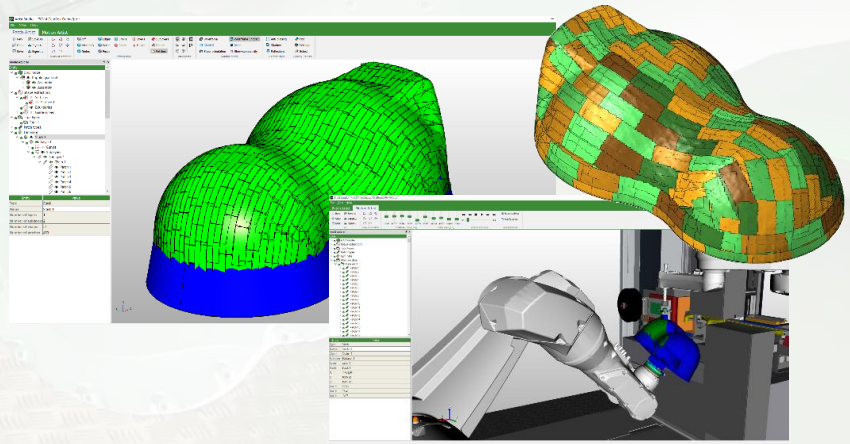
SAMBA *Series*

3D fiber lay-up automation platform



ARTIST STUDIO

CAE software for design & production



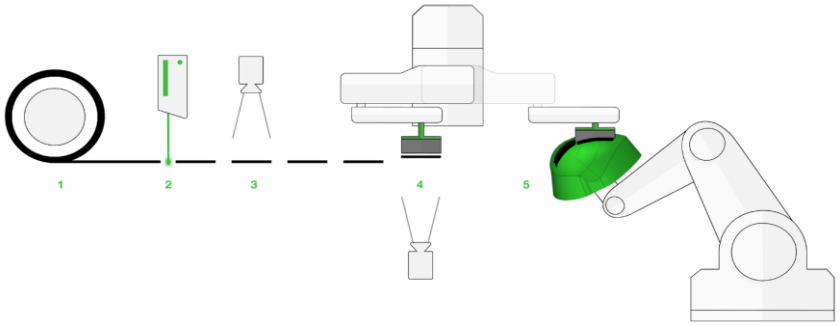
www.cevotec.com/en/fpp-technology/

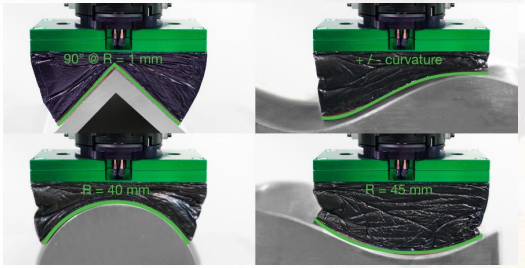
Industries & applications

Focus industries	Applications areas
Aerospace	Multi-material components
Automotive	Complex geometries
Medical	
… Additional	Tailored reinforcements

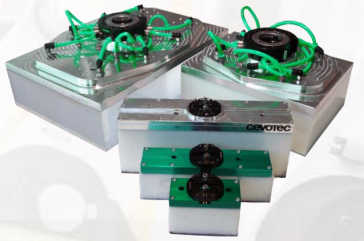
The Fiber Patch Placement process

Flexible lay-up technology for high-performance composites

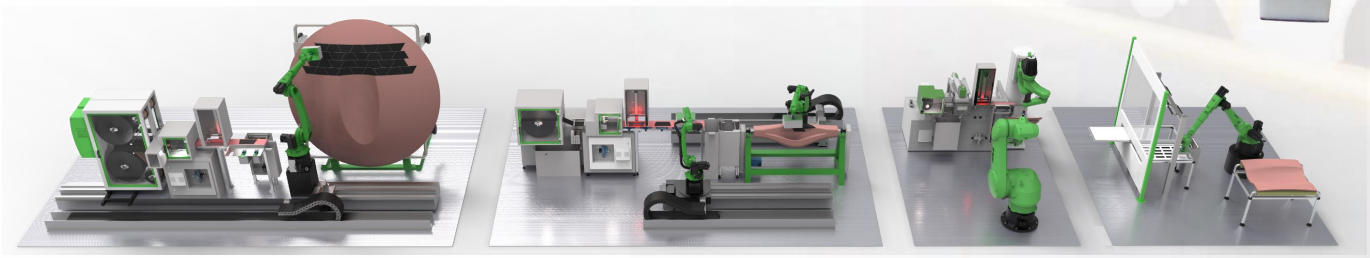




1. Feed fiber tape
2. Cut tape into patches
3. Inspect quality
4. Pick-up, check position
5. Place fiber patch



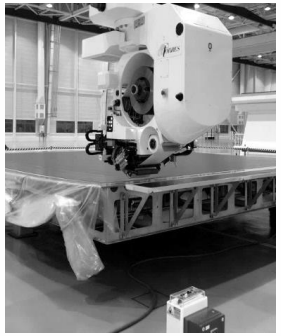
Various equipment options | size, materials, degree of automation



Enabling a fully automated, quality-controlled 3D lay-up for complex composites

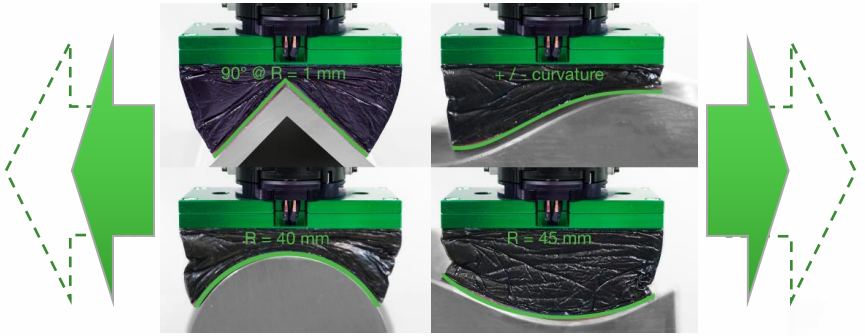
Technology positioning: closing the gap

Fiber Patch Placement technology enables the fully automated lay-up of complex-shaped parts and is compatible with a broad variety of materials.



Automated
Tape Laying

Automated
Fiber Placement



Automated
Fiber Patch Placement

Hand layup and other unoptimized processes

extending capabilities as technology develops

flat / simple-curved parts — *complex to very complex parts* — *highest-complexity parts*

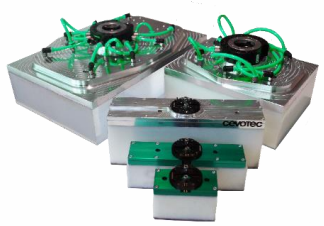
FPP technology enables automation for a new range of complex-shaped parts

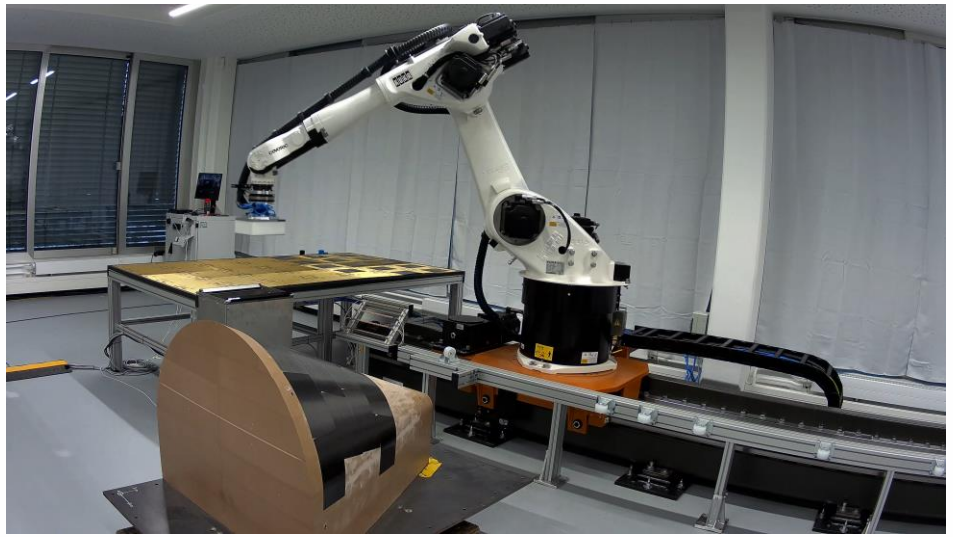
Multi-material lay-up

Closing the gap in lay-up automation

Scaling up for aerostructures (SAMBA Step L)

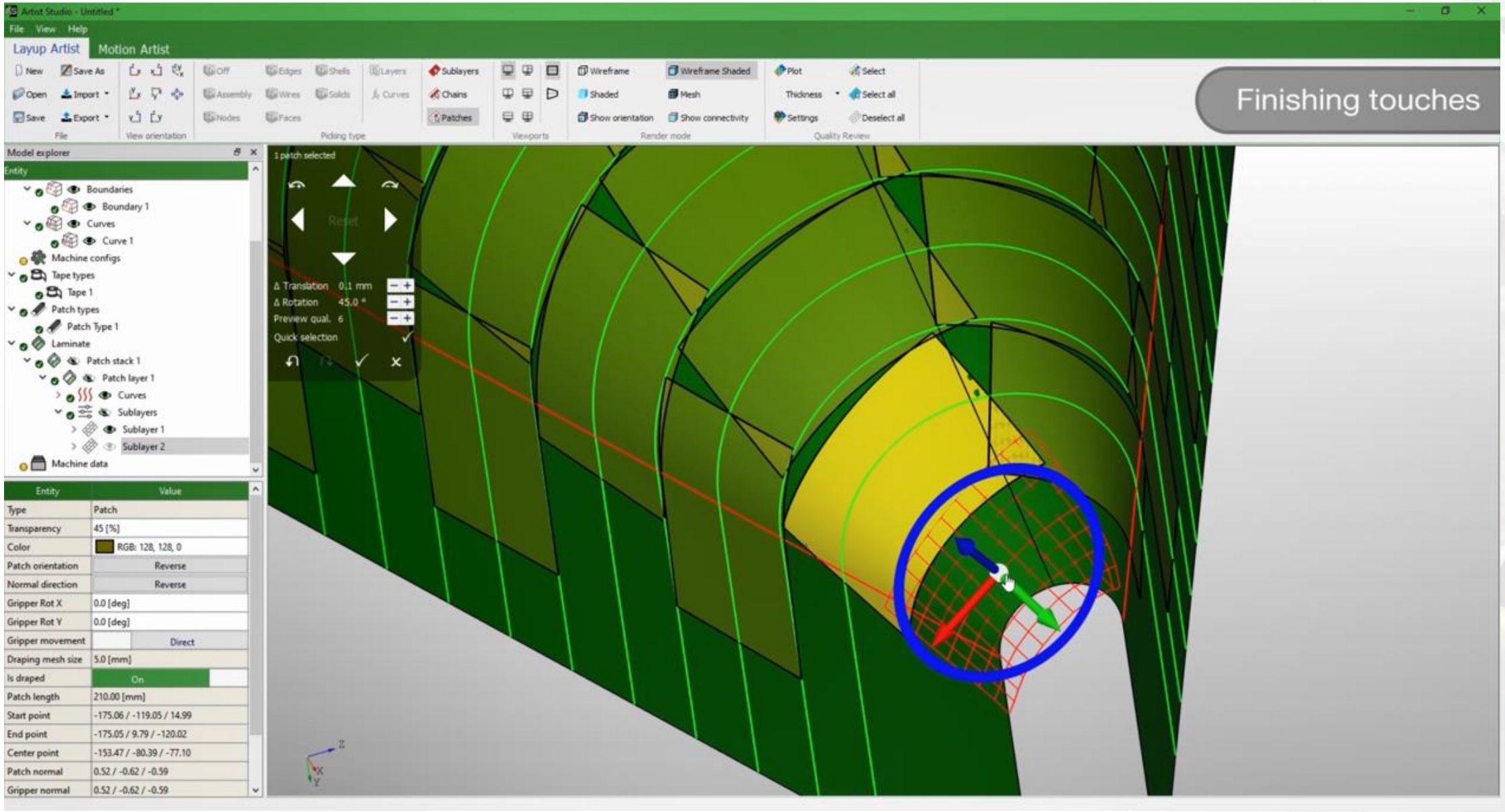
Largest Fiber Patch Placement system to date. Dedicated to application development of aerostructures. Patch sizes: 300 mm x 200 mm, component size: 3 m x 2 m.





- 6-axis robot placement robot on rail
- Patch sizes up to 300 mm x 200 mm
- Incl. rolling-motion placement feature
- Dedicated to application development of next generation aerostructures
- Tool size up to 3 m x 2 m
- Easy offline programming via digital twin
- Fully supported by Artist Studio FPP software, incl. large-ply draping algorithm

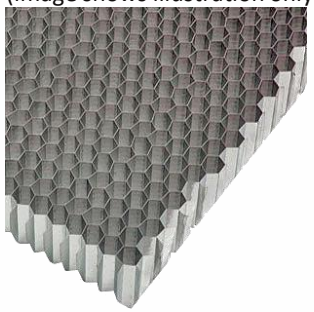
New options available to decrease the cost of next generation aerostructures


Artist Studio - Untitled *
File View Help
Layup Artist
Motion Artist
Finishing touches
Model explorer
Entity
Boundaries
Boundary 1
Curves
Curve 1
Machine configs
Tape types
Tape 1
Patch types
Patch Type 1
Laminate
Patch stack 1
Patch layer 1
Curves
Sublayers
Sublayer 1
Sublayer 2
Machine data
1 patch selected
Reset
Δ Translation 0.1 mm
Δ Rotation 45.0 °
Preview qual. 6
Quick selection
Entity
Value
Type
Patch
Transparency
45 [%]
Color
RGB: 128, 128, 0
Patch orientation
Reverse
Normal direction
Reverse
Gripper Rot X
0.0 [deg]
Gripper Rot Y
0.0 [deg]
Gripper movement
Direct
Draping mesh size
5.0 [mm]
Is draped
On
Patch length
210.00 [mm]
Start point
-175.06 / -119.05 / 14.99
End point
-175.05 / 9.79 / -120.02
Center point
-153.47 / -80.39 / -77.10
Patch normal
0.52 / -0.62 / -0.59
Gripper normal
0.52 / -0.62 / -0.59

Sandwich panel trials with SAMBA Pro system

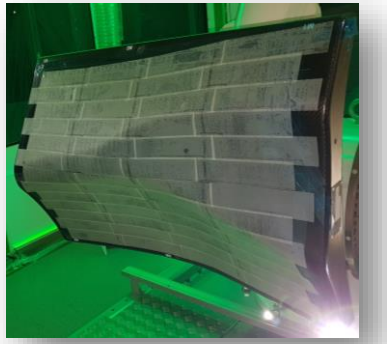
Fully automated lay-up of all fiber materials of component

Honeycomb applied manually
(image shows illustration only)



Autoclave
curing

First skin: GF + CF + adhesive

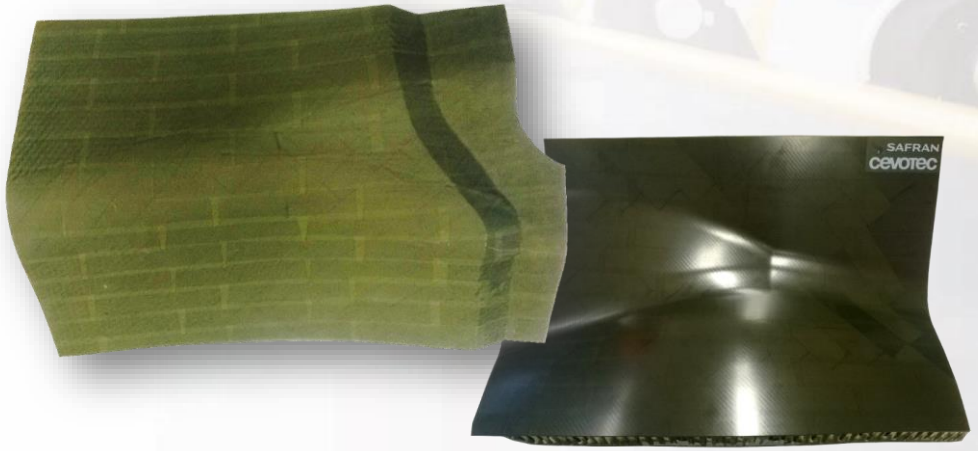


Adhesive and GF layers
patched directly on core

Second skin: CF + GF

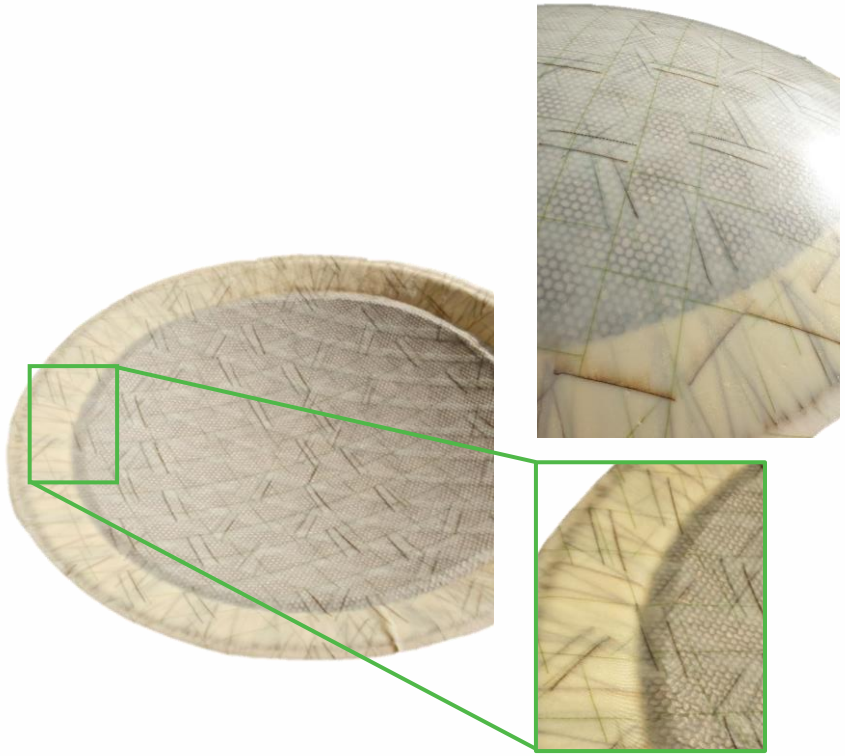
Autoclave
curing

Final cured and trimmed part



FPP glass fiber sandwich structure

Automated placement of glass fiber prepreg into a concave mold



- Plies of glass fiber prepreg precisely placed directly into a concave 3D metal mold
- Manual assembly of honeycomb sandwich core
- Direct placement of second skin onto the sandwich core
- Minimized void content by high compaction pressure
- No bridging effects at chamfered transitions
- Monolithic area placed with the same SAMBA system
- Reduced / no more intermediate debulking steps

Direct 3D placement of glass fiber material. High compaction pressure avoids debulking.

Load-optimized laminate design

Leveraging the advantages of discontinuous patch laminates

Patch laminate architecture for optimized strength

Strength of patch laminates can be optimized by fiber direction and patch overlap length

Considerations

General tensile strength:

discontinuous UD specimen (FPP)
< endless fiber specimen

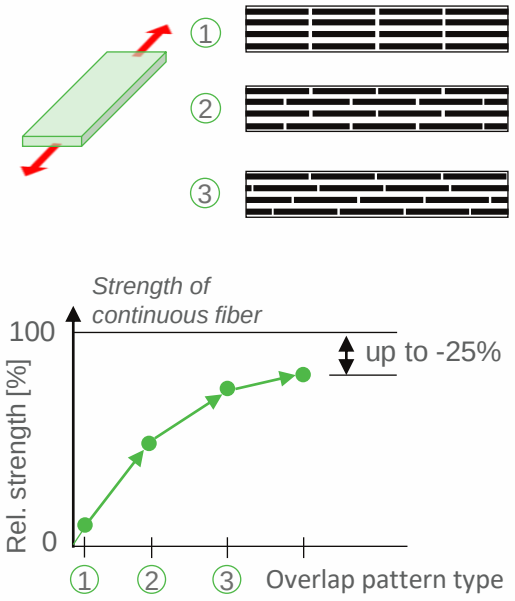
Degrees of FPP design freedom:

- Fiber direction
- Overlap pattern
- Layer order
- Laminate thickness

Objective:

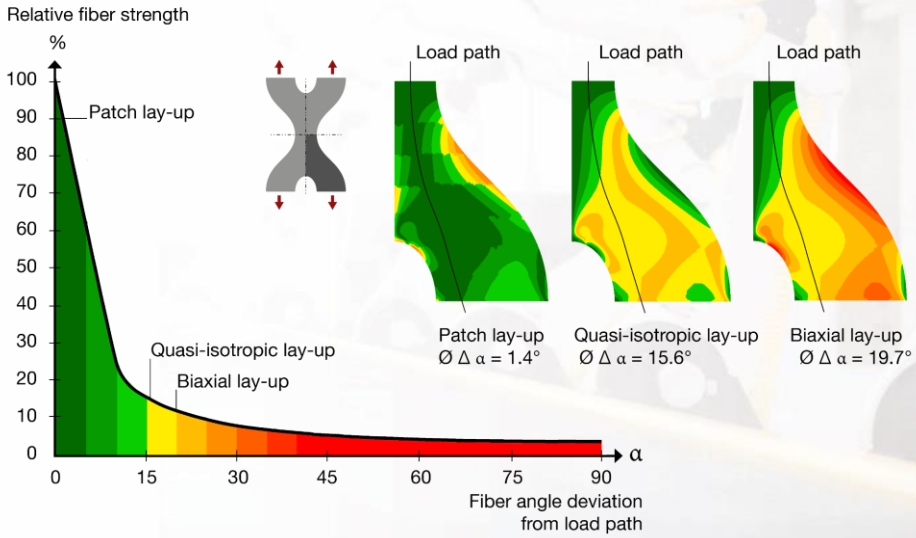
Exploit full fiber potential
(over-compensating discontinuity)

Overlap pattern



Optimized patch overlap pattern increases laminate strength.

Fiber direction



Only 15° deviation between fiber and the tension-based load path leads to 82% reduced laminate strength.

Mechanical investigation of a dogbone specimen (QI vs. FPP)

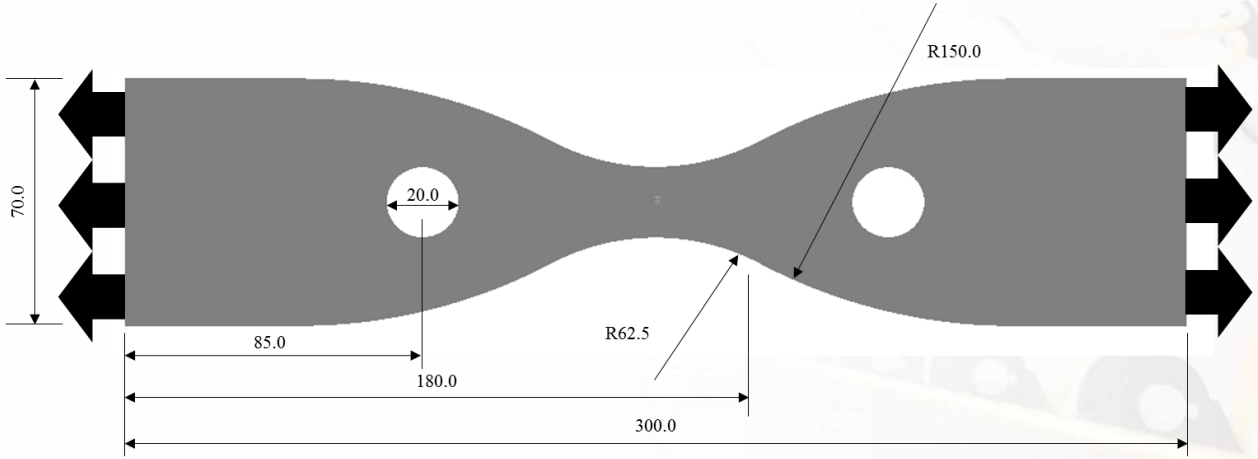
Setup

Goal

Investigation on the mechanical performance of discontinuous fibers based on a dogbone shaped specimen with a curvilinear loadpath

Geometry of specimen

Dogbone specimen with open holes preventing a straight load path between both ends



Dimensions in mm

Loadcase

Tensile loading

Material

Resin: RIM135

Carbon fiber: HTS45

- QI: multiaxial non-crimp fabric (biaxial layers), lay-up $[+45°,-45°,0°,90°]_s$
- FPP: unidirectional tape

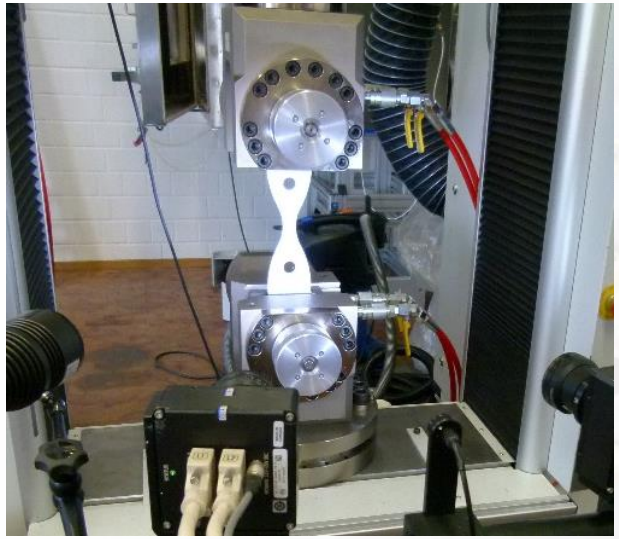
N. Majic, H. Weidinger, F. Michl, K. Drechsler. Experimental and simulation study on the performance of fiber patch placement. 17th European Conference on Composite Materials (ECCM 2016), Munich, 26-30 June 2016, THUR-2_LON_5.05-04.

Manufacturing and experiment

Manufactured specimen

- Preforming with subsequent vacuum-assisted inpregnation process
- 5 specimen for each specimen type

Experimental setup



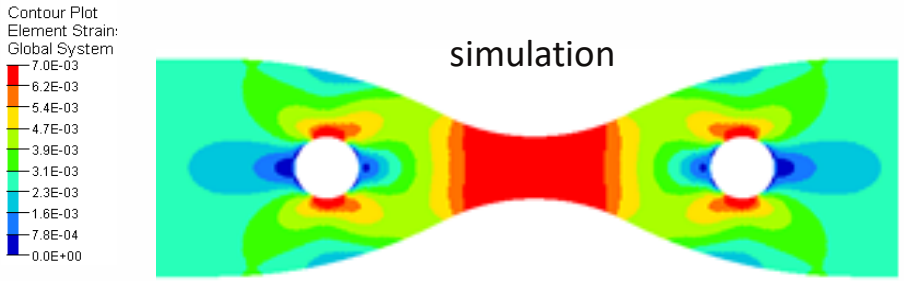
- Test speed: 2 mm/min
- Use of ARAMIS digital image correlation system to measure the strain behaviour

N. Majic, H. Weidinger, F. Michl, K. Drechsler. Experimental and simulation study on the performance of fiber patch placement. 17th European Conference on Composite Materials (ECCM 2016), Munich, 26-30 June 2016, THUR-2_LON_5.05-04.

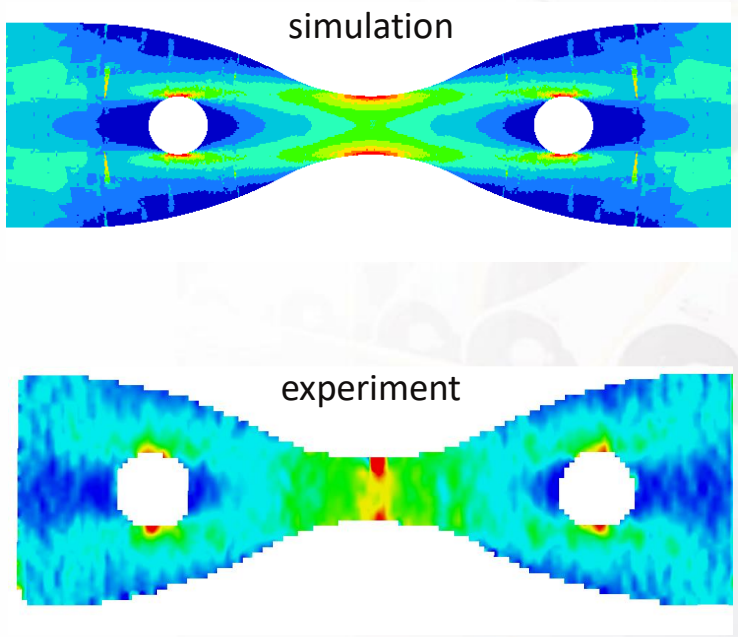
Comparison of strain distribution for a tensile load of 20kN

More homogeneous strain distribution with FPP

QI



FPP



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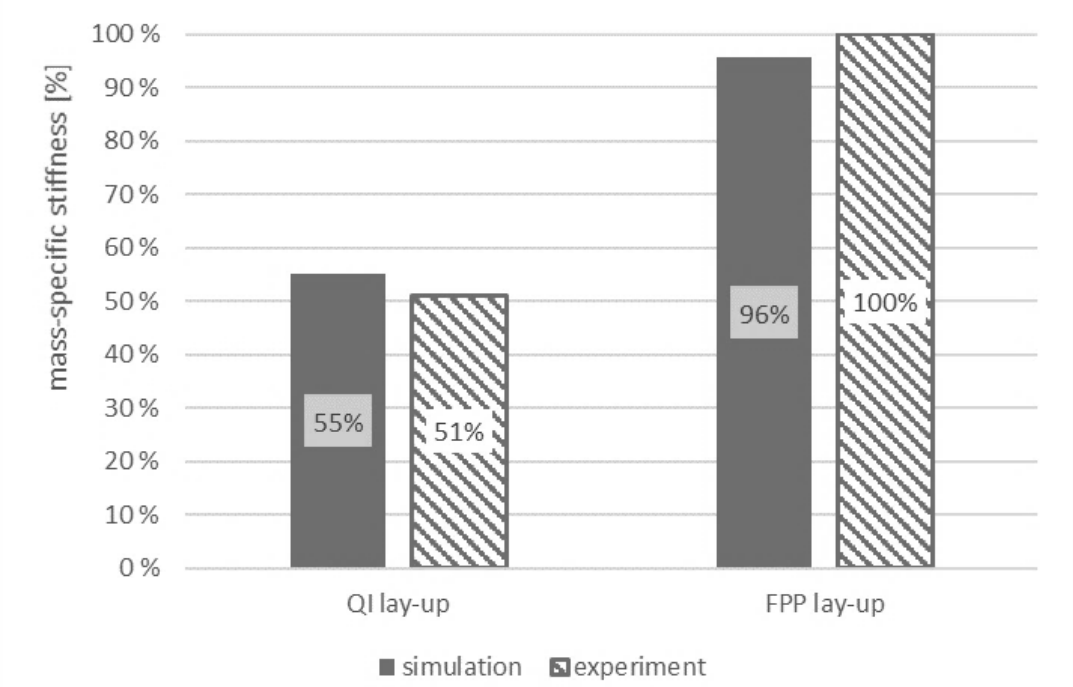
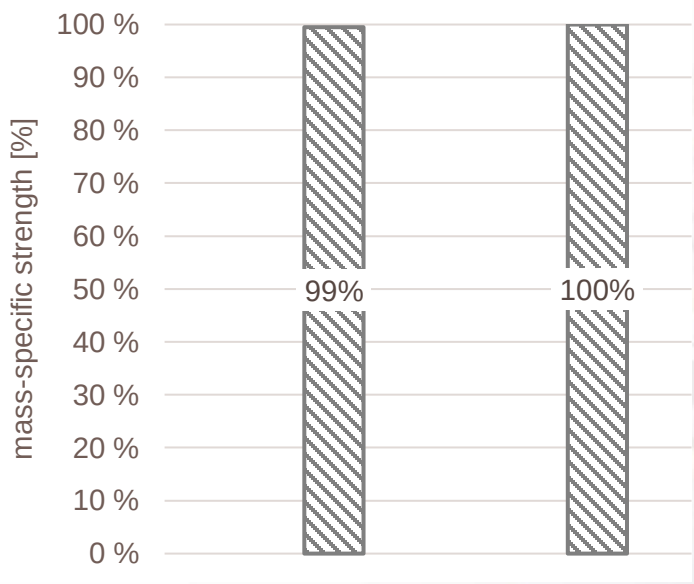
Comparison of mass-specific stiffness and strength

FPP lay-up is increasing the mass-specific stiffness by a factor of 2 compared to QI lay-up.
Mass-specific strength remains at the same level.





N. Majic, H. Weidinger, F. Michl, K. Drechsler. Experimental and simulation study on the performance of fiber patch placement. 17th European Conference on Composite Materials (ECCM 2016), Munich, 26-30 June 2016, THUR-2_LON_5.05-04.

New FPP R&D opportunities at NIAR

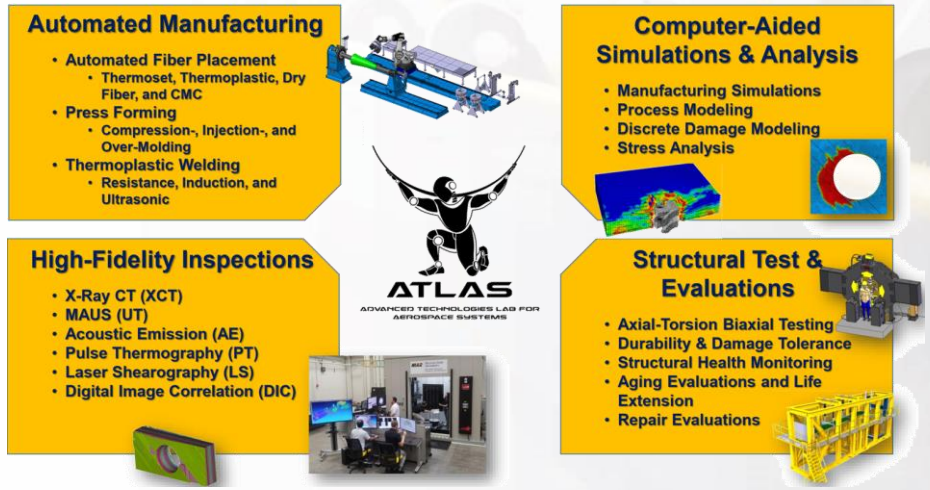
SAMBA Pro FPP system available at NIAR's ATLAS lab in Q4 2021

NIAR's R&D capabilities to extend by FPP lay-up technology

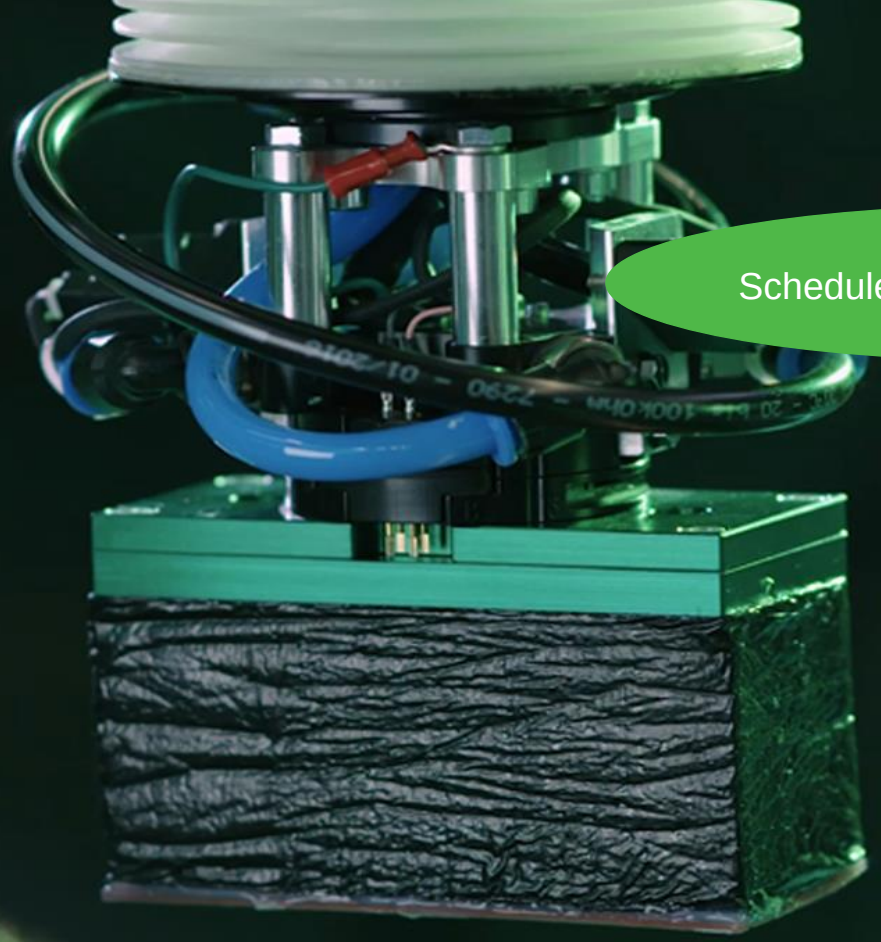
SAMBA Pro FPP system to be installed in Q4 2021. New development options for manufacturers include material testing, application / component developments, simulation & analysis based on FPP technology.

- Material testing and qualification for FPP
  - Testing for automated processability in FPP system
  - Testing of various material property specimen according to aerospace standards
- FPP-based application & component development
  - Digital laminate design & robot programming
  - Demonstrator & prototype development
  - Validation of automated production process
  - Optimizations based on testing & analysis
- Simulation, testing & analysis of FPP components
  - FE-based analysis, optimized for patch laminates
  - FPP process simulations & production run optimizations
  - Economic unit cost analysis for series production settings
  - Testing & analysis of components

SAMBA Pro FPP System



cevotec
milestones in composites



Schedule a 1:1 at our digital booth!

FPP Technology: closing the gap in lay-up automation

- New automation options with FPP, scaled up for aerospace
- One system – multiple materials (carbon, glass, adhesives, etc.)
- New options for designing load-optimized laminates
- FPP R&D opportunities at NIAR

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We enable manufacturers to produce complex composites in high volume and superior quality.

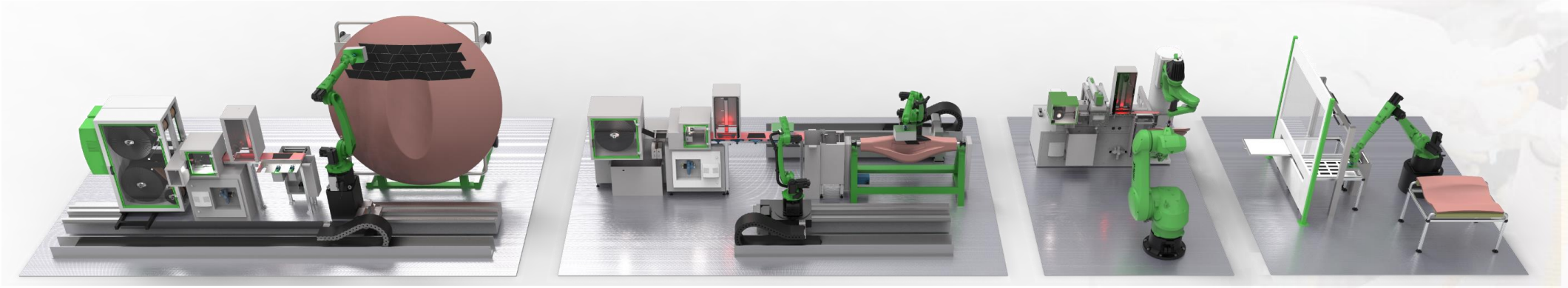
For a lighter, more sustainable future.

Annex

Additional slides for Q&A

SAMBA Series

Additive 3D fiber lay-up systems for multiple fiber materials. Sample configurations for different application scenarios, illustrating the flexibility and scalability of the process.



SAMBA *Multi*

- Up to 4 tapes in parallel feed
- Suitable for carbon, glass, adhesives, etc.
- Long-reach robot for large tools
- **Ideal for multi-material aerostructures**

SAMBA *Scale*

- One material feed with large tape
- High throughput rates
- Multiple placement robots
- **Ideal for volume production**

SAMBA *Pro*

- Fast scara robot
- Robot-based tool manipulator
- **Ideal for batch production**

SAMBA *Step*

- Tray-based material feed
- 6-axis placement robot
- Maximum material flexibility
- **Ideal for prototyping / R&D**

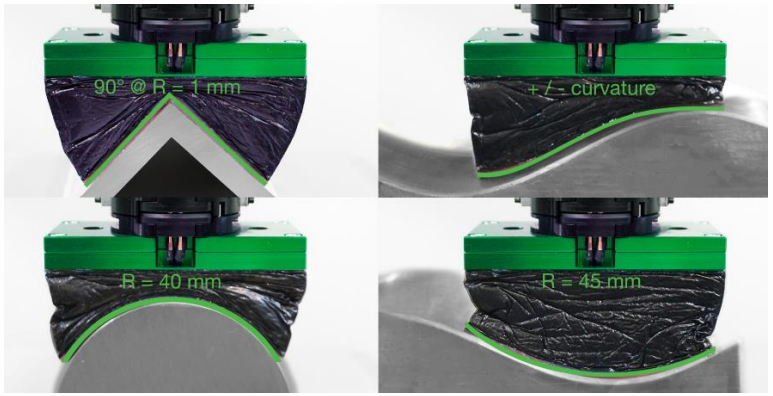
All systems available in dry fiber and thermoset-prepreg configurations

The Patch Gripper: adapting to complexity

Up to 300 mm x 400 mm. Suitable for multi-material placement. Equipped with compaction-force sensor.

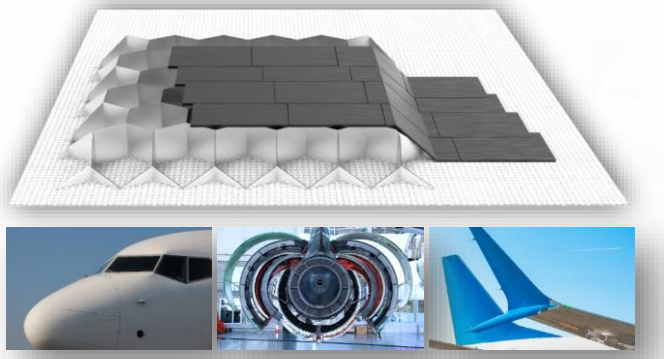
Controlled fiber deposition

on concave & convex surfaces



Placement onto honeycomb cores

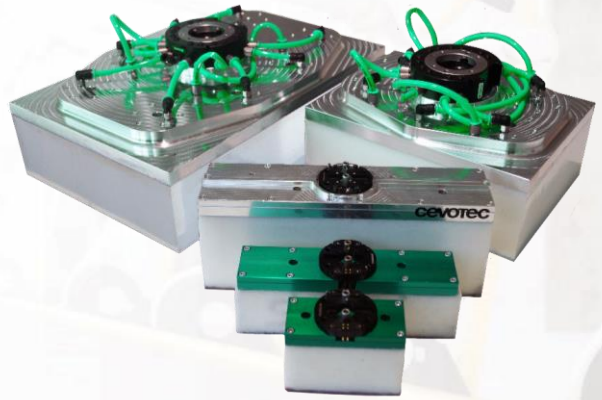
adhesives, glass, carbon, etc.



Examples of sandwich core components in aerospace

Size tailored to application

up to 300 mm x 400 mm



Force-torque sensor for compaction monitoring available

Key for automated fiber placement on complex surfaces

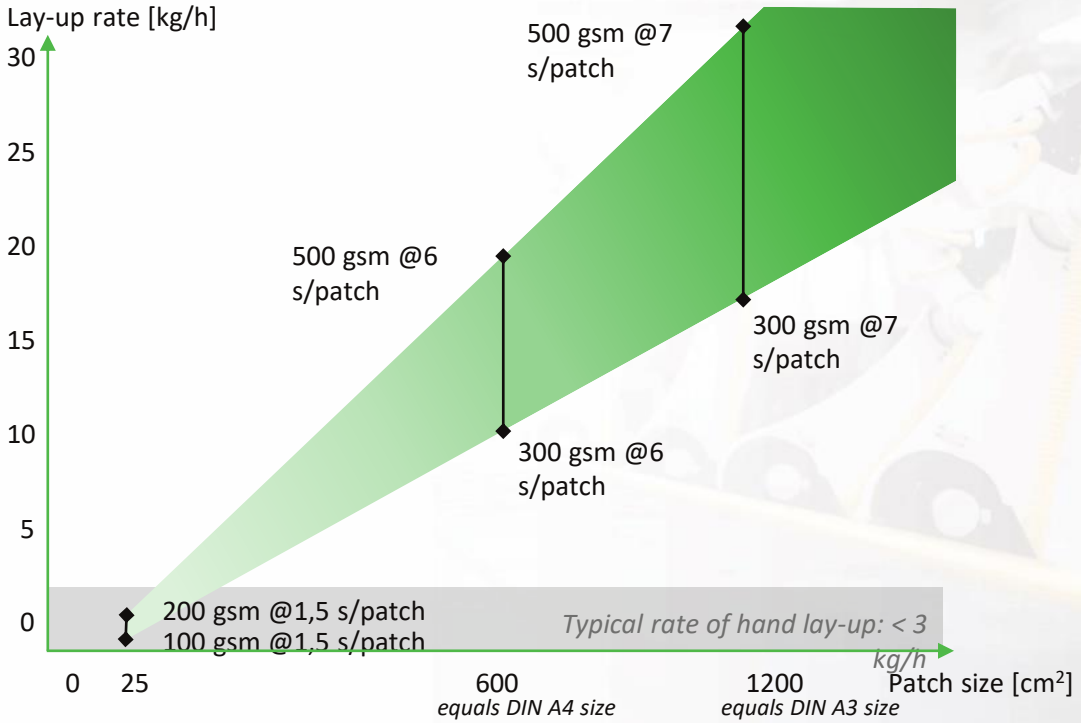
Productivity of FPP lay-up systems

Effective lay-up rates result from process parameters and can be customized to applications.

Lay-up rates of FPP systems

$$\dot{m} = \frac{patch\ length\ *patch\ width\ *areal\ weight\ *no.robots}{patch\ cycle\ time}$$

- SAMBA FPP systems are equipped with placement robots and mold manipulators that best fit your application
- For high throughput requirements, two or more placement robots can be fed by one feeding unit.



Customized to individual applications, FPP systems achieve high lay-up rates

Significantly shortened process for complex composite lay-ups

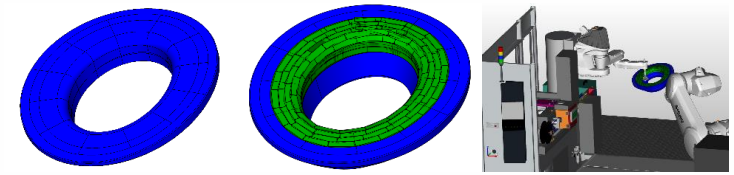
Working with standardized fiber tape cuts process time & cost – no nesting, cutting and kitting required

Development phase

Recurring production

Fiber Patch Placement

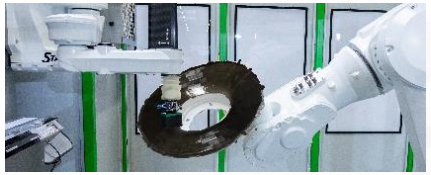
CAD part design → Laminate design → Robot programming



Artist Studio

Fully automated 3D lay-up on mold

<10% scrap



SAMBA Series

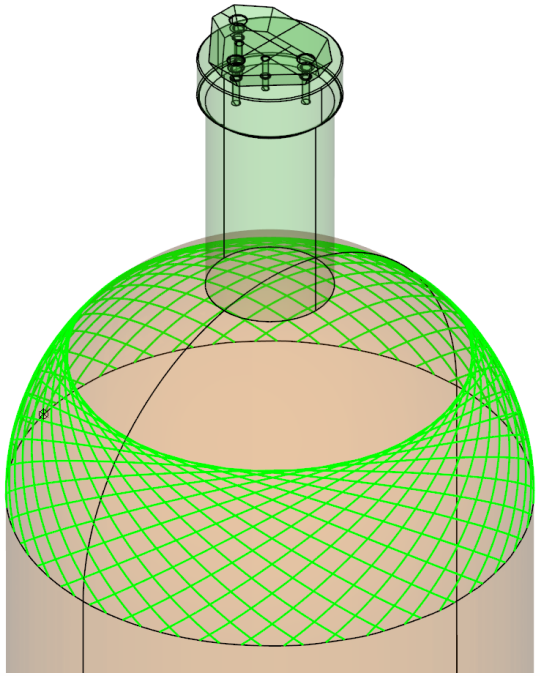
Conventional process

CAD part design → Laminate design → Nesting software → Cutting software → Laser projection software → Cutting on CNC table → Kitting / pre-stacking → Hand lay-up on mold

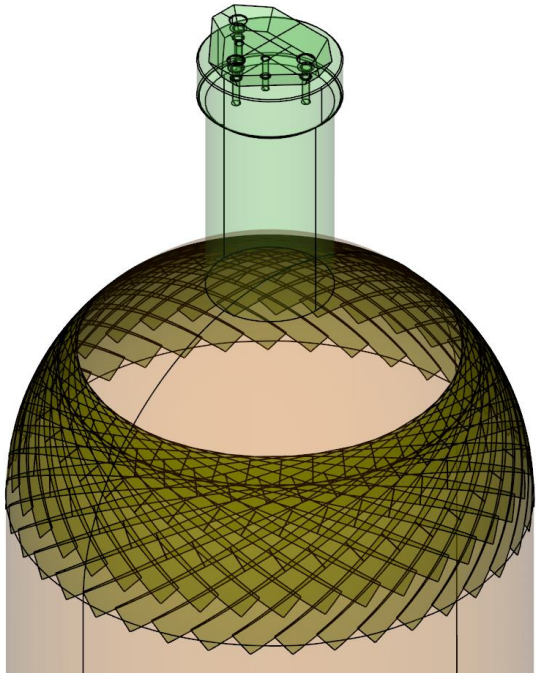
Process time & cost reductions of 20% - 60% with Fiber Patch Placement

Laminates for doylie reinforcements of pressure vessels

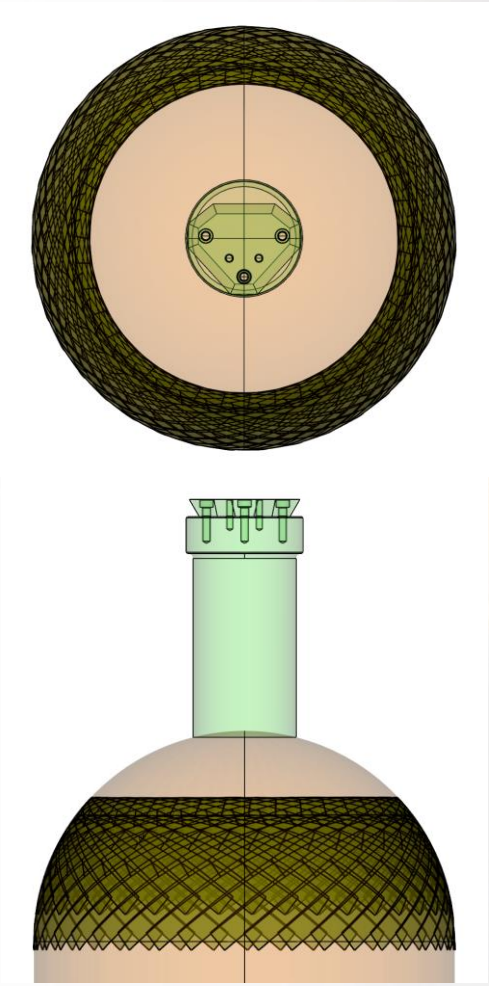
Laminate is created by propagating curves around liner axis according to customer specifications



Curve propagated around liner axis

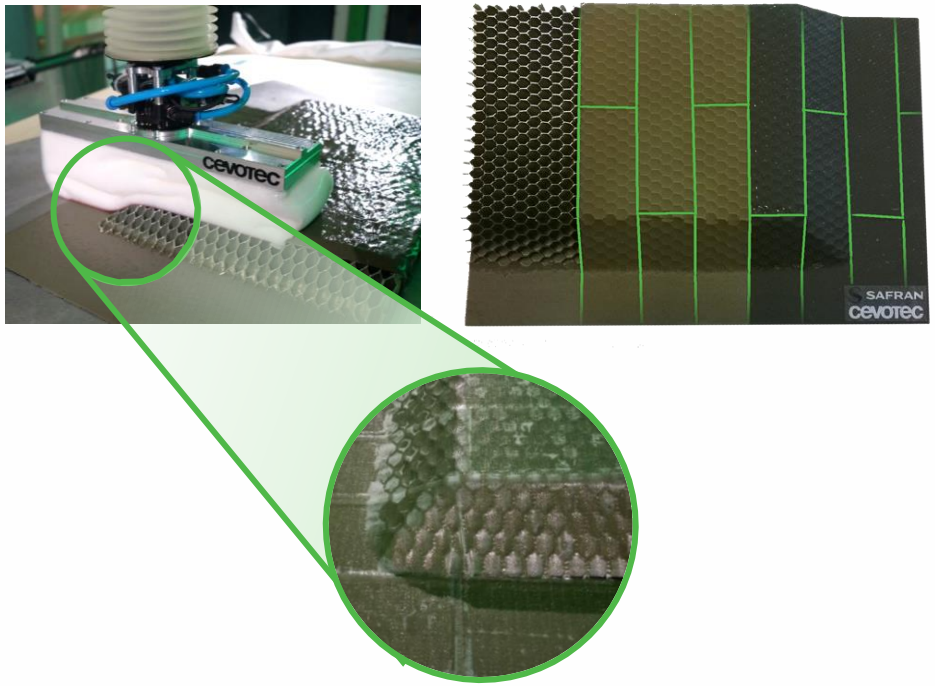


Patches created on propagated curves



Multi-material (ply) placement

Fully automated placement of various technical fiber materials, such as glass fiber prepregs, adhesive prepregs, different carbon fiber prepregs – performed with a single FPP system.



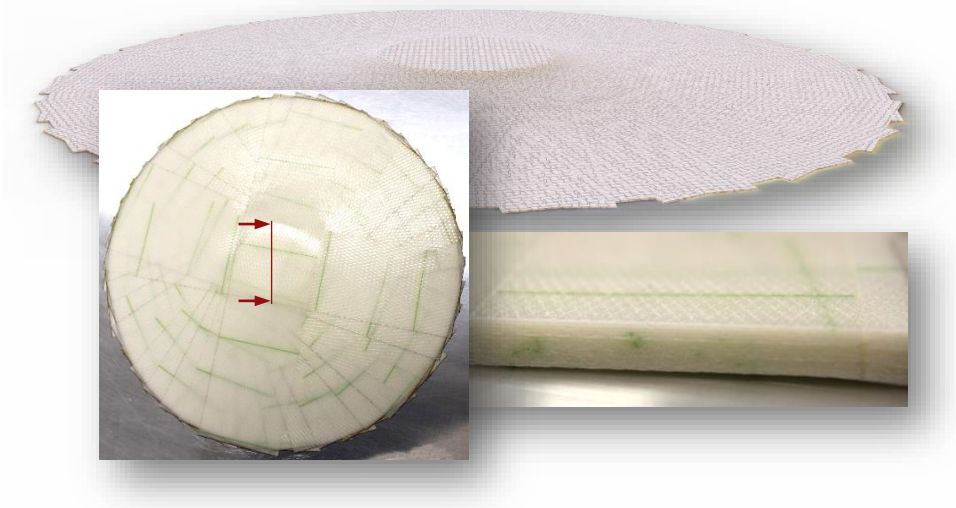
- Larger plies of different fiber prepregs are precisely placed directly onto 3D molds
- Tested materials to date:
  - Carbon fiber prepregs
  - Glass fiber prepregs
  - Adhesive prepregs
- Minimized void content by high compaction pressure
- No bridging effects at chamfered transitions
- Reduced / no more intermediate debulking steps
- 20% - 60% savings in recurring cost and cycle time

Direct 3D placement of multiple materials. High compaction pressure avoids debulking.

Controlled compaction pressure during fiber placement

Eliminating intermediate debulking steps through controlled fiber placement with FPP

Test specimen: cevoPad

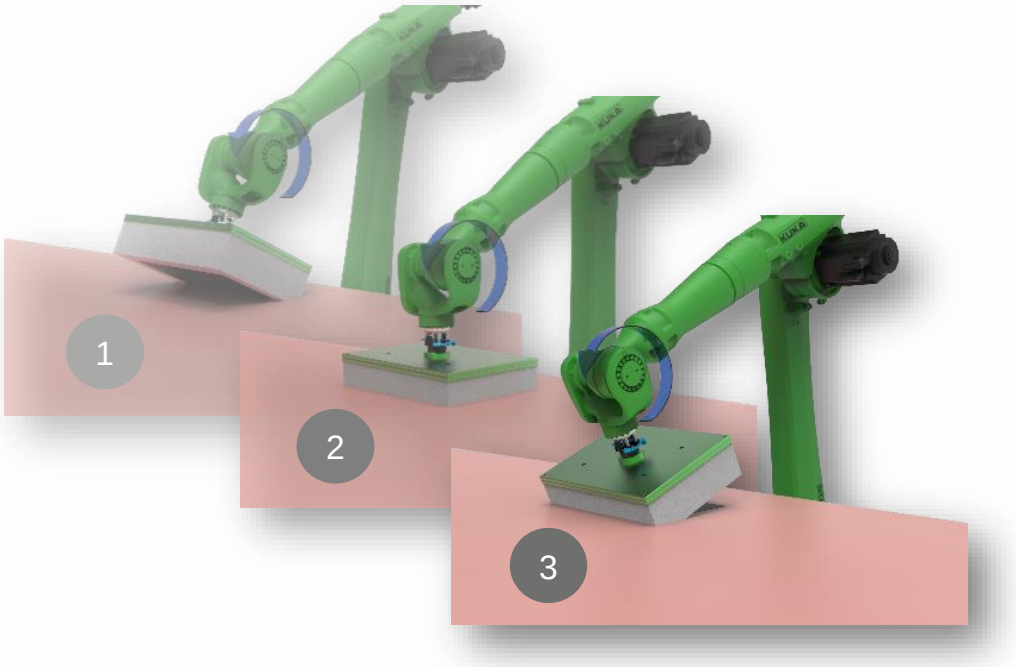


- Glass fiber patches concentrically around a central point
- 24 plies
- Patch size: 45 mm x 200 mm
- Compaction pressure during placement: 17,0 kPa
- No debulking during / after lay-up
- Autoclave curing according to material datasheet

Test result: homogeneous sample, porosity content < 1%, also in overlap areas

Actuated robot movements to enable special placement features

Working with a 6-axis placement robot enables the draping larger patches on curved surfaces as well as the placement with high compaction pressures to avoid air enclosures.

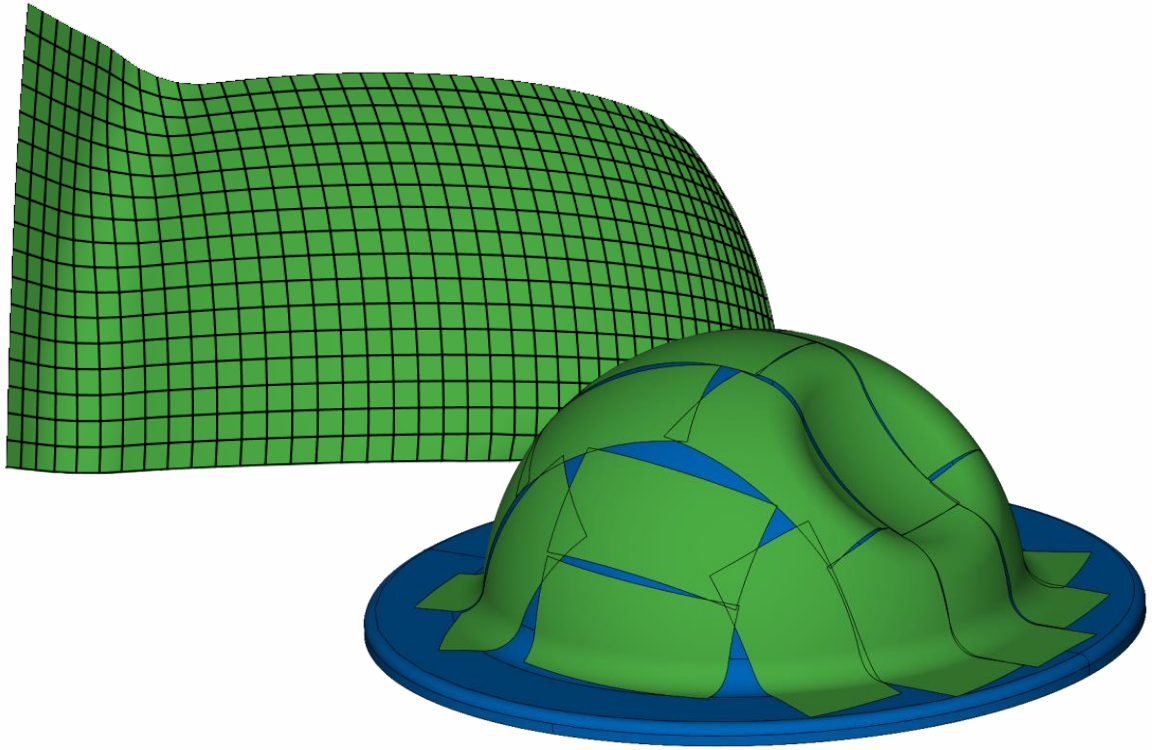


- Using available degrees of freedom for actuated movements of the placement robot
- Preventing air bubbles and enclosures
- Reducing or eliminating intermediate debulking steps
- Draping larger patches on curvatures
- Preventing disorientation of fibers or wrinkles

6-axis placement robots with special features for high-performance aerostructures

New draping algorithm for large patches and plies

To support the design of laminates with scaled patch sizes, the FPP software ARTIST STUDIO features a draping algorithm to apply larger patch precisely on curved surfaces.

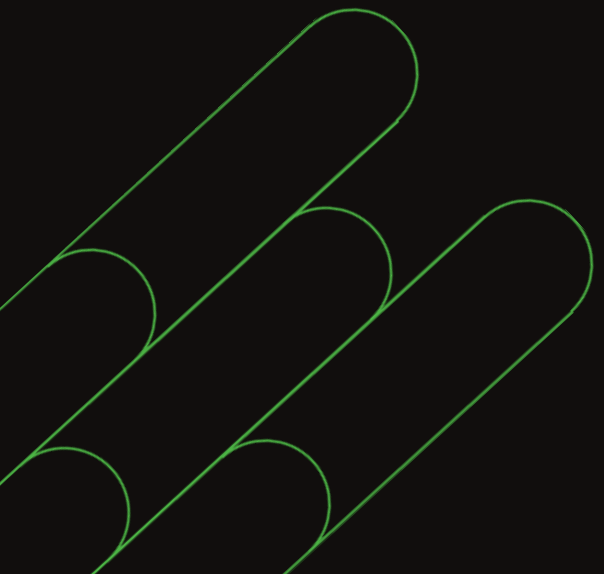


- Kinematic draping algorithm for laminates with large patches on curved surfaces
- Enables precise modeling and manipulation of gaps & overlaps of individual patches, even within one layer
- Supports placement accuracy of large-patch placement +/- 1 mm
- Fully integrated in ARTIST STUDIO software

Scaled FPP concept supported by draping algorithm for precise modeling of large patches

cevotec

milestones in composites



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