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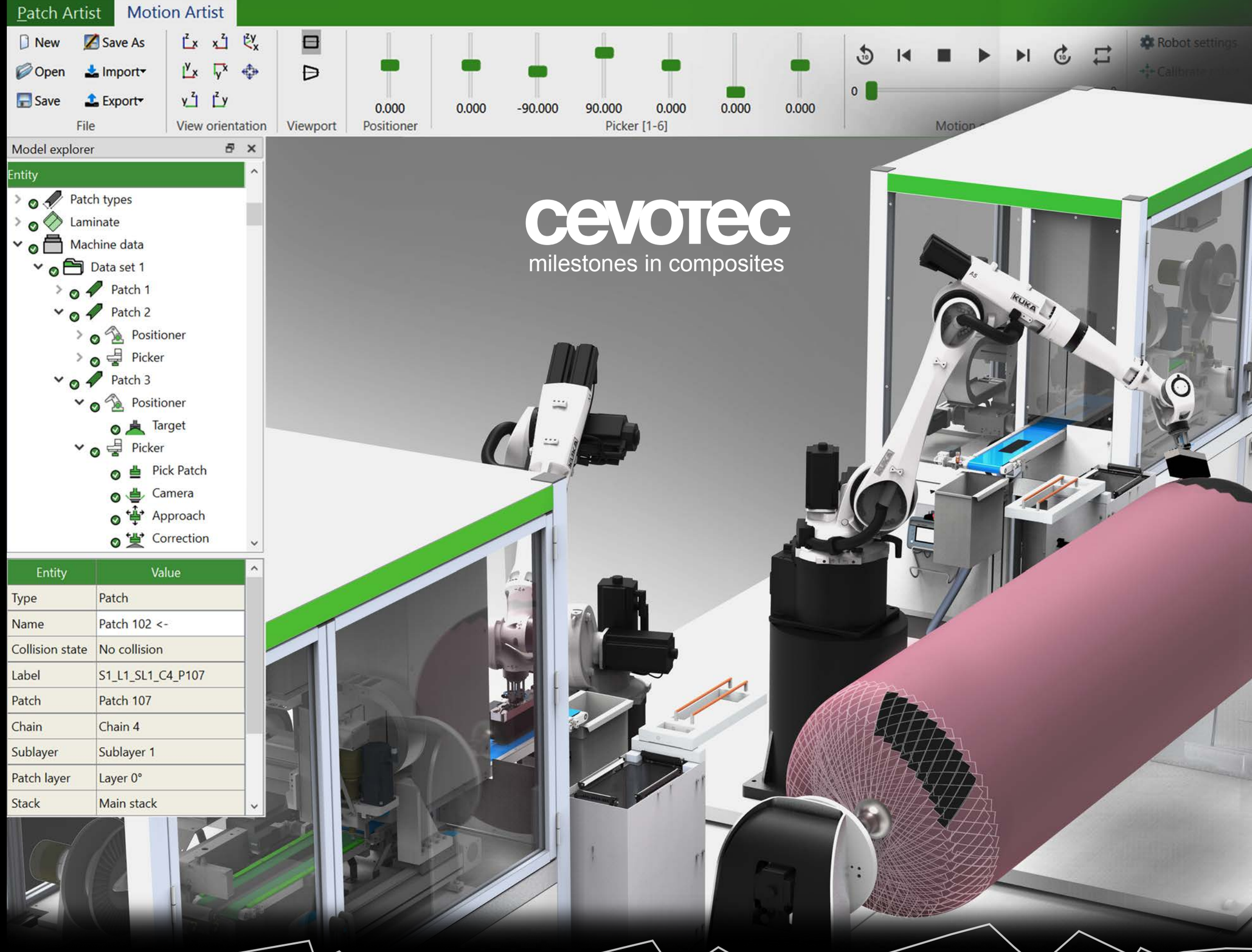
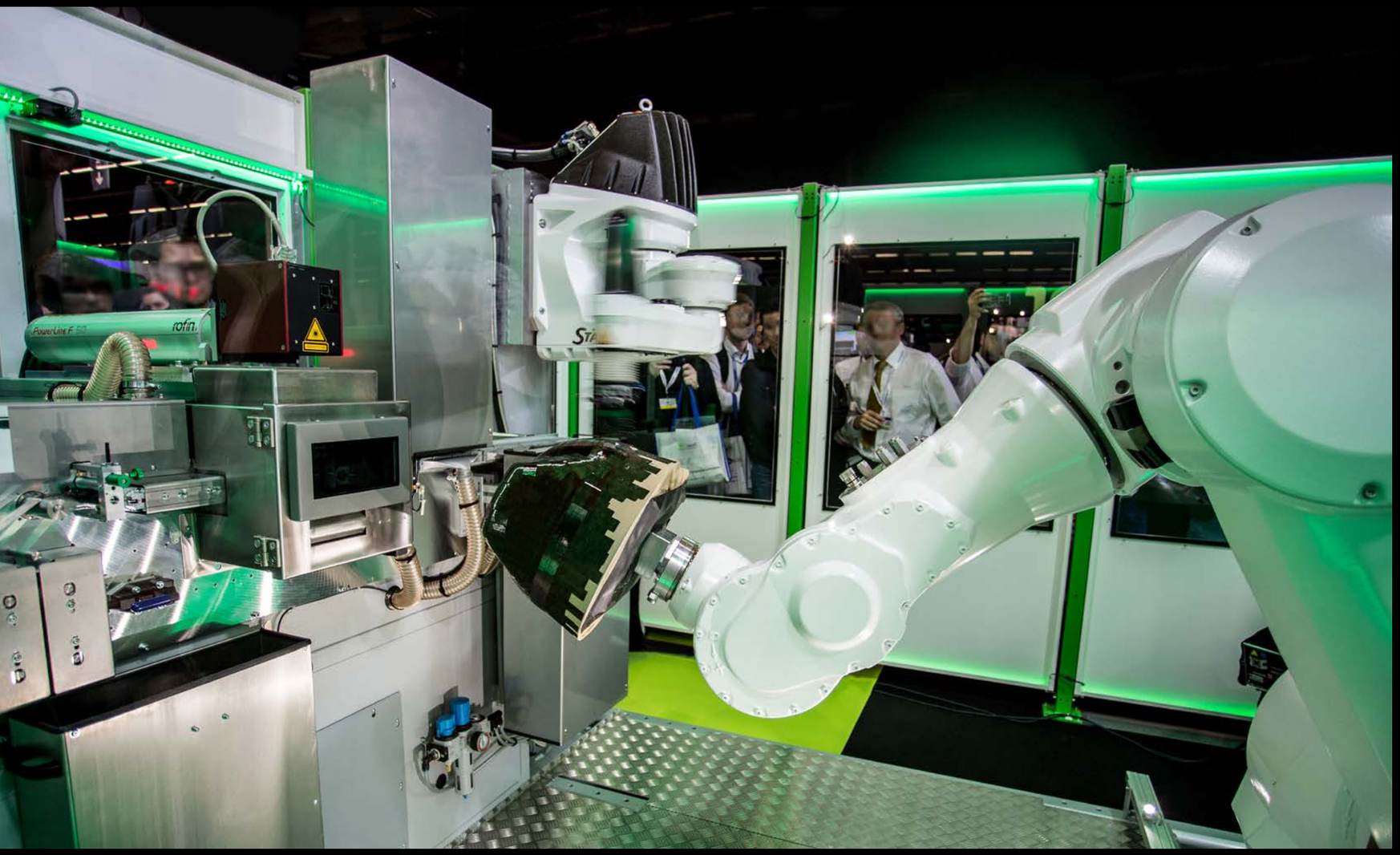


CEVOTEC

Fiber Patch Placement



Fiber Patch Placement is a robot-based, direct-3D placement technology for high-performance composites.

- Digitized, automated process chain
- 100 % in-process raw material inspection
- Multi-material lay-up capability (carbon, glass, adhesives, etc.)
- 20 % - 60 % cost & time savings

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

For a lighter, more sustainable future.

Fiber Patch Placement (FPP) enables a new combination of productivity, flexibility and costs. It offers efficiency even at low volumes through flexible and scalable automation. Adapted to the size and complexity of a component, the technology works additively in discrete increments, called fiber patches. This enables automation for complex 3D shapes, multi-material laminates and locally load-adjusted fiber designs, resulting in efficient lightweight solutions with a remarkably improved buy-to-fly ratio. The ability to handle multiple materials like carbon fiber, glass fiber and adhesives opens up a new range for automated composite production, in particular for complex aerostructures.

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Empowering key industries with lay-up automation

Composite tanks

The new benchmark for COPV:
15% lighter tanks by using dome reinforcements.

Better performance

Lower cost

Scalable process

Aerospace

Automation for next-generation aerostructures and complex, multi-material composites.

Current aircraft programs: rate expansion

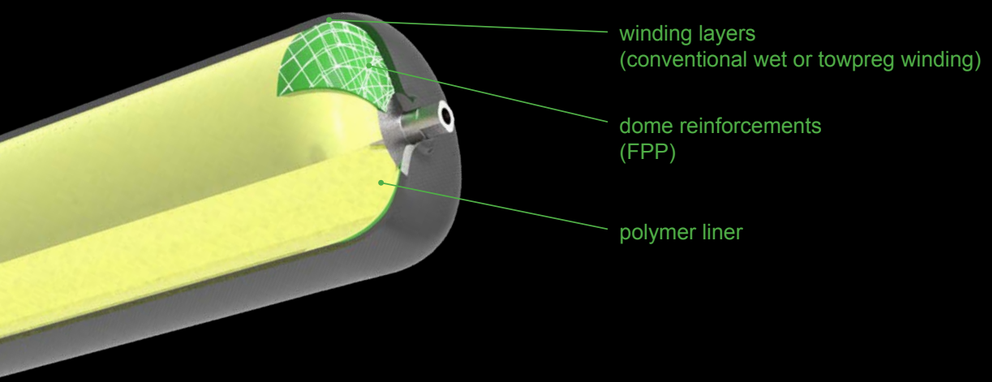
Automate legacy parts
Process multiple materials
Improve first-pass quality

Future aircraft programs: affordability

Realize efficient designs
Improve buy-to-fly ratio
Achieve cost & ESG targets

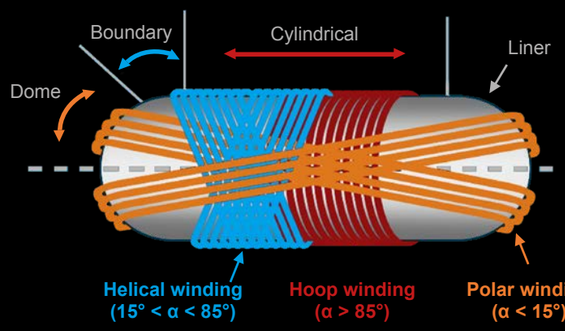
15 % lighter composite tanks by using dome reinforcements

Composite tanks are the key to enable safe and efficient storage of gases for mobility applications, in particular for new hydrogen-fueled mobility supporting the global "net zero" objective. For type 4 composite tanks, the fibers, resin and fabrication amount to more than 50 % of total production cost. Introducing tailored dome reinforcements to the tank design offers an opportunity to reduce the weight by approximately 15 % while maintaining equivalent mechanical properties.



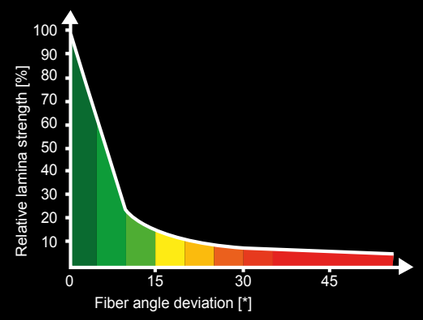
Dome reinforcements offer the opportunity to reduce weight by 15 % and increase the storage volume for a given outer diameter.

Background: Three typical winding patterns of composite tanks



The performance of carbon fibers depend on their alignment to the prevailing stresses in a component. Filament-wound tanks feature three distinct winding patterns: hoop winding (α > 85°), helical winding (15° < α < 85°) and polar winding (α < 15°). While helical layers optimally support the stresses in the curved dome area, they do not live up to their potential in the hoop area due to their fiber orientation.

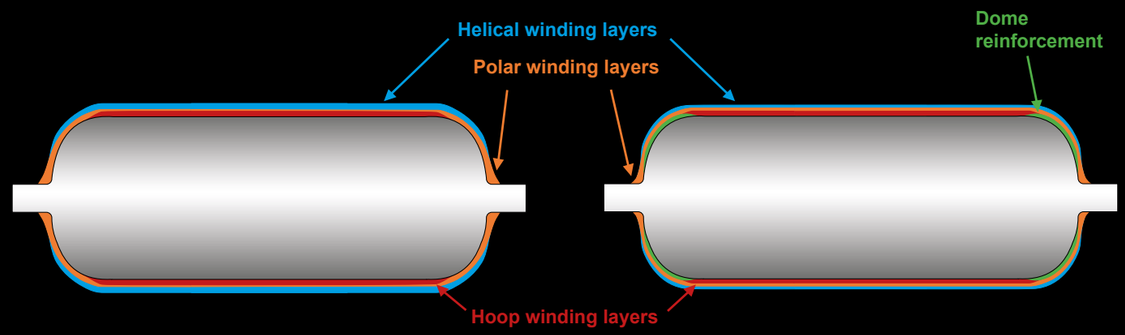
Angle deviation impacts performance



Example: 15° deviation between fiber orientation and load results in approx. 80 % reduced fiber strength.

The concept

Certain helical layers are replaced by local dome reinforcements. This reduces the amount of inefficient fibers in the hoop section, translating into less material required to achieve equivalent mechanical properties. It also enables an increase of the inner tank diameter as the thickness of the hoop area decreases.



Dome reinforcements replace certain helical layers in a winding laminate

DoE Fuel Cell Technologies Office Records

The dome reinforcement concept was published by the US Department of Energy (DoE) in 2013. The DoE concluded that local dome reinforcements ("doilies") offer a solid opportunity to reduce carbon fiber usage for composite tanks by 15 %. However, two years later the DoE discontinued research on doilies because at that time, no industrial technology was available to efficiently produce the reinforcements.

FPP for composite tank reinforcements

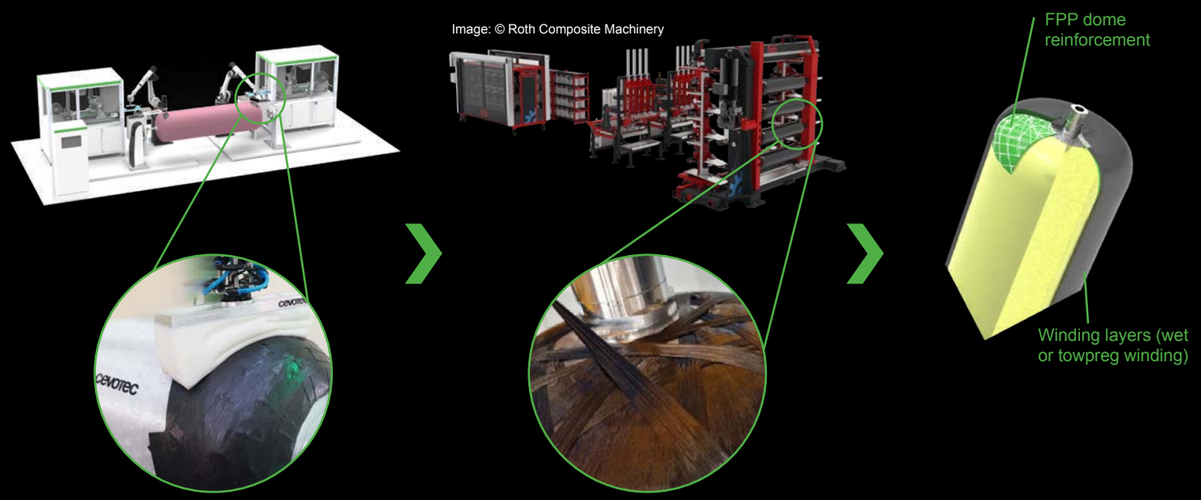
Based on the latest developments of FPP technology, Cevotec now offers dedicated equipment for dome reinforcements in industrial processes, empowering tank manufacturers to fully exploit the benefits of this concept and build lighter, more efficient composite tanks.

SAMBA Pro PV-1: Integrating dome reinforcements in industrial productions

Cevotec's Fiber Patch Placement (FPP) is the first technology able to place dome reinforcements directly onto the liner without additional manual manufacturing steps. This can be combined with established wet or towpreg winding equipment.

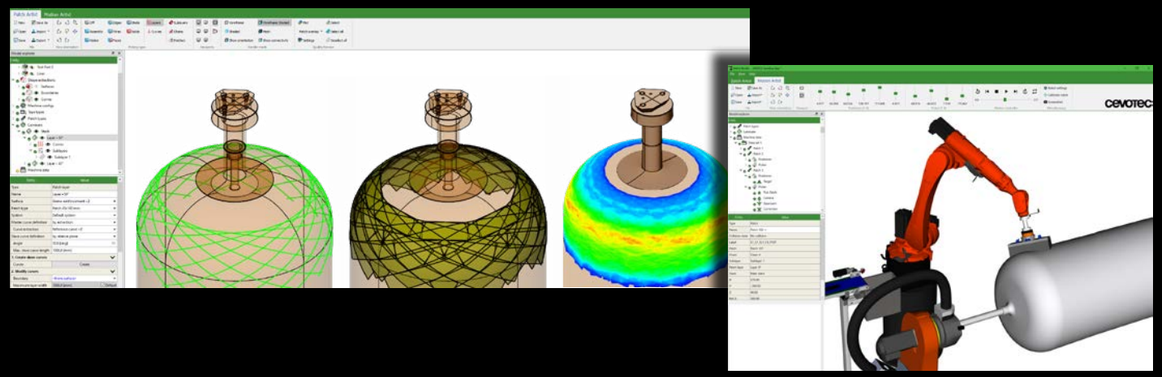
Dome reinforcements enable manufacturers to maintain a tank´s mechanical properties while reducing net fiber consumption by approximately 15 % and similarly reducing tank weight. Reinforced tanks also have an improved CO_2 footprint and can feature more storage volume given a fixed outer diameter.

1 Automated liner reinforcement + **2 Filament winding (less material)** = **3 Lighter composite tank**



Dedicated features in ARTIST STUDIO

for generating the design and production program of dome reinforcements

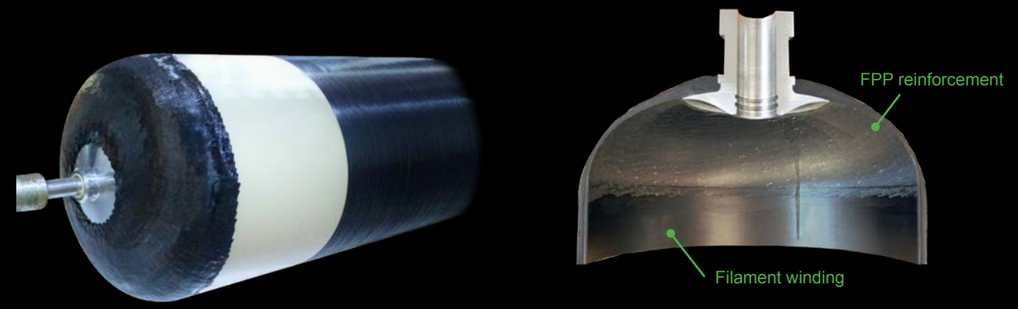


Full-scale industrial demonstrator

To underpin our approach, we developed and tested an optimized, full-scale reinforced type 4 tank in a joint project with industry partners. The project comprised all aspects from the laminate design, simulation and optimization to the actual production and burst testing of reinforced 300 bar composite tanks according to BS EN 12245 (3.0x burst safety factor).

The results are noteworthy: After optimization of the composite laminate with reinforcements, 108% of the required burst pressure was achieved with net 15 % material savings.

In addition, the reduced amount of material offers the opportunity to increase in the inner diameter and storage capacity of the tank while maintaining the same outer dimensions. The storage efficiency, setting the mass of the compressed gas in relation to the total mass of the storage system, could be improved by 17 % from 5.2 % to 6.1 %.



Your advantages with FPP:

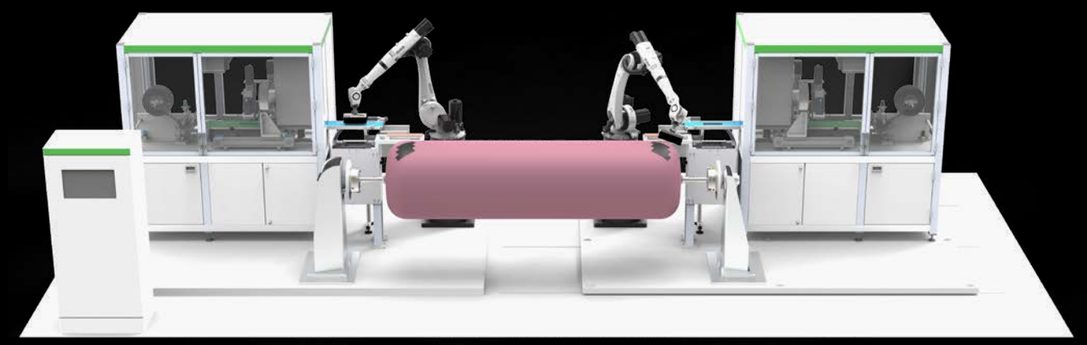
Better tank performance
15 % lighter and up to
20 % better storage efficiency

Lower cost
15 % less material for
equivalent performance

Scalable process
Easy workflow integration,
no manual post-processing

SAMBA Pro PV-1

Dedicated FPP lay-up equipment for the reinforcement of composite tank domes



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Expanding lay-up automation for aerospace composites

The production of composite parts, especially in the aerospace industry, often involves many manual operations, resulting in low material lay-up rates, high quality assurance effort and high component costs. Automation solutions are thus needed to meet future requirements for productivity and quality. Fiber Patch Placement enables the automated lay-up of carbon fibers, glass fibers, adhesive films and other technical fibers on complex 3D geometries. Manufacturers use FPP technology, processing multiple materials such as carbon fiber, glass fiber and adhesives, to produce aerostructures and other high-performance components in a quality-controlled, fully automated process. This enables them to realize cost and takt time savings of 20 % - 60 % when switching from conventional processes to Fiber Patch Placement.

Robotic honeycomb placement
precisely places 3D core material directly on the laminate with a dedicated gripper.

Form-flexible patch grippers
support the automated and precise fiber lay-up for monolithic and sandwich components.

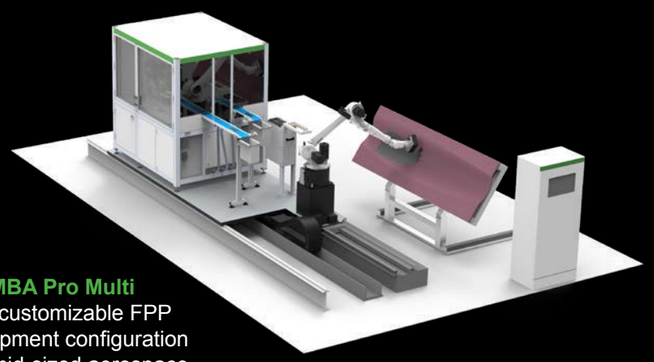
Fuselage
- Radome
- Window frames
- Antenna fairings
- Belly fairings
- Landing gear doors
- Cabin liners

Wings
- Winglets
- Spoilers
- Ailerons
- Flaps
- Slats

Empennage
- Stabilizer
- Rudder
- Elevator
- Dorsal fin
- Aerodynamic fairings

Exemplary overview of suitable aerospace applications

Engines
- Nacelles
- Pylon fairings
- Air duct (e. g. engine heat exchangers, HVAC)



SAMBA Pro Multi
is a customizable FPP equipment configuration for mid-sized aerospace components, capable of processing multiple materials in parallel.

Advanced rolling motion placement
features multiple angles of compaction and enables the placement of larger patches on highly curved tools.

Your advantages with FPP:

Automation for multiple materials
Lay-up capability for many materials. Reduced debulking. Empowers rate increases of legacy parts.

3D precision lay-up
Complex 3D lay-up capabilities. 100% in-process inspection. Supports next-generation designs and improves buy-to-fly ratio.

Efficient design & programming
Comprehensive software with dedicated FPP design features. Integrates into the existing aerospace design workflows.

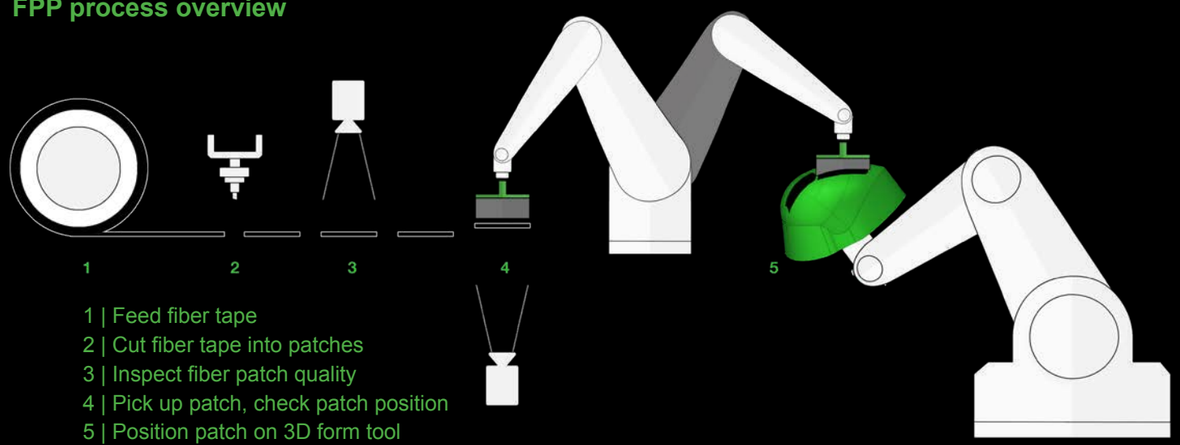
Achieving cost & ESG targets
20 % - 60 % cost reduction. Improved work conditions. Less scrap. Improves sustainability and enables “net zero” for aerospace.

How it works: Fiber Patch Placement technology

The technology

Fiber Patch Placement is the additive manufacturing technology for the automated production of geometrically complex fiber composites. It enables a new degree of freedom in automated fiber placement and is compatible with many materials such as various carbon fiber prepreg systems, glass fiber prepregs, adhesive prepregs, and also dry fibers. Defined patches are automatically cut from a tape and precisely placed by two robots and a flexible patch gripper. The patch size is adjusted to the dimensions and complexity of your component and can be scaled up to A4 format (200 mm x 300 mm). Because the process is implemented as a series of individually-controlled patch placements, FPP technology enables a superior level of process control for the entire laminate lay-up cycle.

FPP process overview



1 | Feed fiber tape
2 | Cut fiber tape into patches
3 | Inspect fiber patch quality
4 | Pick up patch, check patch position
5 | Position patch on 3D form tool

The workflow

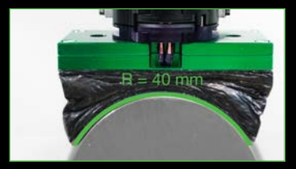
4 simple steps to a complex 3D composite part

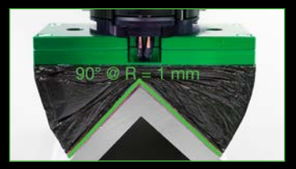
- Design patch laminate in ARTIST STUDIO
- Generate robot program in ARTIST STUDIO
- Set-up SAMBA system, load materials and tool
- Press “Start” on SAMBA system for automated 3D lay-up

cevo**Gripper**

The key to a fast and automated lay-up process for complex shapes is our form-flexible patch gripper. The gripper is available in tailored sizes to perfectly match your product.

The gripper adapts to the most complex surfaces. Even across 90° angles and biaxially curved surfaces, patches are placed precisely and without negative draping effects.





- Sizes from 45 mm x 95 mm up to 240 mm x 360 mm
- Automated quick-mount for gripper change on-the-fly
- Anodized, precisely machined aluminum baseplates
- High mass-flow vacuum stream, powered by pressured air
- Customized foam body for specific compaction requirements
- Optional heating for dry fiber tape with binder

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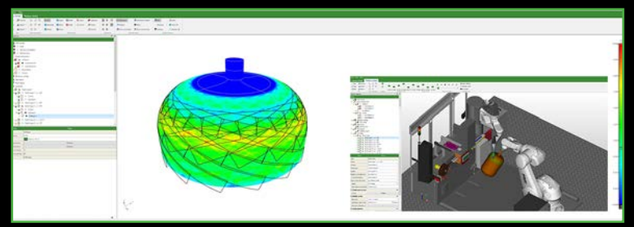
The Cevotec portfolio: Patch-based production technology

SAMBA Series – automated FPP production systems

· Production platform for automated, complex 3D fiber lay-ups
· Multi-material lay-up capabilities (carbon, glass, adhesives, etc.)
· Customizable robot and machine configurations
· Adjusted to component size and complexity



ARTIST STUDIO – FPP-specific software platform

· Virtual product development platform for FPP technology
· Efficient laminate design with FPP-specific lay-up features (CAD)
· Automated offline robot programming, process simulation and collision detection (CAM)
· Interface module for commercial FEA software (CAE)
· Full digital twin of matching SAMBA system

cevoLab – the FPP Competence Center

· Individual application development
· Machine customizations
· FE-simulation and laminate optimization
· Prototyping and small-scale series production
· Tailored patch grippers

cevoServices – support, training, maintenance

· Comprehensive development and production support
· Training and consulting for engineering teams
· Regular maintenance of production systems for highest availability
· Fast repair service, also with remote access option
· Patch gripper refurbishment

Develop your application exclusively in our cevoLab to explore Fiber Patch Placement and adapt it to your specific requirements!

cevotec

SAMBA Series: Modular 3D fiber lay-up systems

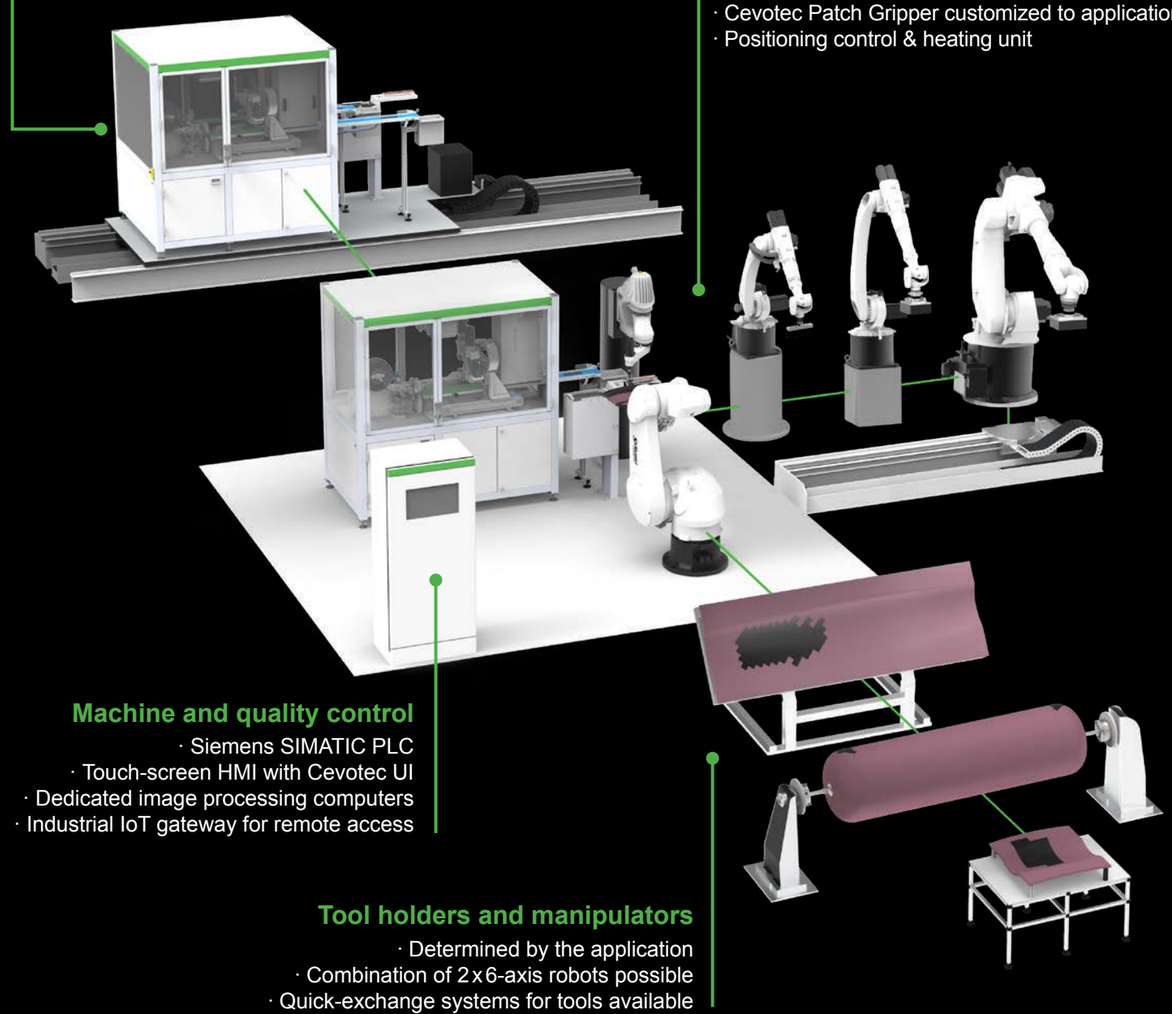
Fiber Patch Placement is a very scalable and flexible technology. We customize SAMBA systems to your requirements based on four key modules. These modules include solutions for material feeding and cutting, placement, mold manipulation and machine control.

Feeding & cutting units

· Compatible with wide range of materials
· Multiple, parallel material feeds possible
· Customizable tape widths
· Ultrasonic cutting unit by GFM
· High-precision patch quality control

Placement units

· Range of placement robots and rails available
· Cevotec Patch Gripper customized to application
· Positioning control & heating unit



Machine and quality control

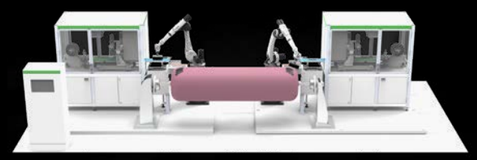
· Siemens SIMATIC PLC
· Touch-screen HMI with Cevotec UI
· Dedicated image processing computers
· Industrial IoT gateway for remote access

Tool holders and manipulators

· Determined by the application
· Combination of 2 x 6-axis robots possible
· Quick-exchange systems for tools available

Sample configuration for composite tanks

SAMBA Pro PV-1



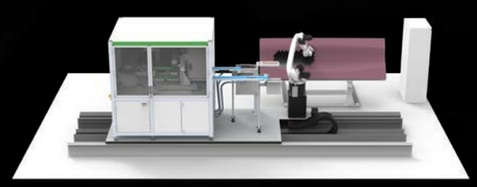
· 2 x feeding and cutting units and 2 x 6-axis placement robots for simultaneous patching of both tank domes
· Linear rail for length variation, adjustable to different tank sizes
· GFM ultrasonic cutting unit, cooled material storage
· In-process quality control and monitoring of process parameters

· System optimized for fast takt time and high vessel throughput
· Compatible with a broad variety of carbon fiber and glass fiber materials
· Fully automated robot offline programming with digital twin in ARTIST STUDIO

Optimized for pressure vessel reinforcements

Sample configuration for aerospace

SAMBA Pro Multi



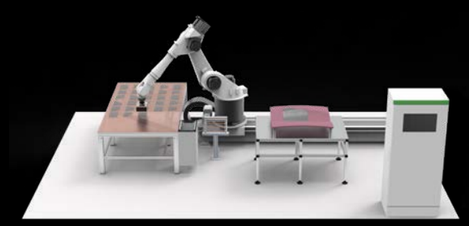
· Large 6-axis placement robot with long reach
· Additional linear rail for extended reach across large tools (3 m x 2 m or more)
· Double feeding unit for processing different fiber tapes simultaneously
· Force-torque sensor for controlled fiber placement e. g. on honeycomb cores
· GFM ultrasonic cutting unit, cooled material storage
· In-process quality control and monitoring of process parameters
· Advanced sensor package for comprehensive process monitoring

· System optimized for large, complex 2D / 3D component lay-up
· Compatible with a broad variety of carbon and glass fibers, adhesive prepregs, insulation layers, as well as lightning strike protection materials
· Fully automated robot offline programming with digital twin in ARTIST STUDIO

Ideal for multi-material composite aerostructures

Sample configuration for research & development

SAMBA Step L



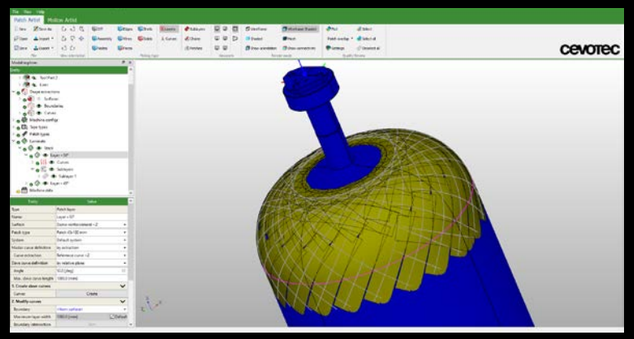
· One 6-axis placement robot (size customizable)
· Additional linear rail for extended reach across large tools (3 m x 2 m or more)
· Maximum material flexibility by feeding pre-cut patches on a table
· In-process quality control and monitoring of process parameters
· Overall degree of automation customized to requirements
· Advanced sensor package to analyze placement operations available

· System optimized for application development, prototyping, material testing and general R&D activities
· Fully automated robot offline programming with digital twin in ARTIST STUDIO

Ideal for application development, prototyping, R&D

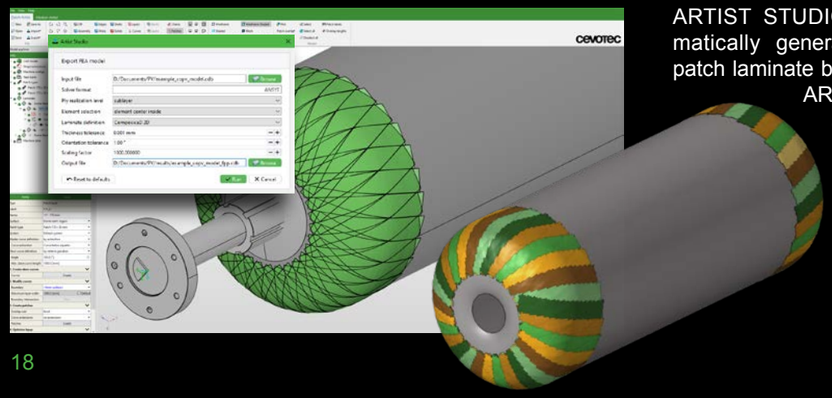
ARTIST STUDIO: CAD-CAM software with FE interface

Your engineering team requires digital tools that reduce the time for product development and integrate smoothly with production planning. ARTIST STUDIO is the perfect tool for digital product development and automated robot offline programming with Fiber Patch Placement. The software creates optimized patch laminates and generates the machine programs for the SAMBA systems.



PATCH ARTIST is the patch laminate design module. Its user interface is designed to define patch zones easily on imported CAD surfaces, as well as layer orientations, tape thickness, tape width, patch overlaps, patch length and patch side angles.

MOTION ARTIST enables you to program SAMBA robots offline in a completely automated fashion. This feature significantly reduces production preparation time while enhancing safety on your shop floor through built-in collision detection and visual process simulation.



ARTIST STUDIO support for FE-modeling automatically generates a detailed FE-model of the patch laminate based on the data defined in PATCH ARTIST regarding geometry, position and orientation of the patches.

PATCH ARTIST - laminate design (CAD)

Interface:	Import of STEP, IGES, STL, CATPart with basic FiberSim support
Laminate:	Layer definition with specific material properties and constraints
Boundary:	Different lay-up strategies at boundaries (reducing scrap, constant layer thickness)
Fiber orientation definition:	Multiple methods to best suit your design specifications (reference curve, plane intersection, reference orientation, geodesic curve)
Patch-shape definition:	Rectangular or trapezoid
Optimization:	Patch overlap optimization along and across fiber orientation; local patch length optimization: faster production and improved mechanical performance
Accurate placement results:	Patch shape prediction on highly curved surfaces based on a kinematic draping approach; Support for thick laminates using intermediate offset surfaces
Visualization:	Mold, laminate, surface normal, fiber orientation deviation Patches and patch normals Individual patch overlap quality and length Laminate thickness distribution
Manual fine tuning:	Position adjustment for individual patches and geometry
Upcoming features:	Patch-overlap measurement and visualization Multi-material production support

MOTION ARTIST - robot offline programming (CAM)

Robot kinematics:	Digital twin of 4 and 6 axis robots, robot on linear axis Robot-to-robot interaction logic
Tool kinematics:	Robot-assisted, linear axis, rotational axis
Mold mount point:	Coordinate-based position and orientation
Calibration:	Robot to robot positioning, tool positioning
Robot movement:	Point-to-Point (PTP), linear
Optimization:	Robot movements with consideration of axis limits, robot range, singularities, collision detection, rolling movements for large patches
Visualization:	Production cell, robot movements, collisions, laminate
Analyses:	Material consumption, production time
Interface:	Input: laminate design from PATCH ARTIST Output: machine data program for SAMBA systems

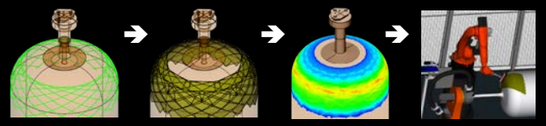
ARTIST STUDIO support for FE-modeling (FEA)

Availability:	FE-modelling support in Artist Studio (currently supported formats: OptiStruct PCOMPP/G, Nastran POMPG and Ansys)
Interface:	Expects an existing FEA solver input deck and enhances it with additional FPP laminate properties Requires an existing mesh
Properties:	Automated modeling of patches, fiber orientation, thickness, patch overlaps Various element selection methods and multiple patch merging strategies available

Additional solver support possible upon request.

cevoLab: The FPP Competence Center

Service offerings



Application development services

You can develop your application with Fiber Patch Placement together with our technical experts. Test and explore patch technology for your products risk-free. Our comprehensive services range from initial planning to finished prototypes produced in our cevoLab.

Prototyping & small series production

No matter if you require only a few prototypes for testing in your development process or you are looking to flexibly source small batches of series products – we can produce your laminates for you. Leveraging the latest Fiber Patch Placement equipment in our cevoLab, we offer FPP-as-a-service to support your R&D and production strategy.

Available equipment

SAMBA Pro

- Ultra-fast scara placement robot
- Precision laser tape cutting
- Tape width 12.5 – 50 mm; patch length 50 – 200 mm
- Build space appox. 1 m x 1 m x 1 m

SAMBA Pro PV Lab

- Dedicated to composite tank dome reinforcements
- Pick & place robot: Kuka KR 22
- Liner size: up to 3500 mm length and 1000 mm diameter

SAMBA Step L

- Large Kuka KR 60 robot on
- Linear rail
- Flexible feed of pre-cut patches (all materials) up to 300 mm x 200 mm
- Build space approx. 2 m x 3 m x 3 m

How to get started with FPP

STEP 01

ROI & suitability assessment

Includes manufacturability assessment, unit cost & time analysis, benefits & ROI estimation. This service is complimentary.

How much does your application benefit from FPP?

STEP 02

Joint application development

Includes virtual studies, application and demonstrator development, process customization, and more.

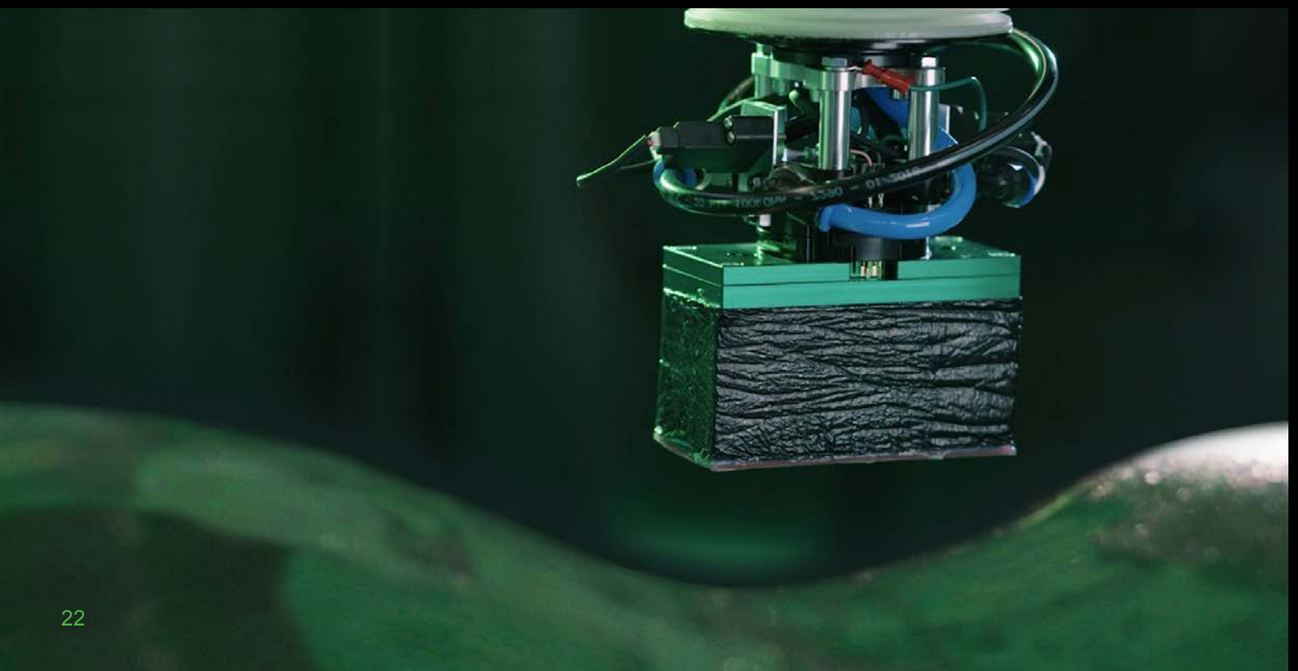
How do you best develop and test your FPP application?

STEP 03

Customized lay-up equipment

Includes SAMBA lay-up systems, ARTIST STUDIO software, customized patch grippers, quality control systems, and more.

Which system configuration is best for your application?



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Customer voices

“Cevotec‘s Fiber Patch Placement system expands our existing portfolio of automated production technologies for composite aerospace parts. With the addition of then SAMBA Pro system, we can now automate manufacturing of composite parts that were geometrically too complex for automation while precisely controlling fiber orientations for optimizing part design. It is the perfect enhancement to our robotic production equipment such as AFP and ATL and it allows us to compare technologies and advise our industrial partners on the optimal lay-up strategy. With the addition of SAMBA Pro system, now we can automate manufacturing of composite parts at high rates regardless of their complexity. I‘m pleased about the good collaboration with Cevotec: We got a great onboarding after the commissioning in our facilities and receive remote support wherever possible.“

Dr. Waruna Seneviratne
Director, Advanced Technology Lab for Aerospace Systems (ATLAS)

NIAR Wichita State University – National Institute for Aviation Research

Partners & references

GFM Automation · baumann · CIKONI composites innovation · FPC Fiber Placement Center · CU Composites United · NIAR Wichita State University – National Institute for Aviation Research · TUM · AIRBUS · Premium AEROTEC · LEONARDO · M.A.I Carbon · The Boeing Company · Mercedes-Benz AG · AZL Aachen Excellence in Lightweight Production Partnership · Fraunhofer IGCV · manroland web production · THA Technische Hochschule Augsburg · ICC Institute for Carbon Composites · bavAIRia Europe's heart of aerospace and navigation · Hydrogen Alliance Bavaria

About Cevotec

Munich-based automation specialist Cevotec offers one of the world’s most advanced production systems for complex fiber composites. At the intersection of composites, mechanical engineering and software, Cevotec develops production systems and software based on Fiber Patch Placement (FPP) technology: SAMBA and ARTIST STUDIO. The production systems enable the automated lay-up of carbon fiber, glass fiber, adhesive film and other technical fibers on complex 3D geometries. Manufacturers use FPP technology to produce various high-performance components in a quality-controlled, fully automated lay-up process. This includes multi-material composite aerostructures as well as composite pressure vessel reinforcements. Switching from conventional processes to Fiber Patch Placement enables cost and time savings of 20 % - 60 %.