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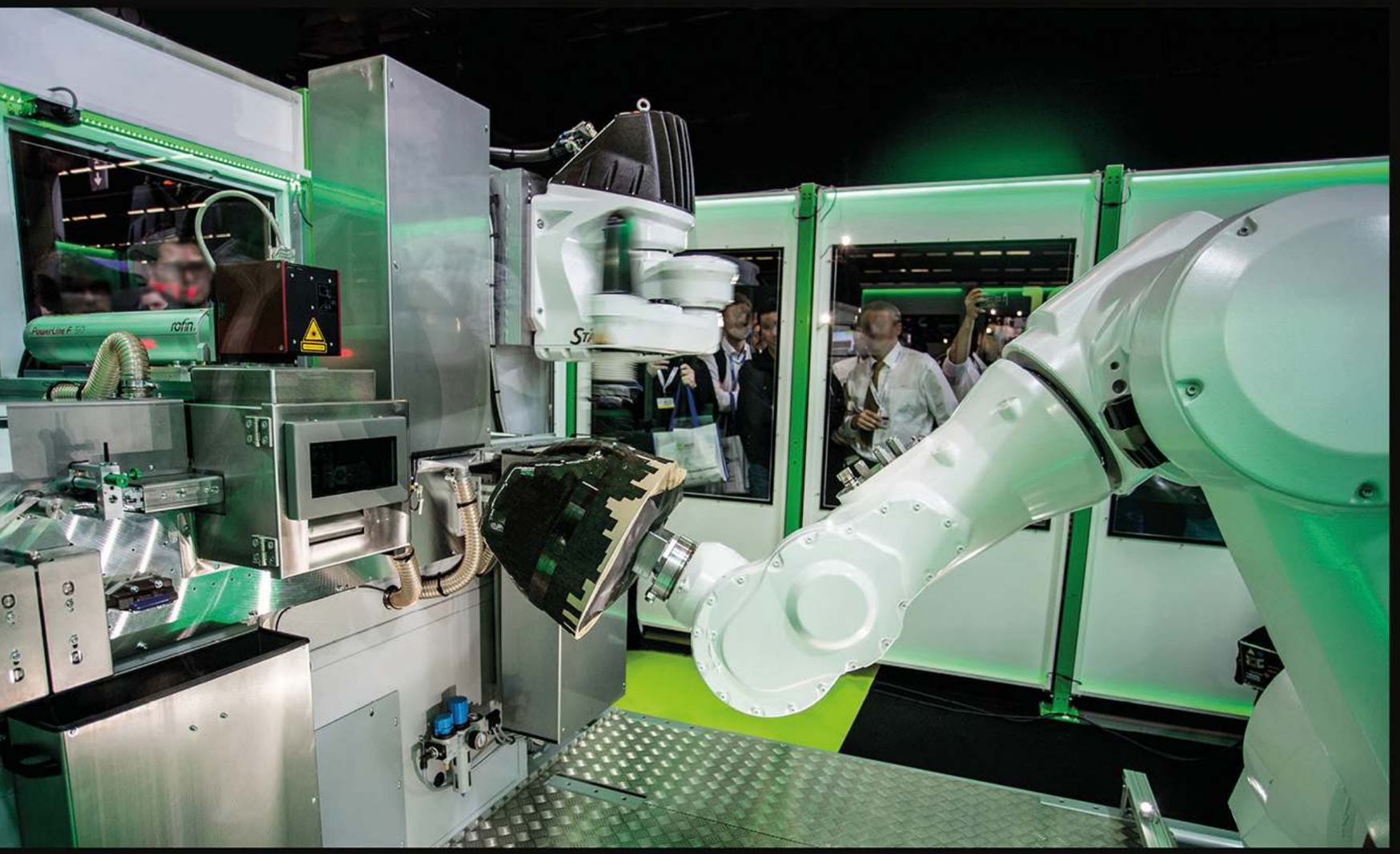
CEVOTEC

Fiber Patch Placement



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

- 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, so 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, such as carbon fibers, glass fibers, and adhesives, is especially important as it opens up a new range of possibilities for automated composite production, particularly in the context of complex aerostructures.

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Empowering key industries with lay-up automation

Composite tanks

20% better storage efficiency with dome reinforcements.

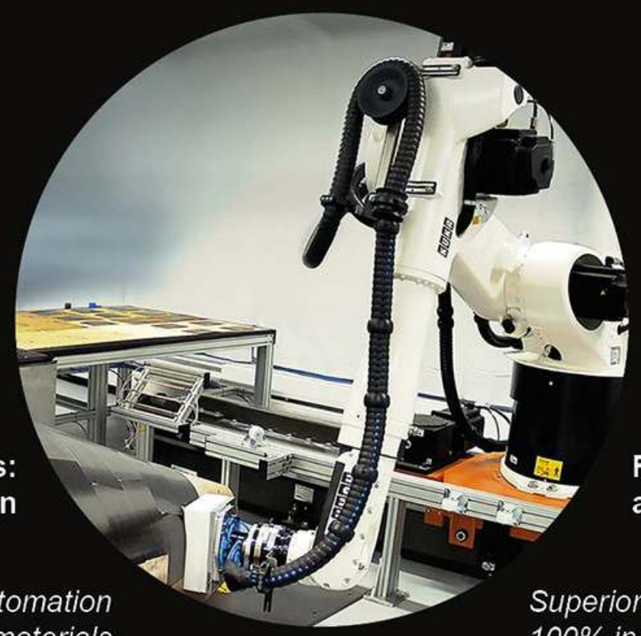
Superior product

Improved CO_2 footprint

Scalable industrial process

Aerospace

Automation for complex, multi-material composites.



Current programs: rate expansion

Automation
Multiple materials
Improved first-pass quality

Future programs: affordability

Superior buy-to-fly ratio
100% in-process inspection
Achieving ESG targets

Better composite tanks with FPP

Volume manufacturing of composite pressure tanks for hydrogen-powered mobility require an efficient use of carbon fibers as they represent over 50% of the total production costs. Cevotec developed an industrial solution using Fiber Patch Placement, which significantly saves material by locally reinforcing the dome areas with fiber patches. Combined with the established filament winding process, tank weight and cost could be reduced by ~ 15% while achieving equivalent mechanical properties. The tank aspect ratio drives the potential for material savings and potential volume increases on available build space. The longer the vessel in relation to its diameter, the higher the improvement potential. In a series production setting, the investment in the equipment amortizes already in 10 - 20 months after production start.

Fiber Patch Placement is the first technology to place dome reinforcements directly on the liner to significantly reduce weight and cost. This enables an automated production on industrial scale combined with the established filament winding process and improve the tank's CO_2 footprint significantly.

Your advantages with FPP:

- Scalable industrial process with no additional post processing
- Up to 20% improved tank efficiency
- Improved CO_2 footprint by 15% material savings
- 100% in-process raw material inspection & control

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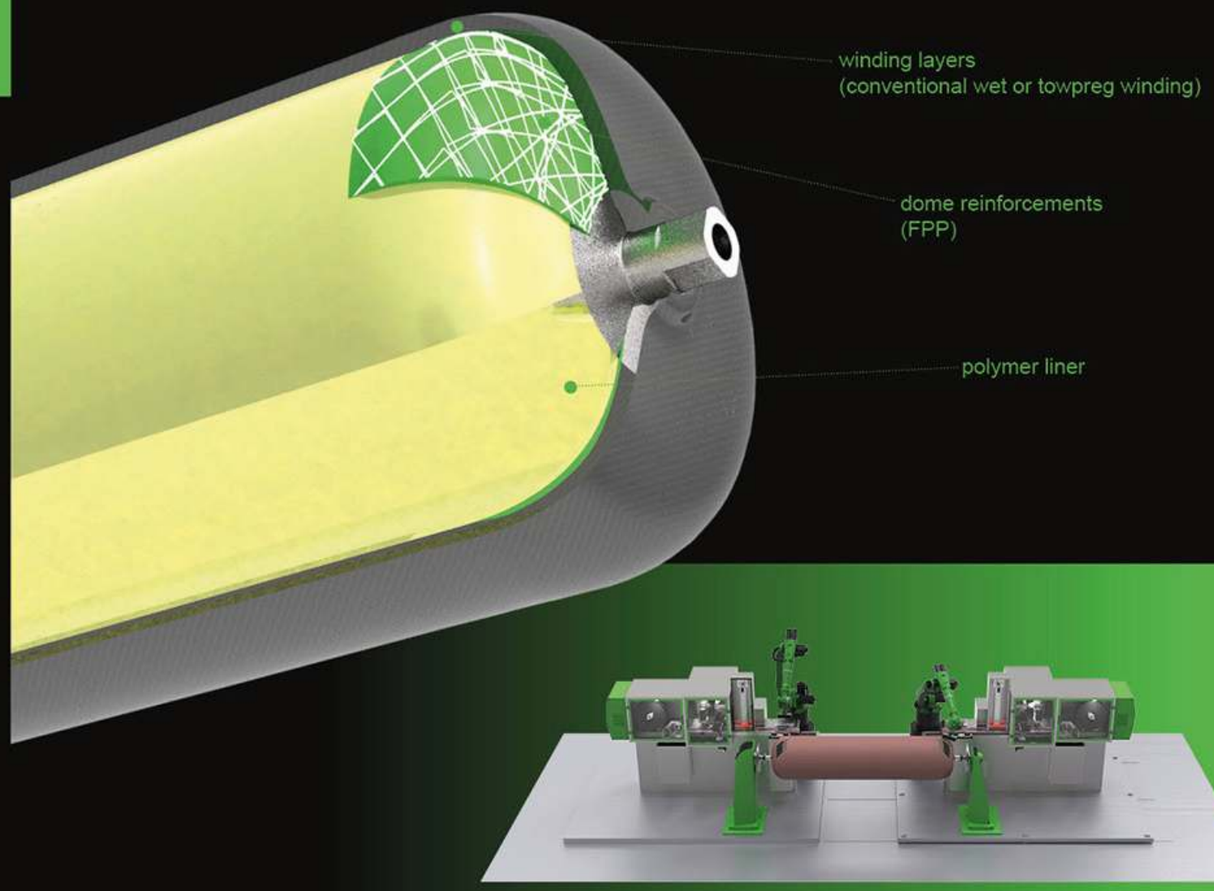

Sample configuration for dome reinforcements:
SAMBA Pro PV

Expanding 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 to produce e.g. multi-material (glass and carbon fibers, adhesives) 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.

The ability to place fibers with controlled high pressure on concave and convex geometries reduces or eliminates time-consuming intermediate debulking steps.

FPP technology empowers manufacturers to

Expand their production rates on current programs &
Ensure affordability for future programs

Your advantages with FPP:

- Multi-material lay-up with one system
- 100% in-process raw material inspection & control
- Reduction / elimination of intermediate debulking steps
- Achieving ambitious ESG targets

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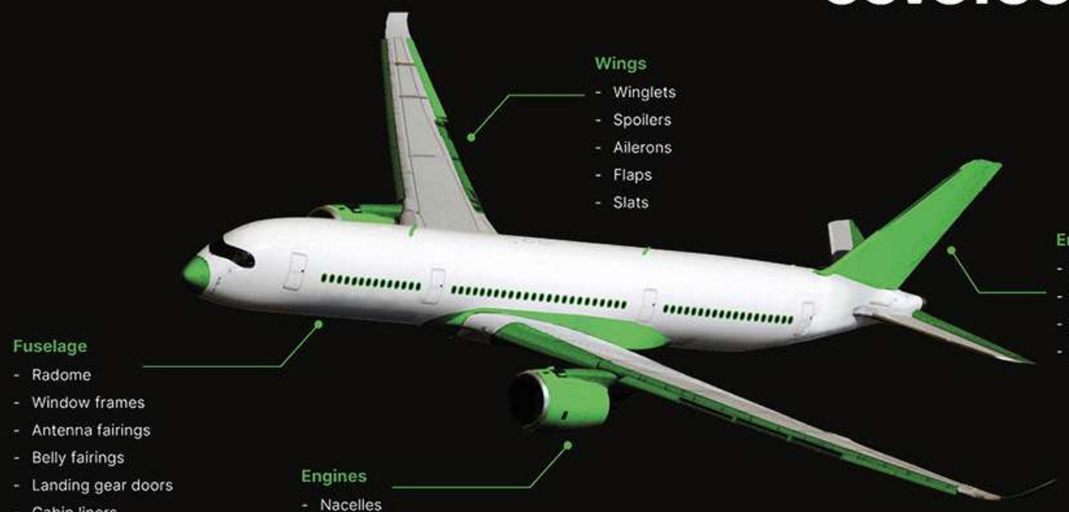
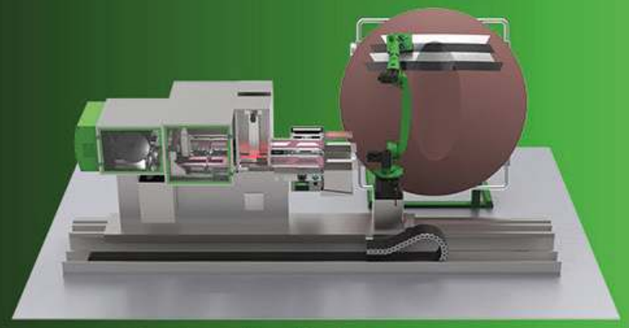


Exemplary overview of suitable aerospace applications

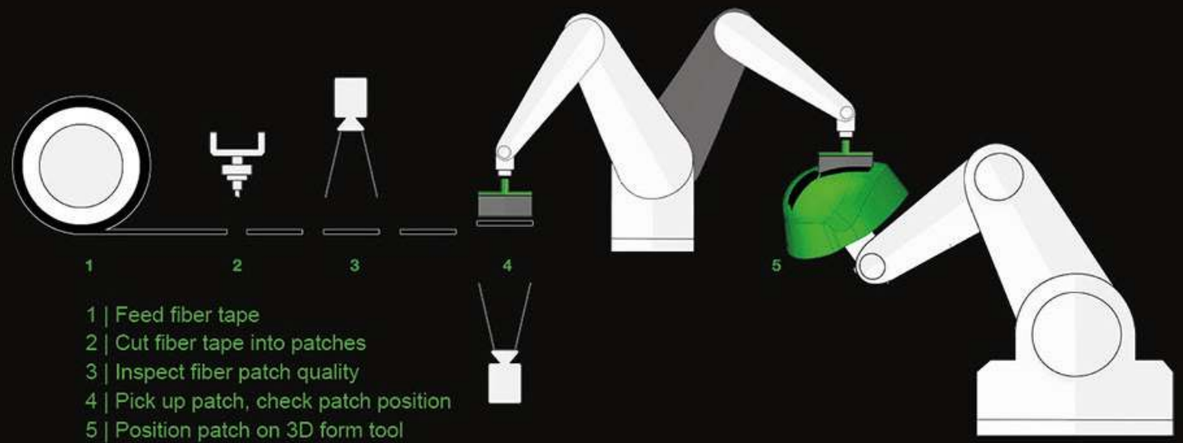


Sample configuration for aerospace:
SAMBA Pro Multi

How it works: Fiber Patch Placement technology

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 different 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 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.



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

5 easy steps to a complex 3D fiber laminate:

- Design laminate in ARTIST STUDIO based on your standard CAD file
- Create robot production data in ARTIST STUDIO by automated offline programming
- Load robot data program on SAMBA system and set production parameters
- Fix tool on robot and load desired fiber material
- Press “Start” on SAMBA system for fully automated lay-up of your component

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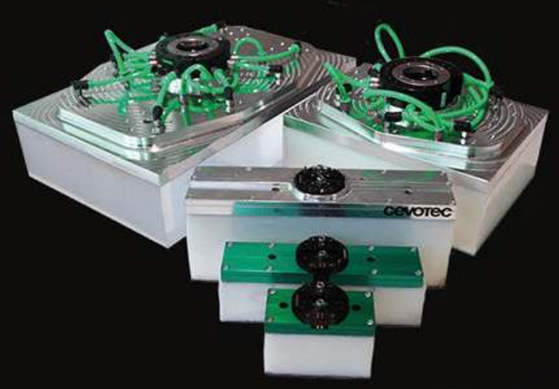
How it works: Fiber Patch Placement technology



cevoGripper

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.

- Available in sizes from 45 mm x 95 mm up to 240 mm x 360 mm
- Automated quick-mount device for fast and easy gripper changing on-the-fly
- Anodized, precisely machined aluminum baseplates
- High mass-flow vacuum stream, powered by pressured air
- Customized body to meet specific compaction requirements
- Optional heating field for dry fiber tape with heat-activated binder

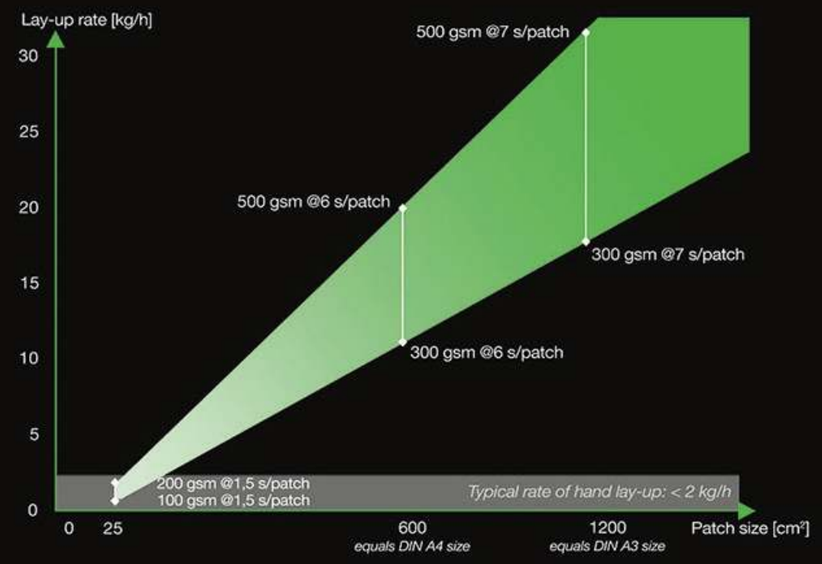
FPP automation accelerates more than just the lay-up rates. As patches are cut directly from a tape, there is no need for cutting and kitting plys from a cutting table. The placement with controlled high pressure reduces or eliminates time-consuming intermediate debulking steps.

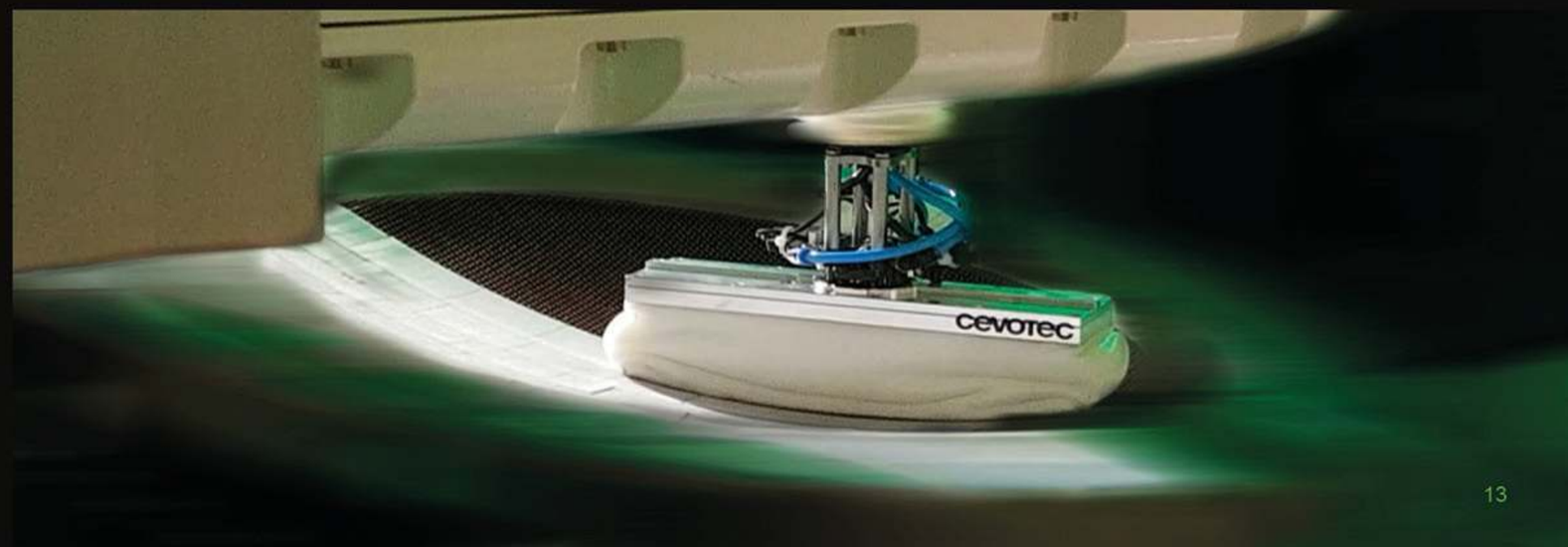
In addition, the development time of new components is significantly shortened with the support of the FPP-specific CAD-CAM software ARTIST STUDIO. The software generates patches automatically along defined guide curves and also performs a fully automated, offline robot programming.

Lay-up rates of SAMBA *Series*

Effective lay-up rates result from process parameters and can be customized to applications.
The productivity of all SAMBA machines follows the same simple math for throughput calculation:

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





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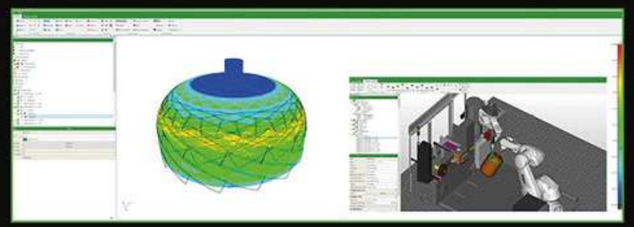
The Cevotec portfolio: Patch-based production technology

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 CAD-CAM 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 FE software (CAE)
- Full digital twin of matching SAMBA system

cevo**Lab – the FPP Competence Center**

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

cevo**Services – 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!

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SAMBA Series: Modular 3D fiber lay-up systems

Fiber Patch Placement is a very scalable and flexible technology. Based on three key modules for material feeding and cutting, placement, and mold manipulation, we customize SAMBA systems to your requirements.

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, remote-access capable
- Touch-screen HMI with Cevotec UI
- Dedicated image processing computers

Tool holders and manipulators

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

Sample configuration for composite tanks

SAMBA Pro PV-1

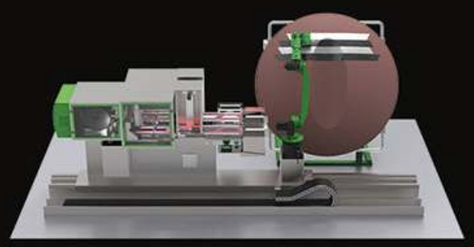
- 2x feeding and cutting units and 2x 6-axis placement robots for simultaneous patching of both tank domes
- Linear rail for length variation, adjustable to tank sizes of up to 3 m length
- In-process raw material inspection and documentation
- Self-corrective positioning control, fully automated lay-up process
- GFM ultrasonic cutting unit, cooled material storage
- Comprehensive monitoring of process parameters

- System optimized for fast cycle 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
- Component sizes of 3 m x 2 m (indicative configuration) or more
- Double feeding unit for processing different fiber tapes simultaneously
- Scaled patch grippers for patches up to 300 mm x 200 mm
- Force-torque sensor for controlled fiber placement e.g. on honeycomb cores
- Automated, in-process patch gripper exchange
- In-process raw material inspection and documentation
- Self-corrective positioning control, fully automated lay-up process
- GFM ultrasonic cutting unit, cooled material storage
- Advanced sensor package for comprehensive monitoring of process parameters

- System optimized for large, complex 2D / 3D component lay-up
- Compatible with a broad variety of carbon fiber and glass fiber materials, as well as adhesive prepreg, insulation layers, 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

- One 6-axis placement robot (size customizable)
- Maximum material flexibility by tray system to feed pre-cut patches
- In-process raw material inspection and documentation
- Self-corrective positioning control, fully automated lay-up process
- Overall degree of automation customized to requirements
- Advanced sensor package to analyze placement operations available

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

Ideal for application development, prototyping, R&D

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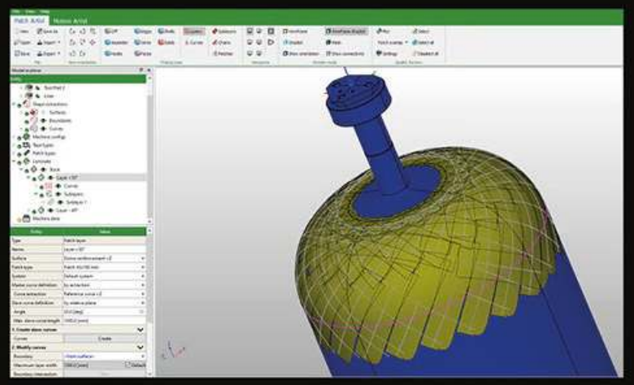
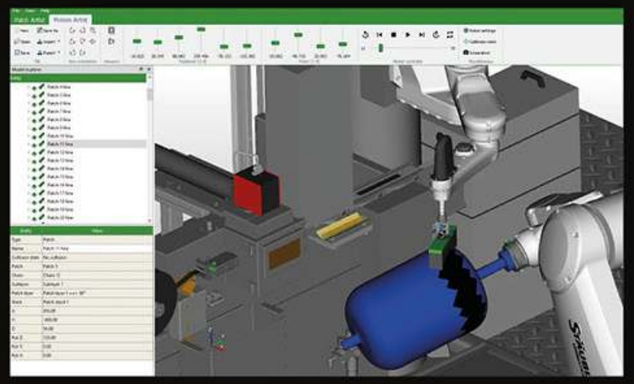
ARTIST STUDIO: CAD-CAM software with FE interface

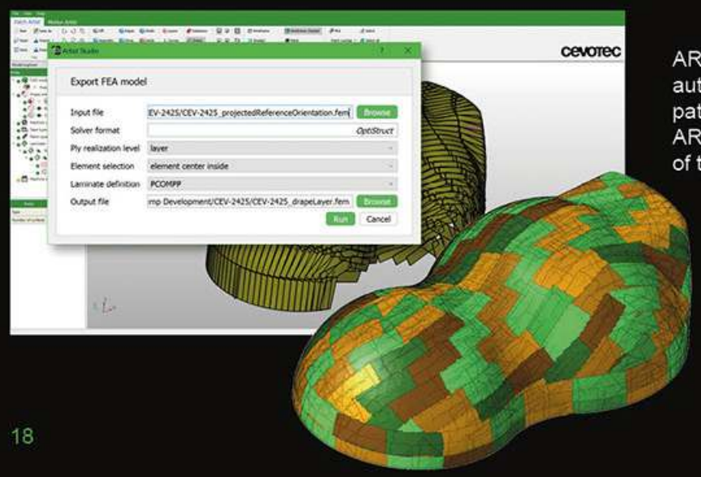
Your engineering team requires digital tools that reduce the time for product development and integrate smoothly with production planning. ARTIST STUDIO is the perfect tool for digital product development and automated robot offline programming with Fiber Patch Placement. The software creates optimized 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 size, layer orientations, layer thickness, tape width and patch length.



MOTION ARTIST enables you to program the SAMBA robots offline in a fully automated way. With that, the preparation time for production is significantly shortened, and the built-in collision detection as well as the visual process simulation increase the safety on your shop floor.



ARTIST STUDIO support for FE-modeling (FEA) 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
Upcoming features:	Enhanced support for large patches Patch-overlap measurement and visualization Robotic cells focusing on pressure-vessel production Multi-material production support

MOTION ARTIST - robot offline programming (CAM)

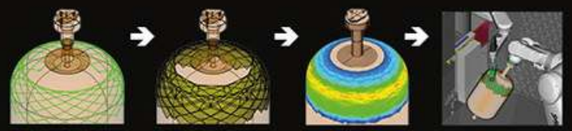
Robot kinematics:	Digital twin of 4 and 6 axis robots, robot on linear axis Robot-to-robot interaction logic
Tool kinematics:	Robot-assisted, linear axis, rotational axis
Mold mount point:	Coordinate-based position and orientation
Calibration:	Robot to robot positioning, tool positioning
Robot movement:	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 and Nastran POMPG)
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



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 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 volume appox. 1x1x1 m³

SAMBA Step L
- Large Kuka KR-60 robot on linear rail
- Flexible feed of pre-cut patch (all materials) up to 300 x 200 mm
- Build space approx. 2x3x2 m³

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How to get started with FPP

Step 1: ROI and suitability assessment

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

→ **How much does your application benefit from FPP?**

Step 2: Joint application development

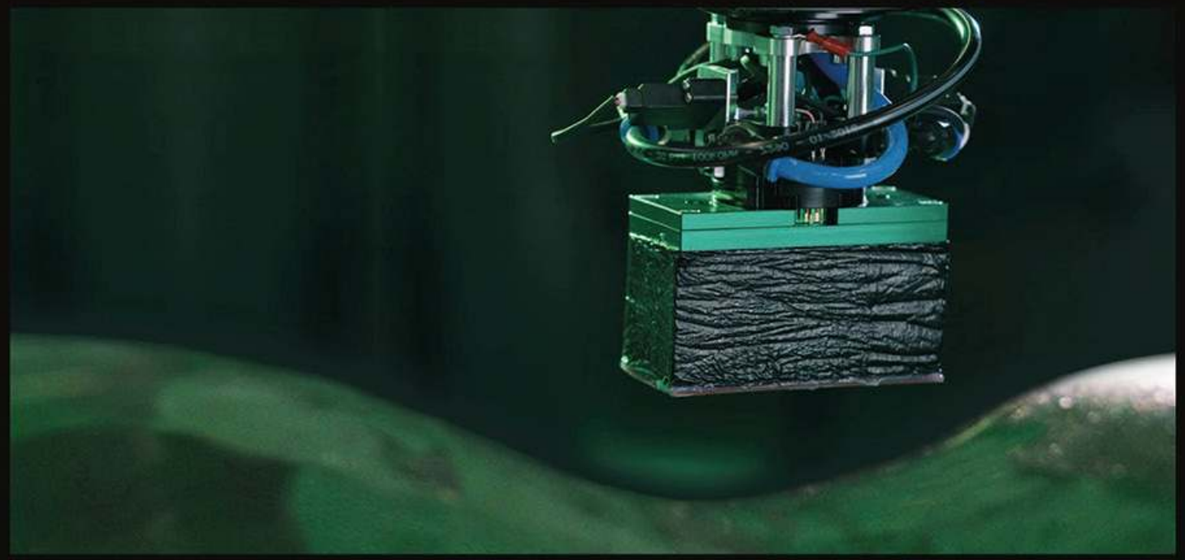
Includes virtual studies, application and demonstrator development, equipment customization, and more.

→ **How do you best develop & test your FPP application?**

Step 3: 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?**



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 part at high rates regardless of its 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 Tech. Lab for Aerospace Systems (ATLAS)

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 fibers, glass fibers, adhesive films and other technical fibers on complex 3D geometries. Manufacturers use FPP technology to produce e.g. multi-material composite aerostructures, composite pressure vessel reinforcements, and other high-performance components in a quality-controlled, fully automated lay-up process. Switching from conventional processes to Fiber Patch Placement enables cost and time savings of 20% - 60%.

Partners & references