New Applications for the Automated Production of Fiber Composite Components

Reinforcement on Approach

Particularly two industries have shown considerable interest in FPP technology: aerospace industry in automating the lay-up processes of multi-material lightweight components with sandwich cores, as well as manufacturers of CFRP pressure vessels for hydrogen-powered vehicles (FCEVs), who can thus achieve savings in the double-digit percentage range. In both areas, FPP is the first technology to automate critical fiber lay-up processes in order to industrialize the production.

Laminate reinforcement of filament-wound pressure tanks. The shape of the patches and the gripper is adapted to the size and complexity of the component. © Cevotec

The robotic manufacturing technology Fiber Patch Placement (FPP) expands the possibilities for the automated production of geometrically complex fiber composite components. In the FPP lay-up process, defined fiber patches are cut from a fiber tape and placed by two robots and a fexible patch gripper directly on a 3D mold (**Title figure**). The size of the patches and the gripper is adjusted to the dimensions and complexity of the component. Since the process is implemented as a series of individually controlled patch placements, FPP enables a superior level of process control for the entire laminate lay-up cycle. A dedicated CAD-CAM software simplifies the creation of patch laminates. As a core element of the process, the software includes a FE-interface and, equipped with a digital twin of the production system, performs a fully automated robot offline programming. In-process quality control systems detect potential defects before the fiber lay-up is performed (**Fig. 1**). Furthermore, there is the possibility of increasing the overall productivity by up to factor 5 to 10, depending on the application. This usually translates into savings of 20 to 60 % in cost and process time.

The characteristics of FPP technology are particularly beneficial in lay-up auto-

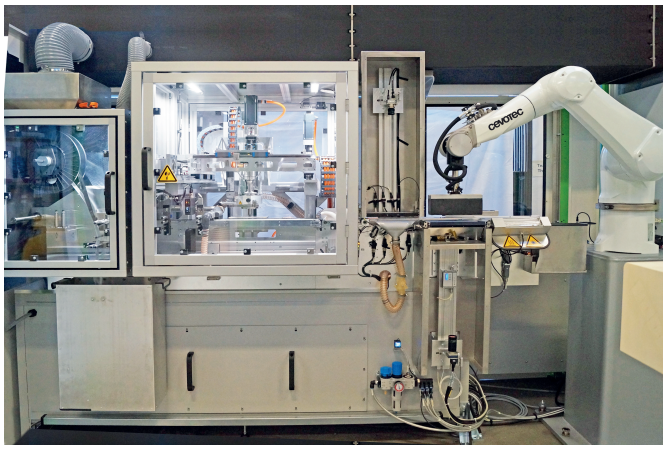

Fig. 1. The FPP system combines several modules for feeding, cutting, material control, position control and fiber placement. © Cevotec

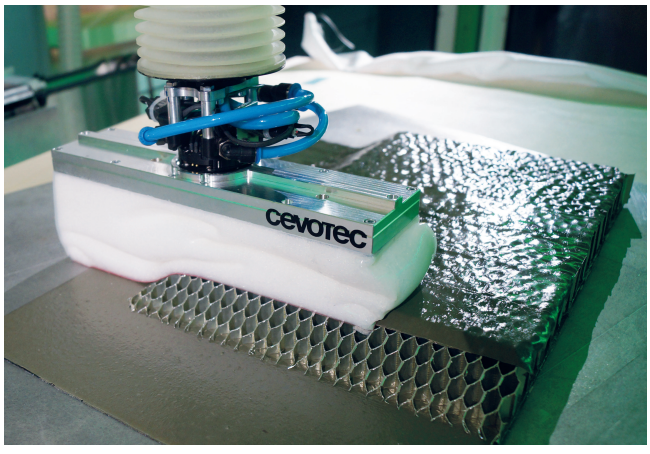

Fig. 2. The fiber material can be placed directly on the chamfered transition of a honeycomb core. © Cevotec

mation for complex, multi-material aerostructures and in reinforcing the laminate of filament-wound composite tanks, which are described in the following sections.

Lay-up Automation for Complex, Multi-Material Aerostructures

The high mass-specific stiffness renders composite sandwich structures suitable for the demanding weight-restricted applications on aircrafts. But in the production of these components, geometric complexity and the multi-material mix of adhesive film, glass and carbon layers (among others) pose a particular challenge. Production usually requires several process steps and involves time-consuming manual lay-up work and intermediate debulking steps.

FPP technology, with its ability to process a broad variety of fiber materials, is able to produce such components fully automated with one production system. Fiber material can be placed directly on curved or chamfered honeycomb cores (**Fig. 2**). This replaces manual lay-up steps and usually increases lay-up precision and repeatability.

The deposition pressure of the placement robot can be adjusted and controlled. Thus, intermediate debulking steps can significantly be reduced or even eliminated, resulting in valuable savings in process time. Test samples with 24 plies have shown porosity values of less than 1 %.

The real-time process control ensures constant high part quality: two visual inspection units analyze

- the quality of each patch before placement, and
- the relative position of the patch on the placement gripper.

Thereby the system guarantees that only 100 % in-spec raw material is placed precisely on its intended position.

The flexible process also allows the combination of sandwich-core structures and monolithic sections in one integrated production process (**Fig. 3**). The combined laminate approach is fully supported by the FPP-specific Artist Studio software. This offers flexibility for laminate adjustments in the development process whenever needed – with significantly reduced effort and time for design iterations.

H_2 Composite Tanks with FPP Dome Reinforcements

Composite pressure vessels are the key storage system for hydrogen-powered mobility. The main cost driver of the cylindrical tanks with operating pressures of up to 700 bars is the carbon fiber material with over 50 % of total tank cost. To improve efficiency of composite pressure vessels, the US Department of Energy examined the positive effect of dome reinforcements already in 2013, but until today, there was no industrial process available to produce them.

Cevotec adapted its FPP technology to create an industrial solution that places the tank reinforcements fully automated (**Title figure, Fig. 4**). Afterwards, the vessel including reinforcement is transferred to the established filament winding process (FW). The weight and manufacturing costs of a tank are thereby reduced by 15 % while achieving equivalent mechanical properties.

The robotic FPP system places the reinforcements patches directly on the dome areas of the liner. The patches substitute the high-angle helical layers (HAHL) traditionally applied by the FW process. However, unlike the HAHL, the patches do not span across the cylindrical portion of the vessel, where they would contribute only marginally to the mechanical performance. This translates into a considerable saving of material, depending on the aspect ratio of a vessel. The reinforcements also facilitate a smoother stiffness transition between the cylinder and dome sections, leading to a further optimized laminate design.

The patches are applied in an independent process, parallel to the FW. This parallelization leads to an overall cycle time reduction of about 15 %, resulting in more tank capacity on existing FW lines. Overall, the combined benefits for composite vessels in series production pay off fast for any manufacturer: the necessary investment for FPP dome reinforcements amortizes within one to two years.

Customized Production Systems Based on Flexible Modules

Industrial customers as well as R&D partners see a great benefit in FPP technology. In 2020, the Fraunhofer Institute for Casting, Composite and Processing Technology (IGCV) commissioned a Samba Pro Prepreg production system from Cevotec at the Fiber Placement »

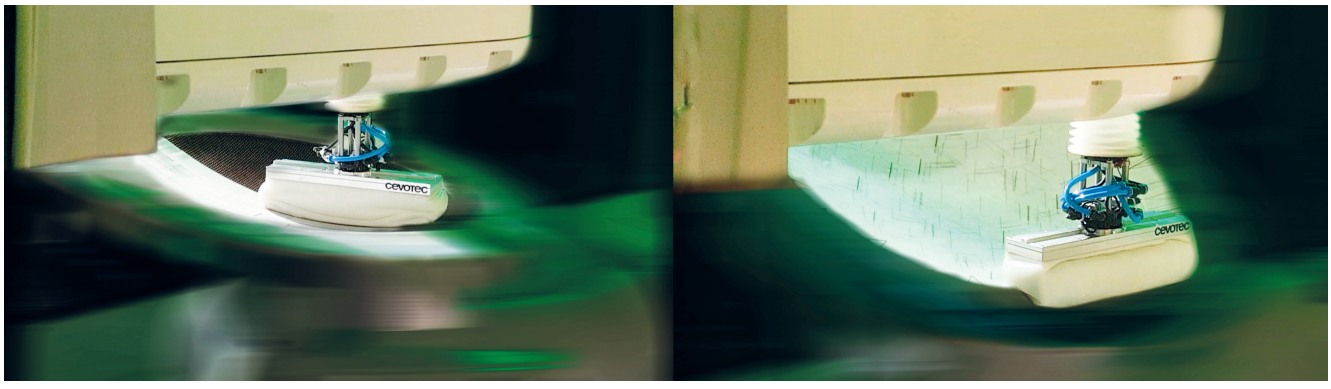

Fig. 3. The process also enables the combined lay-up of sandwich core skins and monolithic sections, as shown here for an aerospace component.
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Center (FPC) in Meitingen, Germany. The Samba series FPP systems are automated production platforms for demanding fiber lay-ups, programmed with Artist Studio software. They are based on three scalable key modules for material feeding and cutting (ultrasonic or laser cutting), patch placement, as well as tool holders and manipulators with a quick-change system, which can be flexibly combined and adapted to specific requirements. The system is at the disposal of FPC's industrial partners as well as all interested companies to develop automated CFRP production processes based on the FPP technology.

Since summer 2021, a Samba Step system extends the research opportunities for Materials Resource Management in Augsburg, Germany. Augsburg University and Augsburg University of Applied Sciences rely on Fiber Patch Placement technology for R&D in the fields of Artificial intelligence (AI) and new materials. Cevotec's Samba Step system is located in the recently opened Materials Resource Management (MRM) building in Augsburg Innovationspark, Germany.

In the first quarter of 2022, the National Institute for Aviation Research (NIAR) at Wichita State University (WSU), KS/USA, has commissioned a Samba Pro Prepreg system, which will be the first FPP production platform on U.S. soil. NIAR, as the leading aerospace research institute in the U.S., is heavily involved in the advancement of composite structures for aerospace applications. Cevotec's FPP system will be included in Niar's Atlas (Advanced Technologies Lab for Aerospace Systems) portfolio of automated manufacturing technologies for composite research and will create new R&D opportunities for U.S.-based composite developers and manufacturers, particularly in the defense community. ■

Info

Text

Dr. Daniela Klotz works as a freelance journalist for Cevotec;
communication@cevotec.com

Company Profile

Cevotec GmbH 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 (Samba) and software based on Fiber Patch Placement (FPP) technology (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 FPP enables cost and time savings of 20 % to 60 %.
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Fig. 4. The robotic system places the reinforcement patches directly on the dome areas of the pressure vessel. © Cevotec