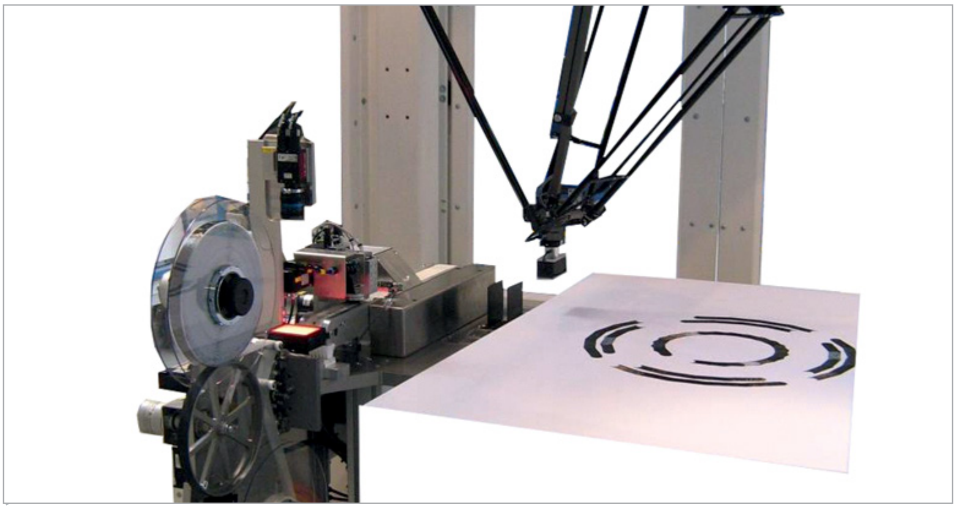
Success Story

Altair

Fully Automated in a Single Process: Optimization & Manufacturing of CFRP Components



manz
passion for efficiency

Key Highlights

Industry Mechanical Engineering

Challenge
Integration of Design Optimization in a Fiber Patch Performing Facility

Altair Solution
Use of HyperWorks and adapted three-step optimization process for composite materials integrated in the production process

Benefits
- Process suitable for large volume series
- Flexibility in production
- Short learning curve for users
- Light and yet stiff components

Technology leap and innovation thanks to intelligent automation

Producing carbon fiber reinforced plastic (CFRP) components economically and in high volume is a serious challenge. Complex design shapes and a primarily manual manufacturing process have meant that components made of fiber composite materials could be produced only in small series or as single products. Yet the strong, lightweight potential and excellent mechanical properties of CFRP components make them desirable for many industry applications. Using the recently developed Fiber Patch Preforming (FPP) method as a starting point, Manz AG undertook a research project to create a manufacturing facility that would enable economically viable series CFRP production.

By incorporating intelligent automation and design optimization, Manz developed a production machine which can manufacture the desired preforms quickly and automatically.

Based on its high-strength, high stiffness yet lightweight potential, fiber reinforced composite material is the preferred substitute for metal in many applications. Reducing weight while maintaining strength is a critical need in many industries, such as automotive and aerospace. Along with leveraging its pure material properties, fiber reinforced composite structures can take advantage of the material’s anisotropy by means of a load-specific design, allowing a component to be adjusted to its individual use case.

Keywords: Optimization, Lightweight Design, FPP, Automation

Manz Success Story

The disadvantages of CFRP materials have been the complex design and cost-intensive manufacturing processes. Simulation software, such as the optimization tool OptiStruct from Altair Engineering, has simplified the design process. Recent developments in production approaches are also helping to open the door to series manufacturing. The fiber patch preforming (FPP) method, developed under the leadership of Airbus Group Innovations (formerly EADS Innovation Works) as part of a BMBF (German Federal Ministry of Education and Research) project, enables the automated production of composite preforms from a software lay-up plan.

With FPP as a basis, the next challenge for researchers was creating a manufacturing facility suitable for mass production and efficient processing of the fiber patches. SOWEMA, a research project funded by BMBF, pursued this goal. Under the roof of SOWEMA, Manz together with other partners (EADS Deutschland GmbH, Technische Universität München, CTC GmbH, Technische Universität Clausthal, Cenit AG, Wethje GmbH, and Otto Bock Health Care GmbH) investigated a flexible and fully automated manufacturing process using the FPP method, the production of 3D preforms (near net shape blank of the laminate), the integration of a robot to position the single fiber patches, and the automation of the entire process.

Within the scope of the project, Manz developed a production machine that could manufacture the desired preforms in an automated manner and within a short time. With that success, a new goal was set – adding a preceding load-specific design and component optimization to the process. For this purpose, Manz partnered with Altair and its engineering services division, Altair ProductDesign, which built the optimization process. A bicycle seat was used to demonstrate this process with excellent results achieved in a very short time.*

Extending FPP manufacturing with optimization

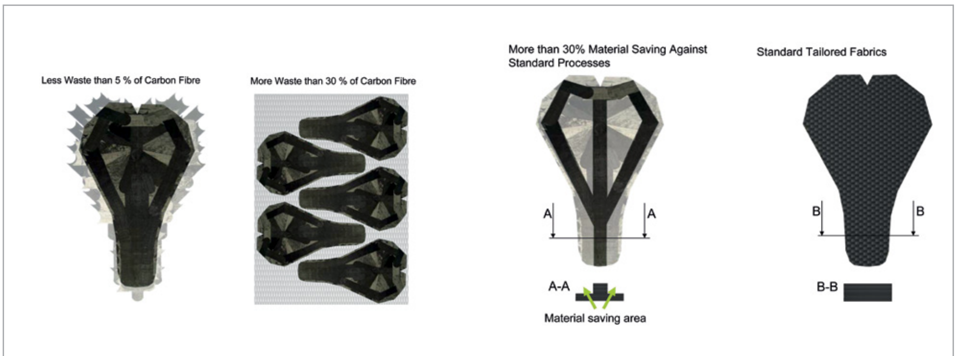
Manz AG, based in Reutlingen, Germany, is a leading high-tech engineering company that has grown in recent years from an automation specialist into a supplier of production lines. With four main business divisions in Battery/Fuel Cell, Display, Electronics, and Solar applications, Manz provides turn-key production plants for various industries. The company's New Business division was already involved in the SOWEMA project and had experience in lightweight design and composites.

The New Business division was one of the driving forces behind the collaboration with Altair to extend the process of flexible FPP manufacturing with preceded component optimization. Altair Engineering, a global software and consulting company, has many years of experience in simulation and optimization of composite components as well as lightweight innovations for many industries.

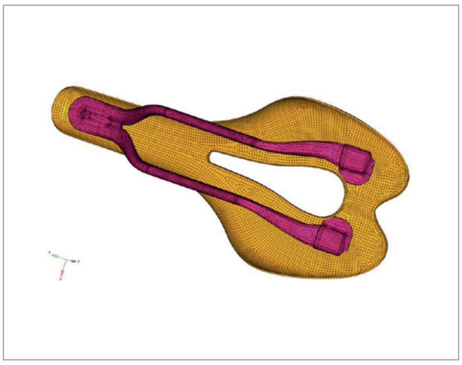
The overall goal of the SOWEMA project is to shorten the entire development and production cycle, from CAD drawing to final product, while maintaining the flexibility and repeatability the FPP facility offers. Shorter cycles pave the way for much more cost-effective manufacturing, making the process applicable to large production volumes. An FPP facility could be of great benefit to many industries, including aerospace, automotive, medical, and consumer goods.

To study the feasibility and assess the advantages and disadvantages of the entire process, including an automated optimization, the combined Manz Altair ProductDesign team used a bicycle seat as their first test object. The bicycle seat under investigation was also used in the original project, where no integrated optimization was in place. Although good results had been achieved, the effort of programming

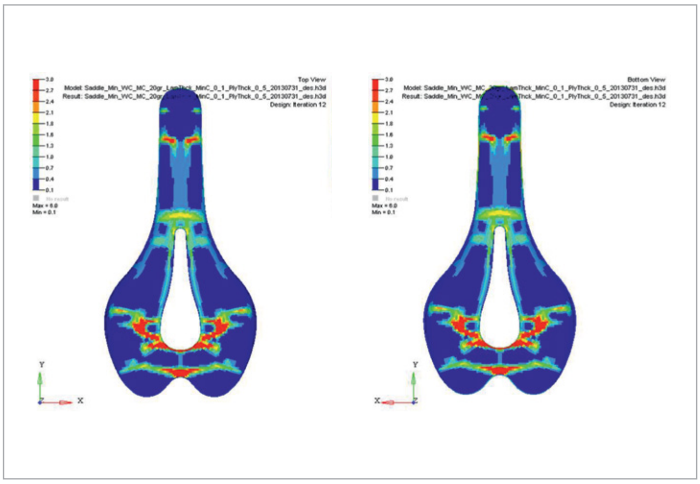
* The project partners also applied for public funding of this project.



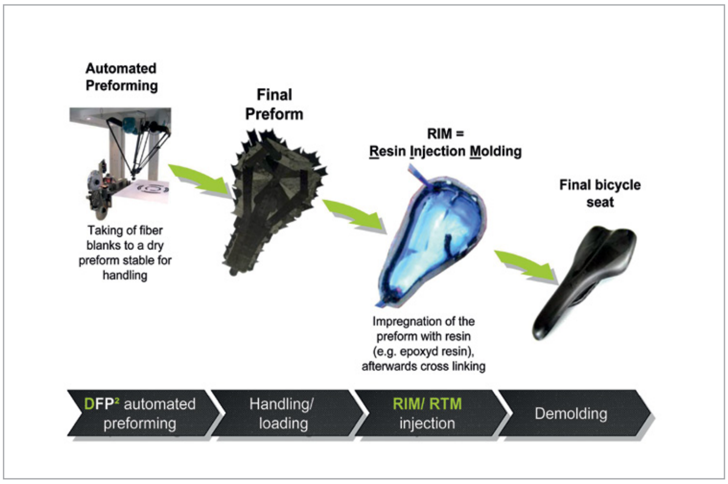
The FPP-process has very little material waste. Compared to the traditional manufacturing method without optimization, the automated optimization process helped to reduce the material waste by 50 percent



FE-Model of the bicycle seat – the pilot test object of the process



The optimization prior to production (here layer thickness optimization) creates a load efficient and weight minimized component structure



Production steps after the optimization

the production machine, based on pure engineering knowledge, was very high. In the new project, this step was subject to automation, including optimizing the seat's laminate structure, its manufacturing, and verification. As a result, the engineers expected an optimized and lighter product, simplified machine programming, and a continuously automated process.

Approaching optimization with automation

When optimizing a composite component, especially for FPP manufacturing, many variables must be considered.

The load paths in the component have to be identified and the predominant fiber orientations of the plies have to be determined. In addition, it is necessary to define the shapes of the single patches, the layer thicknesses, and the stacking sequence of the final composite material. This multitude of variables leads to a complex optimization task, which can quickly overwhelm even experienced users. The researchers completely automated this first step, so a user only needs to insert the CAD model and the occurring loads. Anything else, up to and including the production itself, is automated.

The result of the automated optimization is a file containing the optimized structure of the component, including load-specific fiber orientation and laminate structure. This file is subsequently complemented with process and machine data. Using Cenit's software environment, the manufacturing process is also automatically simulated, robot paths are generated, and the data is translated into a machine code. The Manz production machine then manufactures the part using the FPP method.

To optimize the bicycle seat, the research team followed the three-step optimization process for composite materials, which was developed by Altair Engineering and awarded with the AVK (Industrievereinigung verstärkte Kunststoffe) Innovation Prize in 2012. This standard process for the design of composite material components uses Altair's optimization software tool OptiStruct and provides answers to questions such as layer thicknesses, ply orientation, patches and stacking sequence of the component.

In the first step, component areas that require patches with a specific material orientation are determined. To do so, the ply distribution in every element of the simulation model is used as an optimization parameter and is modified. The result of the first step is a design proposal for the distribution, representing the optimal shape and thickness of each individual patch. This design proposal provides the numerically ideal design for the given optimization task. Based on the results of the first optimization, the next step determines the discrete thicknesses of the patches and consequently the exact number of layers needed. The third and final step is a so-called shuffle optimization, with which the stacking sequence of the layers is defined. Other manufacturing constraints, such as special stacking sequences, can also be considered.

Expanding the entire process with preceded optimization

Of course, to automate an optimization process like the one described here, it first has to be conducted manually, so the individual steps can be programmed accordingly. In the present case this was done with the bicycle seat in order to identify the parts of the entire process where further development and automation work is required.

The starting point of the bicycle seat optimization was an existing CAD model and the standard, describing the occurring load cases. The optimization followed the standard design process for composite materials, the only difference being the step size of the possible fiber orientations. Since the Manz production machine has hardly any restrictions for positioning the fiber patches, a large number of optional fiber orientations (from minus 170 degrees to plus 180 degrees in 10-degree steps) was studied. This design freedom in fiber orientation allowed the researchers to take full advantage of the benefits offered by the carbon fiber patches.

Fiber Patch Performing (FPP)

FPP (Fiber Patch Preforming) is a manufacturing method in which a fiber band is cut into different patches, which are then positioned in a preform by a robot in the desired fiber orientation. Like this, it is possible to produce material-efficient preforms with complex and load-efficient fiber orientations. This leads to a form with a load-efficient internal structure, shaped almost like the end product and with up to 50 percent less material waste. The final preforms are then positioned in an pre-prepared tool form and filled with resin, using the RIM (Resin Injection Molding) method. The final component can then be demolded.

FPP-tool by Manz

As an important optimization constraint, the engineers restricted the overall mass of the final preform to 20 g. In order to preserve the component's geometry, the optimization identified for production only those laminate sequences, which promised the best results. The optimized and manufactured bicycle seat met all requirements regarding mass and stiffness. In comparison to the non-optimized seat from the first phase of the SOWEMA project, the new model also offered higher safety against failure and a 30 percent reduction in weight.

Outlook

The Manz-Altair research project demonstrated the viability of an automated FPP manufacturing process. By providing a fully optimized component as a direct input to the production facility, the ability to flexibly manufacture material-optimized and load-specific composite structures in large volume series comes within reach.

The advantages of the automated process are significant. Due to the lower cutoff of the FPP process compared to traditional composite manufacturing methods and the preceded weight optimization, better cost-effectiveness and shorter cycle times can be achieved. The process is suitable for large volume series.

The flexibility of the facility is another benefit. Single patches can be almost freely positioned and oriented. The machine can switch between products within minutes, producing for instance a tennis racket, then a bicycle seat and then an orthotic device. Only a few modifications – a change of tool, a new preform form, and a new machine code – are needed as input parameters. Automation and optimization also smooth the learning curve for users, allowing even inexperienced users to manufacture an optimized component. Theoretically, a trained user could produce a completely new component within one day, a task that traditionally has taken one or two weeks.

Based on the success of the pilot project "bicycle seat", the project members are confident that a fully automated facility suitable for large-volume series production of small and mid-sized fiber composite parts can be achieved. Today, Manz prototype machines are in place at Airbus Group Innovations (formerly EADS Innovation Works) in Ottobrunn and TU Munich at the LCC. Integrating the results of the Manz-Altair study into the SOWEMA research project is the second step in this promising CFRP manufacturing approach.

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