Self-Regulating Production Plant

Economic Production of Fiber-Reinforced Plastics in High Volumes

In the iComposite 4.0 research project, it has been possible to cut the costs for a prototype component by more than 50 percent and throughput time by 40 percent. The project focused on a new material mix, the use of 3D fiber spraying, and adaptive compression molding. The limitations of the newly developed process lie in the control technology.

View of the production system built for the iComposite 4.0 project at the RWTH Aachen AZL © Campus GmbH/Moll

Carbon fiber-reinforced plastics (CFRP) are still used only sparingly in lightweight automotive engineering and have not yet made the broad leap into serial production. The manufacturing costs of parts produced from carbon fiber-reinforced plastics are still simply too high. A completely new process has been developed for the iComposite 4.0 research project. The project completion report was presented at the end of 2020. The name of the project was chosen to reflect the two main approaches to the project, i.e. the new material combination on the one hand and the intelligent process on the other.

In all, nine project partners participated in the design and construction of the production cell (**Title figure**). The production system was built at the Aachen Center for Integrative Lightweight Production (AZL), Germany, in collaboration with the Institute for Plastics Processing (IKV) at RWTH Aachen University, Germany. The research team's starting point for production of the demonstrator was state of the art conventional resin transfer molding technology (RTM). Comparison of the conventional technology with the iComposite 4.0 production system shows the cost reduction approaches that were followed (**Fig. 1**).

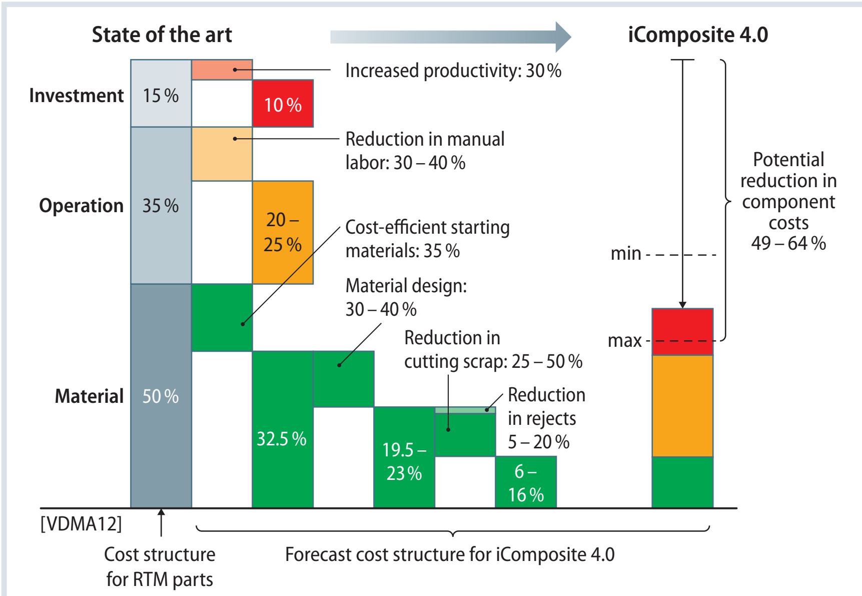

Fig. 1. Comparison of the conventional technology (left) and the research project shows the cost reduction approaches followed Source: Schuler; graphic © Hanser

Where the New Production System Saves Money

Summary of the key points:

- New multimaterial design: cost-efficient starting material with the focus on glass instead of carbon fibers.
- Less scrap: made possible by 3D fiber spraying of long glass fibers using rovings instead of rolls; no semi-finished product-based preform production necessary (**Fig. 2**).
- Economical use of carbon fibers: only employed as reinforcement in the form of a towpreg just a few millimeters wide.
- HP RTM: short cycle time through use of highly reactive epoxy resin system.
- Reduction in rejects: an intelligent self-regulating process takes into account variations in real time.

The reference component is a floor pan with a wall thickness of 2.15 mm, mounted under the engine and passenger compartment of an English sports car. Its structure must be designed for frontal impact, high torsional rigidity, and seat load.

The iComposite 4.0 System Step by Step

In the first production step, for which the Aachen Institute for Plastics Processing (IKV) is responsible, a robot sprays the basic structure of glass fibers. Then, an algorithm – developed by AZL and CRP supplier Teijin Carbon – calculates the individual tensile strength. Depending on this, another robot places the carbon fibers as required in a very specific process originally developed by Siemens and Broetje Automation Composites, so compensating for variations in component properties. Visual inspection is performed by a 3D measuring system from Apodius.

Resin is then injected into the composite fiber mat produced in this way. The resin cures under the high pressure of the Schuler hydraulic press, which finally shapes the component. Tool technology developed by specialists from Frimo also contributes to this process. For the required wall thickness, the press can directly influence the deflection of the tool. This makes it possible to produce good-quality parts right from the start, so reducing the reject rate. So far, manufacturers of fiber composite parts have been using carbon fiber mats as the starting material; these have to be cut at the beginning of the process (sequential preforms). This operation can reduce fiber utilization by up to 50 %, meaning that producers are wasting almost half of the expensive carbon fibers. With iComposite 4.0, the required fibers are placed in the form of towpregs just a few millimeters wide and are completely used up. At the same time, throughput time is decreased while output increases.

An integrated RFID chip from ID-Systec ensures traceability of the production data. All components of the production line operating at the RWTH Aachen AZL during the project were interlinked.

Concluding Evaluation

Particularly for lightweight design technology, where long process chains and material combinations are routine, linking quality control loops offers an excellent opportunity to make component production more robust and so more economic. In the iComposite 4.0 project, a method for designing such feedforward control loops was developed and implemented (**Fig. 3**). An important key to this is to combine individual processes in »

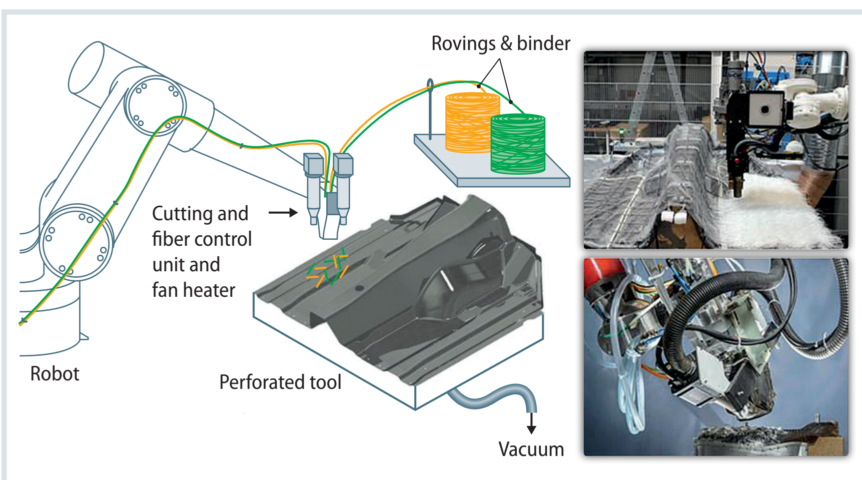

Fig. 2. In the 3D fiber spraying process, near-net-shape preform production is carried out directly from the roving Source: IKV; graphic © Hanser

such a way that a downstream process can detect and compensate for faults from the upstream process steps. For this purpose, a digital image of the component is used to predict its resulting properties for simulation and modeling. A target/actual value comparison combined with knowledge of the compensation function permits active adaptation of the product function by adapting individual process steps. This was demonstrated in the project, for example, by the adaptation of the reinforcing structure to the individual component.

The properties determined on the components produced by the fiber spraying process show that these parts have great potential for withstanding crash loads. The process can produce components flexibly and economically that are suitable for crash elements in automotive applications. As a rule, the development of fiber-reinforced composite parts takes place sequentially, starting with material selection, then design/simulation, followed by production and component testing. In the project, back coupling of an individual process (closed loop) was achieved by comparing the production result with the CAD design and simulation data. Through the new digital loop, deviations can be quantified and suitable countermeasures calculated. In this way, the basis for automated, self-adjusting production line control was created. For sustainable production of fiber-reinforced composites in the future, NX-CAx software from Siemens should be developed with integrated closed loops instead of the offline iteration loops demonstrated in the project, so making it accessible for inline process control. In the project, the congruent bending line in the RTM process has been made adaptive and adjustable for each production cycle. The influence of this on wall thickness was shown using the floor pan as an example. With this demonstrator component, the wall thickness could be changed by up to 0.5 mm, which – given a target wall thickness of 2.15 mm – has a considerable influence. Use of the adaptive congruent bending line is not just confined to the process in the project (3D fiber spraying and dry fiber placement) but can also be applied to other processes.

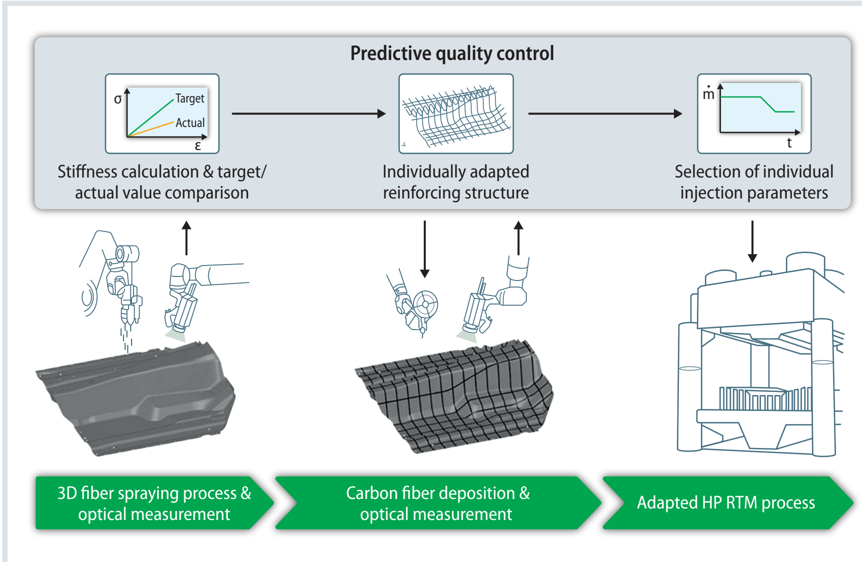

Fig. 3. The iComposite 4.0 production concept developed in the research project Source: AZL; graphic: © Hanser

Throughput Time Reduced by up to 42 Percent

The throughput time of the iComposite 4.0 production system ranges between 51.1 min and 41.4 min, depending on the design, and is therefore 28.1 to 41.6 % faster than the throughput time of the reference chain. Based on the calculations performed, a reduction in unit costs of over 60 % and in throughput time of up to 42 % can be expected in comparison with the reference process. The calculations are based on a scenario that assumes sufficiently accurate measurement to calculate the compensation measures and automated production of the demonstrator component.

Besides these numerous potentials that result from the use of feedforward control loops, some limitations of the control loop described were also identified. Precise control of flexural, torsional and tensile stiffness cannot be achieved with the compensation algorithm developed because the different stiffening effects of the towpregs for the three specific load cases of tension, torsion, and flexure and the resulting different compensation requirements are not compatible. If oversizing of individual values is not acceptable, another compensation measure must be used. The extent to which the removal of material is possible to reduce local properties must also be discussed. Precise determination of target values is also essential for the control process.

Even though not all the approaches followed in the project could be realized, the project partners see the project as being successful overall. The methods developed are suitable for the design of feedforward control loops, particularly for multistep process chains, and can be applied to other process chains and further developed in the future. The automated, self-optimizing production system and the reduction in unit costs and throughput times show what economic production of fiber-reinforced plastics can look like in future. ■

Susanne Schröder

Acknowledgment

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Service

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Five Questions to …

… Patric Winterhalter, Product Manager Composites at Schuler Pressen GmbH, Waghäusel, Germany.

So far, carbon fiber-reinforced plastic components have always been too expensive for the automotive industry. Have you come to different conclusions in your research project?
We can change nothing about carbon fibers except use them sparingly. The overall approach is to use glass fibers as an economic base material and only employ the far more expensive carbon fibers where their higher mechanical performance is required. At which points this is necessary will be determined by FEM simulation.

Another important point is cutting scrap. How can you save on this?
In the classic RTM process, the reinforcing material is in roll form. This gives rise to a large amount of scrap when cutting the component contour using a textile preform. In the 3D fiber spraying process used by us, rovings are employed instead of rolls. This eliminates sequential preform production and the material is only sprayed where it is needed.

Were there any special requirements for the press in your project?
Some years ago now, Schuler developed a press design with a congruent bending line that counteracts the deflection of the ram and table plate. In this way, we achieve a harmonic deflection ratio and constant wall thickness. We have raised this technology to a new level for the research project. With a self-optimizing process, we can now set close tolerances, even for thin-walled components.

Does adaptive mean a system that adjusts to changing conditions in real time?
Yes. We can take into account, for example, when more material has been applied at a particular point – then the press closes with increased or decreased pressure. Through this adaptivity, adjustment of wall thickness to 0.5 mm is possible.

Were there sensors in the mold?
Yes, including for pressure and temperature, but not for measurement of our component. To be honest, I must admit that the state of development of the sensors at the time of the research project was unfortunately not as far advanced as we would have wished. We obtained the control parameter information for the press process using optical measuring methods. Carbon fibers are electrically conductive; in addition, a chemical exothermic reaction takes place that generates intense heat. This combination of factors and extremely fast control accuracy meant that we were unable to use sensors to measure the thickness of the component. That would require further development of this technology, which we have actually discussed in the outlook section of our project completion report.

Interview: Susanne Schröder

Patric Winterhalter, Product Manager Composites at Schuler Pressen GmbH © Schuler

Asahi Kasei Introduces a Semi-Aromatic Polyamide to the European Market

Excellent Processability and Good Surface Quality

Asahi Kasei Europe GmbH, Düsseldorf, Germany, is introducing the Leona SG series, a new semi-aromatic polyamide, to the European market. It is available in grades reinforced with 40%, 50 % and 60% glass fiber. Even with a high glass fiber content, it features a good surface quality and gloss at shorter cycle times. This can be achieved without additional surface treatment or additional coating.

Furthermore, according to the company, the material offers an excellent inherent mechanical strength even under moisture. In a conditioned state the 50% glass fiber filled SG105 shows a clear superiority compared to standard and other semi-aromatic polyamides: while standard PA66 shows a deterioration of 30% in tensile modulus compared to its dry state, SG105 maintains its performance. In addition, SG105 shows an 8% better flexural strength than comparable semi-aromatic polyamides

Application fields inside the automotive include venting blades, armrests, covers or door handles. The material also can be used in other areas, for example as a replacement for metal die casting in construction, industrial or furniture parts.

To the product presentation:
www.kunststoffe-international.com/a/article-312602

Premium-looking automotive interior surfaces are growing in importance. To address this growing demand, Asahi Kasei is introducing the semi-aromatic polyamide Leona SG series to the European market © Asahi Kasei