SPECIAL:
LIGHTWEIGHT CONSTRUCTION

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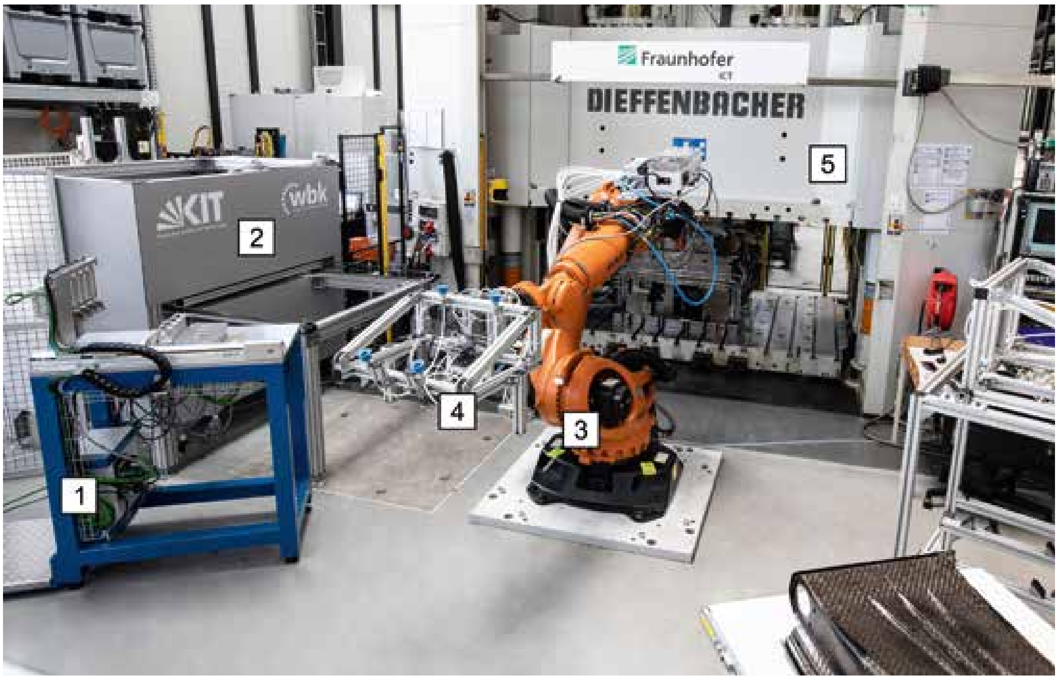
Modular Thinking

Development of a Production Plant for Hybrid Fiber Composite Components

"The right material in the right place" is the maxim of the multimaterial design. A lack of economical production methods has so far prevented commercialization at current batch sizes. To overcome this obstacle, a modular control and production plant concept was developed and demonstrated in the MoPaHyb collaborative project.



MoPaHyb automation cell of the reference plant with feeding module for metallic inserts (1), heating module (2), robot (3), gripper system (4) and hydraulic downstroke press (5) (© Fraunhofer ICT)

Many research activities in the automotive and supply industry are currently driven by overarching trends such as increasing energy and resource efficiency. At the same time, the industry faces economic and competitive challenges. This is due for example to increasingly dynamic product life cycles, variant diversity and smaller batch sizes.

A highly promising approach is the use of new, lightweight construction materials and material combinations of metallic and fiber-reinforced plastic components. Producing these composites in a direct or forming process is commonly referred to as intrinsic hybridization. The advantage of this process is that joining can potentially be avoided and dependent processes reduced. Fiber-reinforced plastics (FRPs) and intrinsic hybridization enable the manufacture of products with improved component weight, integrated functions and the potential for component substitution.

However, the production of intrinsic hybrids poses significant challenges to the industry. Mechanical engineering and plant construction approaches have not yet achieved economically viable production plants for this growing market that can also meet the specific requirements for processing or integrating FRPs and metallic structures. The manufacturing process has so far been adapted to component-specific requirements, or carried out on specialized and investment-intensive production lines. A consortium of 14 partners has therefore developed a concept for the production of intrinsic hybrids, which was successfully validated by a reference system at Fraunhofer ICT in Pfinztal, Germany (**Title figure**).

Elements of a Modular Plant Architecture

"Plug & work" functionality, fast and efficient plant retooling and integrated engineering, i.e. intelligent equipment that can independently translate raw data into process control, are the three requirements identified as essential to the modular production concept. The basic principle is a unified plant architecture. Individual components are designated as production modules and equipped with standardized communication interfaces. The individual elements are linked via a central line control, which is the basic module. The OPC Unified Architecture (UA) communication protocol is used to ensure manufacturer- and platform-independent communication. The modules function as servers and the superordinate basic control as the client. A standardized status description of the production modules completes the plant architecture as far as the software is concerned.

In addition to the simple plant control for component manufacture, the superordinate basic control fulfills two further basic requirements of a production line. Quality assurance modules ensure component-specific quality monitoring, and safety-related communication via Profisafe (communication standard for the IEC 61508 safety standard) is also integrated. The latter can be individually adapted to the respective line via the basic control.

Adaptability of the Production Line

The hardware and software adaptation of a production line to a specific component begins with the generation of a PI sheet. The modular system developed by the wbk (the Institute of Production Technology at the Karlsruhe Institute of Technology, KIT-wbk), which is an operating-system-independent web application, is used for this purpose. By this means a suitable manufacturing process is selected for a specific component. The required production modules are chosen from a library structure and combined by drag-and-drop, and the executable and parameter-based functions and any process limits are stored for each individual module. For example, for an injection molding module the functions "dosing", "injection" and "holding pressure" would be included, and a parameter for the function "dosing" would be the dosage volume.

The PI sheet is exported into AutomationML, which is a high-level language independent of the manufacturer. It serves as the basis for the line »

Fig. 1. Seat backrest demonstrator for process route 1 with molded-on reinforcing ribs and metallic inserts (© Fraunhofer ICT)

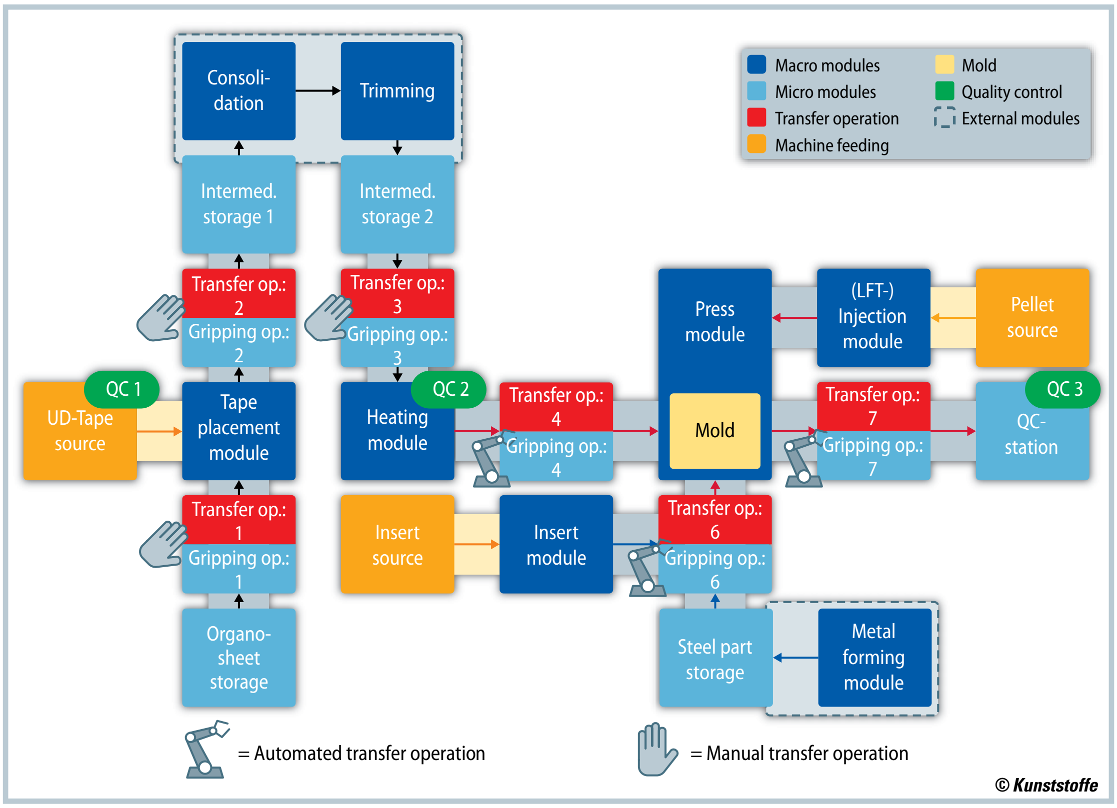


Fig. 2. Schematic diagram of process route 1. Automated transfer operations (AT) or manual transfer operations (MT) show when the operator must intervene or when the process is carried out automatically (© KIT-wbk)

Fig. 3. Modular LFT injection molding module coupled with a hydraulic downstroke press for thermoforming and back-injection of laminated semi-finished products (© Fraunhofer ICT)

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control. Siemens AG, Nuremberg, Germany, together with its subsidiary Evosoft GmbH, developed a code generator that automatically translates the PI sheet into a programmable logic controller (PLC).

Demonstration on the Reference Plant

The approach was validated on a reference plant at Fraunhofer ICT, on which two demonstrator components were manufactured. The aim was to demonstrate both the configuration and the reconfiguration with two different process routes: process route 1 focused on hybrid injection molding technology and process route 2 on extrusion pressing for long-fiber-reinforced thermoplastics (LFTs). This included the integration of an intelligent tape laying process, the development of a modular LFT injection molding unit for connection to the existing press at Fraunhofer ICT as well as gripping systems for semi-finished FRP products and investigations to optimize the metal FRP interfaces.

The first demonstrator was a seat backrest (based on the collaborative project Camisma, **Fig. 1**) from the automotive sector. The required production line (configuration 1) combines continuous-fiber-reinforced thermoplastic UD tapes and composite laminates through a long-fiber-reinforced injection molding compound and metallic load-introduction and reinforcement elements within an intrinsic joining process (**Fig. 2**). The following modules developed by the project partners were applied:

- A flexible tape laying module Fiberforge from the company Dieffenbacher, for the production of laminar semi-finished products from composite laminates with patched, local UD tape reinforcement.
- An injection molding module SPE 4600 from Arburg, incl. fiber direct compounding unit (FDC), in combination with a hydraulic downstroke press from Dieffenbacher (**Fig. 3**).
- An IR heating module developed by KIT-wbk for heating laminar semi-finished products.
- A highly-flexible feeding module from A. Raymond for the automated and individual supply of metallic load-introduction elements.
- A handling module, consisting of a Kuka robot in combination with grippers developed by the KIT-wkb and gripper technology from the company J. Schmalz.
- A feeding module for metallic reinforcing elements that are sequentially formed on a Trumatic from Trumpf.

Project Partners

- Adient LTD. & Co. KG, Burscheid, Germany
- A. Raymond GmbH + Co KG, Lörrach, Germany
- Arburg GmbH + Co KG, Lossburg, Germany
- Dieffenbacher GmbH Maschinen- und Anlagenbau, Eppingen, Germany
- Dr. Ing. h.c. F. Porsche AG, Stuttgart, Germany
- J. Schmalz GmbH, Glatten, Germany
- Kuka AG, Augsburg, Germany
- PTKA – Projektträger Karlsruhe, Germany
- Siemens AG, Nuremberg, Germany
- Trumpf GmbH + Co KG, Ditzingen, Germany
- Vitronic Dr.-Ing. Stein Bildverarbeitungssysteme GmbH, Wiesbaden, Germany
- VDMA Arbeitsgemeinschaft Hybride Leichtbau Technologien, Frankfurt, Germany
- wbk Institute for Production Technology at Karlsruher Institute of Technology (KIT), Karlsruhe, Germany

- A basic module from Siemens, for the centralized line control of the reference plant.
- Quality assurance modules from Vitronic.

The hybrid FRP underbody segment (developed in the collaborative project MaiQFast, **Fig. 4**) of the second process route served to illustrate the hardware and software adaptability of the reference plant and the MoPaHyb approach (modular production plant for hybrid components). The underbody segment consists of a local continuous-fiber reinforcement made from thermoplastic UD tape combined with an LFT extrusion compound. For the production of this demonstrator, the injection molding module was replaced by a continuously operating LFT-D extrusion press module. This also demonstrated the plant's potential for integrating continuously operating modules into a sequential manufacturing process. The retooling and restarting of the automated production line in configuration 1 could be carried out within a few hours and thus successfully demonstrated and validated.

Fig. 4. Underbody segment of process route 2 with reinforcing ribs formed through extrusion compression molding (© Fraunhofer ICT)

Conclusion

The modular production plant concept, developed in combination with the large-scale processing approach, offers the potential to produce thermoplastic hybrid structures economically in the future. The basic modular idea is not limited to intrinsic hybrids, but can be extended to any production plant. In addition, it was shown that existing production plants can also be cost-effectively integrated into the MoPaHyb approach through hardware and software upgrades. ■