EDITION MARCH 2021

AVK COMPOSITES REPORT 03

Innovative

PROCESSES AND PROCESS TECHNOLOGY

CONTENT

REPORT 03

Dear reader,

Our current Composites Report primarily centres around the topics of innovative processes. There are so many innovations in the realm of fibre-reinforced plastics, and for several years now there has been a special focus on the various thermoplastic processes. These can be applied in a variety of ways, and the end of the development is not yet in sight. The market share in this segment is continually increasing.

Moreover, tried and tested processes such as SMC technology have shown, not only through many innovations, that they are extremely attractive and have reached a high level of technology. Yet the research projects in this issue cover a much wider range. You can therefore look forward to a surprisingly large number of news items – including a winner of the AVK Innovation Award.

Kind regards,

Elmar Witten,
AVK Managing Director

Imprint
AVK – Federation of Reinforced Plastics
Am Hauptbahnhof 10, 60329 Frankfurt am Main,
Fon: +49 69 271077-0, Mail: info@avk-tv.de,
Homepage: www.avk-tv.de
Managing Director: Dr. Elmar Witten

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LEIBNIZ-INSTITUT FÜR POLYMERFORSCHUNG DRESDEN E. V. – IPF

Tailored fiber placement on rCF-nonwovens

Authors: Dr. Kai Uhlig, Katharina Heilos, Marcel Hofmann, Dr. Axel Spickenheuer

Within the SAB-project "Tailored fibre placement (TFP) on recycled carbon fibers (rCF) nonwovens" (InfraPro-Projekt, 100319942), the project partners Leibniz-Institut für Polymerforschung Dresden e. V. (IPF) and Sächsisches Textilforschungsinstitut e. V. (STFI) investigated the applicability of rCF-nonwovens for the Tailored Fiber Placement (TFP) process and the production of carbon fiber reinforced plastics (CFRP) with high stuctural properties containing a significant proportion of recycled carbon fibers.

By combining primary carbon fibers (pCF) deposited in the TFP process with an anisotropic or quasi-isotropic nonwoven structure made of recycled carbon fibers (rCF), it is possible to produce load adapted semi-finished products with a recycled fiber fraction of ≥ 50 %. With the help of new design tools like the software EDOstructure load adapted variable-axial fiber layouts can be automatically generated, which compensate the reduced mechanical properties of rCF nonwovens compared to pCF-based semi-finished products such as non-crimp fabrics or woven fabrics.

The research partners developed 100 % rCF nonwovens for CFRP with thermoset matrices and hybrid nonwovens consisting rCF and PA6.6 staple fibers for CFRP with thermoplastic matrices. In the hybrid nonwovens, the PA6.6 staple fibers are used to provide the matrix material for the pCF rovings fixed by a PA6.6 sewing thread developed in the IPF.

In the project, different nonwoven forming processes (Airlay & Carding process) were tested, grammage as well as rCF-PA6.6 mixing ratios of the nonwovens were varied and extensively characterized. The suitability of the nonwovens for the TFP process was evaluated by a benchmark embroidery pattern developed with the software EDOpath. The rCF and rCF-PA6.6 nonwovens developed by STFI exhibited an excellent TFP process reliability, an extraordinarily good draping and infiltration ability as well as in the consolidated state a higher energy absorption capacity up to total failure. The developed semi-finished products were further processed to CFRP either by the RTM process, by hand lamination and by hot pressing. With the RTM process a fiber volume content of about 35 vol% could be achieved. The 100 grams light demonstrator part „Bike Saddle“ (Fig. 1) proved that with the developed approach particular complex, double-curved geometries based on a one-piece preform design can be realized as a competitive high-performance lightweight component with an rCF content of more than 50 %.

Fig. 1 Bike saddle – preform and final part

Diese Maßnahme wird mitfinanziert durch Steuermittel auf Grundlage des von den Abgeordneten des Sächsischen Landtags beschlossenen Haushaltes.

Europäische Union

Europa fördert Sachsen. EFRE Europäischer Fonds für regionale Entwicklung

The SAB project Carbonstickgrund (InfraPro project, 100319942) was funded by the European Regional Development Fund (ERDF) and by the Free State of Saxony.

TU DRESDEN INSTITUTE OF LIGHTWEIGHT ENGINEERING AND POLYMER TECHNOLOGY – ILK

3D PRINTING OF CONTINUOUS FIBER-REINFORCED COMPOSITE STRUCTURES WITH (UV-)LIGHT

Development of an additive manufacturing process for continuous fiber-reinforced plastics based on light-curing reactive resin systems.

Author: Sirko Geller

D3D printing is regarded as one of the future technologies for economical, resource-efficient and individualized component production. However, the advantages of established processes based on thermoplastics in terms of simple process control due to their hot melt behavior and the availability of preimpregnated fiber-reinforced printing filament are often offset by low heat resistance and very high processing temperatures. In contrast, thermosets have high glass transition temperatures, good adhesion properties and low viscosities, but often exhibit long curing times. To address this topic, scientists at the TU Dresden Institute of Lightweight Engineering and Polymer Technology (ILK) have developed a novel manufacturing process based on highly reactive, UV-light-curing thermosetting resins for continuous fiber-reinforced structural components as part of the research project 3D³ funded by the Sächsische Aufbaubank (SAB).

UV light-curing resins exhibit excellent thermo-mechanical properties and extremely fast curing. The new processing technology comprises the following steps: impregnation of a continuous fiber filament (roving) with the reactive resin, exposure of the resin to UV-light to activate a photoinitiator, and then deposition of the wet fiber. Due to the dark cure behavior of the resin, the curing reaction continues after exposure to UV-light. Oscillating UV-rheological measurements and printing process studies yielded a comprehensive understanding of the manufacturing technology. The relevant process parameters for the 3-component resin system - exposure time and UV-light intensity, as well as printing speed - must be tuned in a way that gelling occurs right after fiber deposition.

Post-curing can be achieved at room temperature or in a downstream post-cure step at elevated temperatures.

Fig. 1: Automated manufacturing cell for 3D-printing of continuous fiber reinforced composite parts

Fig. 2: Robot-guided print bed

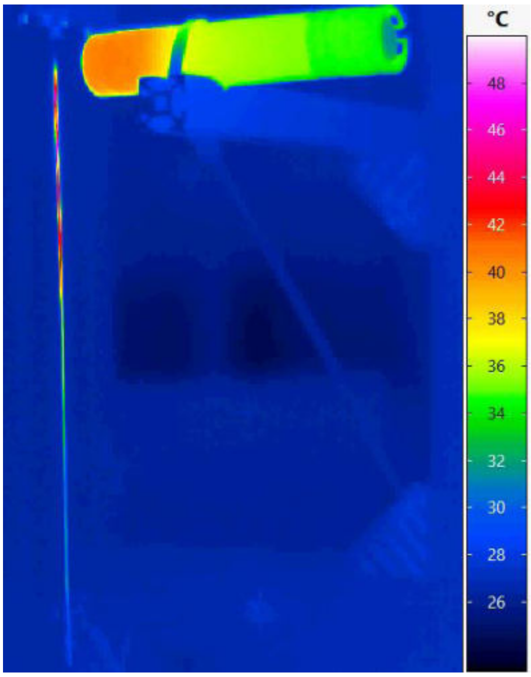

Fig. 2: Process study via thermal imaging to evaluate the curing reaction of an impregnated fiber roving while exposure to UV-light (UV-light source at the top)

To implement the new 3D printing process, an automated manufacturing cell with a robot-guided print bed and stationary print head was developed. The core element of the manufacturing cell is the highly integrative printing head developed at the ILK. It consists of a metering pump with static mixer, the impregnation tool with fiber-adapted roving feed and a self-developed, individually adjustable UV-LED exposure unit, which is responsible for initiating the crosslinking reaction. A ceramic nozzle is used to deflect the partially crosslinked roving into the printing direction. To achieve high process efficiency, a comprehensive parameter study aims at the definition of an optimized process window, which ensures the highest possible deposition speed. Further research work involves 3D printing of specimens for material testing and the deposition of curved path patterns for parts with high geometric complexity.

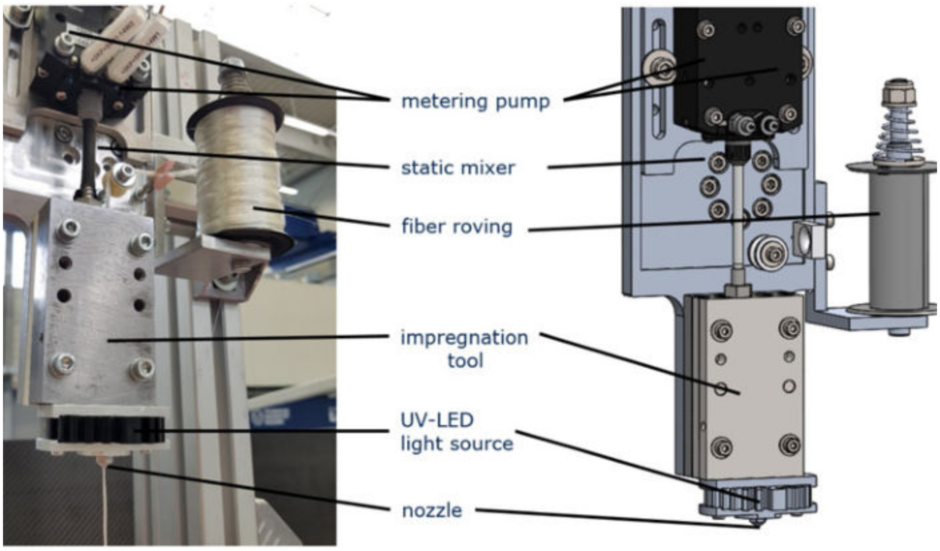

Fig. 3: Print head for 3D printing of continuous fiber-reinforced polymers with its basic components (left), detailed view of CAD-model of the print head (right)

AZL – THE AACHEN CENTER FOR INTEGRATIVE LIGHTWEIGHT PRODUCTION OF RWTH AACHEN UNIVERSITY

INCREASING PROCESS UNDERSTANDING FOR LOCALLY CONTINUOUS FIBRE-REINFORCED SMC

by means of automated coupling of production and test data with process and structure simulations

In cooperation between the Aachen Center for Integrative Lightweight Construction (AZL) and the Institute for Plastics Processing (IKV), a method is being developed that uses mechanical end-of-line testing to draw conclusions about the internal morphology of locally reinforced SMC components and, in combination with process simulations, provides information about the causes of property deviations.

Authors: Dr. Kai Fischer, Dr. Michael Emonts, Hao Wang, Jonas Neuhaus

With low material costs and scrap losses as well as the potential to produce geometrically complex and functionally integrated components, SMC is an attractive material for cost-efficient lightweight construction. The potential for lightweight construction can be increased in a cycle-time-neutral manner by, among other things, the process-integrated and load path-compliant introduction of towpregs based on continuous carbon fibres, which makes attractive solution concepts possible, particularly in weight- and cost-sensitive areas of application.

When SMC is processed by compression moulding, deviations in the material and process parameters are well known to have a strong influence on the component properties. The influencing factors are additionally increased by the continuous fibre inlays.

As part of the „HybridSMC“ project with four other partners, a method is therefore being developed, in addition to the process technology, to investigate the material/process/property interactions of this material combination. By using a modular SMC press tool, investigations of process parameters and resulting component properties are made possible (Fig. 1). The parts are manufactured on the AZL‘s large press (clamping force up to 18,000 kN, 2x3 m² table size), which demonstrates the immediate economic and large-scale feasibility of this technology.

By means of a non-destructive inline characterization implemented at the AZL, component deformations and surface strains resulting from different elastic deformation modes (e.g. bending) can be measured. The measuring cell was developed and implemented specifically for this application. It consists of a flexibly configurable test frame, and the load is applied via a high-precision servo motor. In addition to measuring the test load at the servo motor, the displacements and the surface strains are successively recorded with a fine resolution high speed 3D measurement device (ATOS 5, GOM GmbH, Braunschweig)

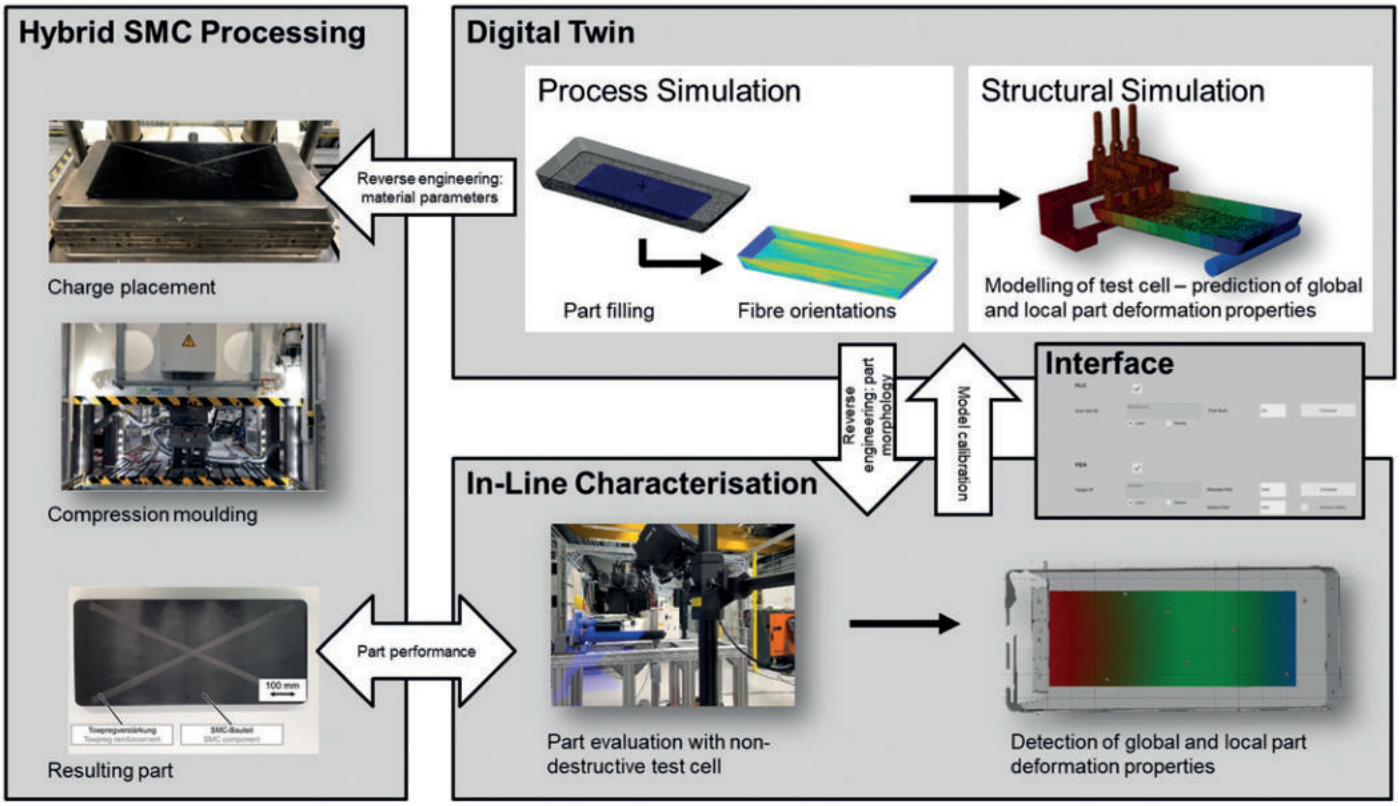

Fig. 1: Concept for coupling in-line testing with various simulation tools

during the application of the deformation steps. The results are automatically transferred from the test station to a finite element simulation via an interface developed at AZL. The results are then transferred back and made available on the machine for comparison purposes. In the further course of the project, the data and interfaces will also serve as a basis for coupling the measurement data with the modeling approaches available at the IKV for coupled process and structure simulations, which will enable conclusions to be drawn in a re-engineering approach about the local fibre orientations and about process influences acting during processing.

EUROPEAN UNION
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The research project „HybridSMC" (No. EFRE-0801121) is supported by the European Regional Development Fund (ERDF). Our thanks go to all institutions.

CONBILITY GMBH

KEY-READY MACHINE SYSTEMS

for the Production of Fiber-reinforced Thermoplastic Tailored Composite Blanks and Parts

Authors: Dr. Michael Emonts, Dr. Kai Fischer

Tailored composite blanks made of unidirectional fiber-reinforced thermoplastic tapes are a key-technology to reduce production costs for continuous fiber-reinforced thermoplastics - either within thermoforming and subsequent injection overmolding or as stiffening insert structures to reduce wall thicknesses in injection molded components or to substitute stiffening ribs. To achieve a repeatable subsequent thermoforming and a fast, homogeneous heating of these blanks, a consolidation of the tape layers of the blanks is necessary.

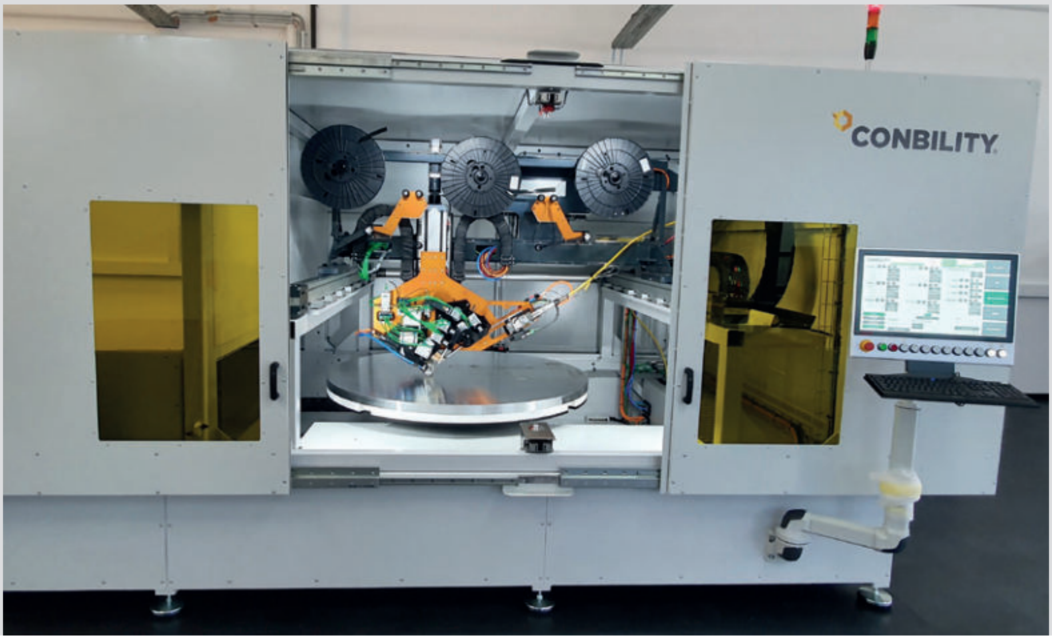
Like CONBILITY´s 3D tape placement heads, the new 2D tape placement machine uses laser radiation to directly weld the tapes together during the placement process (in-situ consolidation) with a minimum of energy effort in comparison to energy-, time- and cost-consuming post-consolidation processes. By that, the blanks can be directly processed further in classical thermoforming or in one-shot forming and overmoulding processes.

The new table-based 2D tape placement machine is laser safe (laser safety class 1) and equipped with a 3-spool tape placement applicator, a rotating heating table (1,5 m diameter) and a 4 kW laser system. Each tape can be processed individually by “add-and-cut on the fly” and has a closed-loop tape tension control unit. The machine can be configured according to customers´ requirements (table diameter, laser power, number of spools on the applicator, tape widths) and due to the precise and fast closed-loop controlled laser-assisted heat input, any tape material can be processed reproducibly at high speeds without overheating: from PP to PEEK tapes.

A first “proof of principle” prototype machine has been developed within a bilateral research project in cooperation between Conbility and Fraunhofer IPT, Aachen and has been further enhanced by the engineers of Conbility GmbH to an industrial suited machine product which is available on the market and currently successfully introduced into several industrial applications of different customers. Due to the small machine footprint (approx. 5 x 2,5 x 2,6 m³) it can be flexibly arranged on the shop floor and integrated into fully automated production lines. Besides the in-situ consolidation, this machine system allows for the production of tailored blanks with different wall thicknesses within on laminate. This 2D machine system is installed at CONBILITY´s technical center in Herzogenrath near Aachen and available for trials, evaluations and job-shop manufacturing of parts and laminates.

Additionally, the machine product portfolio of CONBILITY includes a 3D tape placement and winding applicator which can be integrated modularly as a “plug-in” into existing robot or machine systems. CONBILITY also offers complete key-ready and laser-safe manufacturing cells comprising the robot system (with optional linear axis), winding axis, heating table and 3D tape placement and winding applicator for both laser-assisted tape winding of rings, tubes and vessels as well as 2D and 3D placement of tailored composite sheets or local tape-stiffening of injection molded parts.

USP of CONBILITY´s 3D tape processing applicator is its multifunctionality: it can be used for dry fiber placement and upgraded with a backing paper unwinding unit and a cooled guidance system for the processing of thermoset prepregs: One investement for 3 different technologies. CONBILITY´s 3D applicator is already



CONBILITY 2D Tape Placement Machine with integrated 4 kW laser (right) and 3D Tape Placement and Winding Head (left)
Machine Process Video:
https://youtu.be/Q_pKDH006xo

in use by international customers from different countries: Germany, Spain and Ireland.

Currently, CONBILITY is setting up a manufacturing cell for laser-assisted thermoplastic tape winding and placement within the technical center in Herzogenrath which will be available for trials, evaluations and job-shop manufacturing of parts and laminates in spring 2021.

DEUTSCHE INSTITUTE FÜR TEXTIL- UND FASERFORSCHUNG DENKENDORF – DITF

Innovative method
to study the effect of internal mold release for pultrusion process

Authors: Sathis Kumar Selvarayan, Prof. Markus Milwich, Götz T. Gresser

The production of continuous fiber-reinforced profiles with a constant cross-section by means of pultrusion offers enormous economic advantages over other discontinuous composite manufacturing processes. However, the process requires elaborate determination and precise control of the process parameters, especially for the production of high-quality composite profiles, e.g. with epoxy matrix. Fig. 1 shows a schematic of the process dynamics prevailing in the pultrusion die. This is influenced, among others, by the combination of fibers (incl. sizing), matrices and additives. Important additives are internal mold release (IMR), which reduce the friction between the fiber-matrix mass and the die wall and prevent the matrix from sticking to the die wall. If the IMR is dosed too low or not chosen appropriately for the overall system, the frictional resistance can become so high that the profile breaks off after the die. So far, however, there are no easy-to-use methods available to quantify the effect of IMR for a given fiber-matrix combination in pultrusion, so that elaborate preliminary tests have to be carried out.

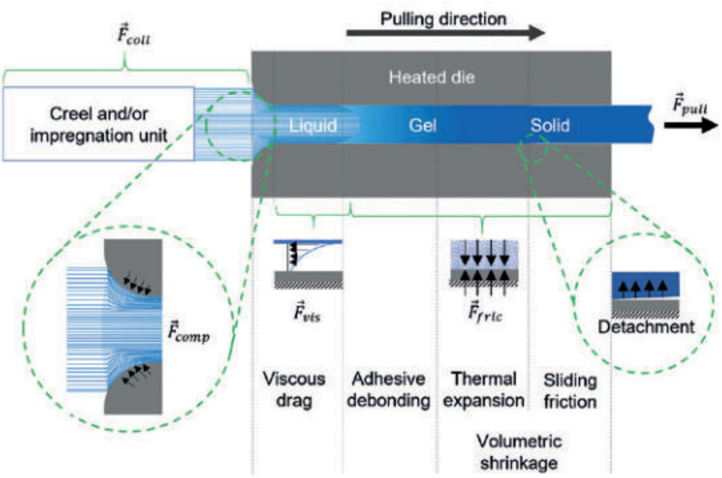


Fig. 1: Die dynamics of a thermoset pultrusion process

SIMULATION OF DIE DYNAMICS

As part of a research project at the DITF, the novel, swift and resource-efficient „Rotating Core“ method and a corresponding apparatus, called „Die Dynamics Simulator (DDS)“, were developed. This allows the efficacy of different IMR and their concentrations to be quantified in advance of pultrusion and the pultrusion process parameters to be determined for a given fiber-matrix combination. Fig. 2 shows the newly developed approach. Essentially, linear pultrusion is transferred to a rotating system.

Fig. 3 shows the „Die Dynamics Simulator DDS“. Pre-impregnated rovings are wound onto a cylindrical core with a defined fiber volume fraction. The wound core is inserted into a hollow cylindrical heated die and set in rotational motion. The rotational speed of the rotating core is set to be identical to the line speed of the pultrusion process. The fiber-matrix mass polymerizes during rotation to form the solid composite material. This mimics the phenomena that occur in a pultrusion die.

The DDS continuously measures the torque exerted by the rotating fiber-matrix on the DDS die during the consolidation process. The measured torque represents the drag forces generated within the pultrusion tool during the consolidation of the fiber-matrix combination. With the DDS, it is possible for the first time to quantify the dynamics of a pultrusion process.

DDS experiments with different concentrations of IMR confirmed the validity of the method and clearly showed the differences in evaluating the developing drag forces within the die (Fig. 4). The results also provide information on which polymerization phase of the matrix the IMR are most effective. Subsequently, the developed methodology is validated by means of a pultrusion experiment. The comparison of the measured forces on the DDS with those on the pultrusion system shows good agreement. The new approach is further used to investi-

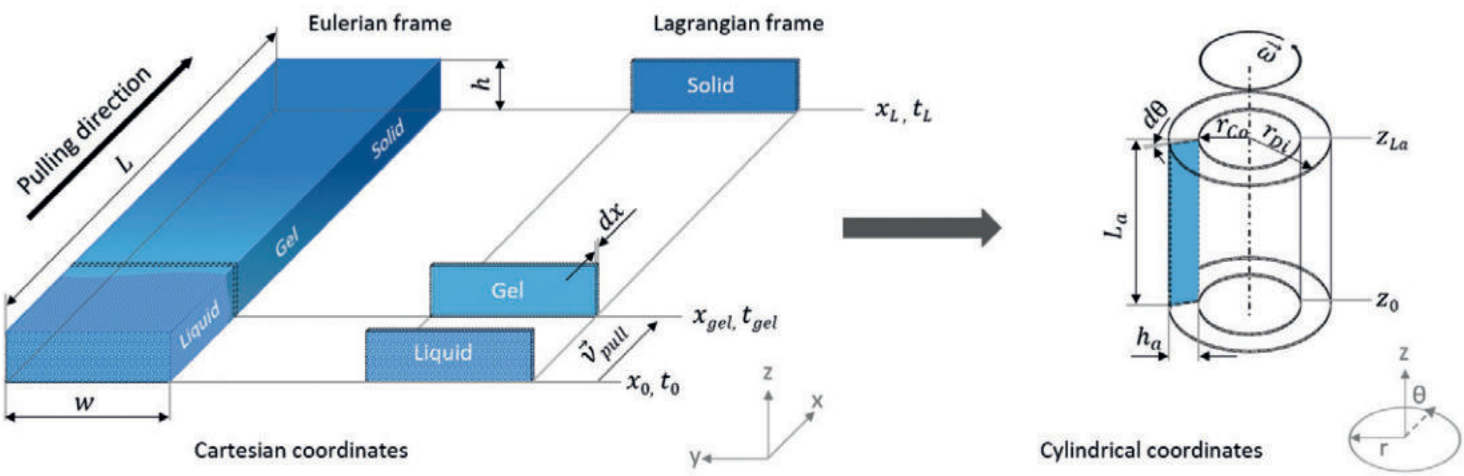


Fig. 2: Rotating core method – Transformation of linear pultrusion process (left) to rotational process (right)

gate the influence of the following parameters on the die dynamics: (1) die temperature, (2) fiber-matrix velocity, (3) die and fiber-matrix contact area, (4) part thickness, and (5) fiber volume content.

Therefore, the application of the patented rotational core method can be extended to the determination and optimization of the process parameters, the resin formulation, the additives as well as the tooling prior to processing the material combination on a pultrusion line. For the DDS, only a few grams of material are needed to analyze the process dynamics. Compared to previous optimization trials on the production line, DDS trials require very little time. Both advantages therefore result in an enormous economic benefit.

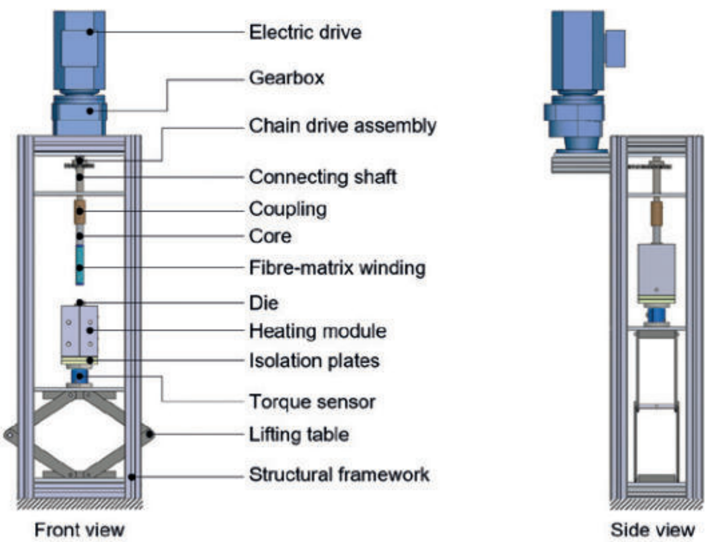


Fig. 3: Die dynamics simulator - DDS

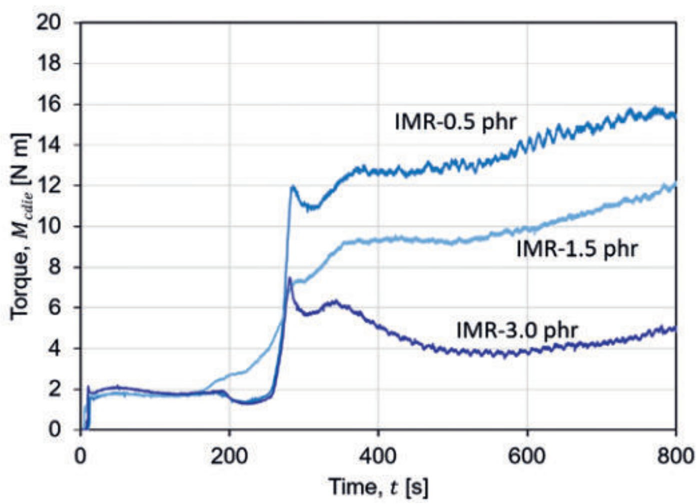


Fig. 4: Torque-Time curves showing measured torques with fibre-matrix formulations having varying concentration of IMR: 0.5 phr, 1.5 phr and 3.0 phr

FRAUNHOFER INSTITUTE FOR CHEMICAL TECHNOLOGY – ICT

VliesSMC

Processing of recycled carbon fiber nonwovens in sheet molding compound

In the series production of fiber reinforced plastic components, several hundred tons of carbon fiber, containing woven and knitted fabric production waste is generated every year. This corresponds to up to 40 % of the material used in the processes. The potential for cost savings by returning the new waste materials to high-quality applications is therefore significant.

Authors: Florian Wafzig, Patrick Griesbaum, Fraunhofer-Institut für Chemische Technologie ICT; Marcel Hofmann, STFI Sächsisches Textilforschungsinstitut e.V.

Within the research project VliesSMC, the suitability of different types of nonwovens based on recycled carbon fibers (rCF) for processing in the SMC process chain is investigated. In particular, open questions regarding the different textile manufacturing processes, production and handling of SMC semi-finished products, as well as the flowability in the compression molding process are addressed.

The following research topics are being pursued in the project:

- Development of adapted nonwovens made from recycled carbon fibers
- Influence of different web formation methods on the impregnation quality and the flowability of the SMC semi-finished product
- Equipment and process development with the aim of automated processing of rCF-nonwovens in the SMC process chain
- Limits of part complexity in the molding process of rCF-SMC depending on the achievable fiber volume content
- Cost analysis and economic feasibility study of the VliesSMC recycling process

The processabilty of rCF-nonwovens in the SMC process chain was successfully demonstrated in a first test campaign. The system technology is currently being set up at the Fraunhofer ICT and adapted for processing of nonwovens.

The mechanical entanglement of the individual fibers due to the bonding of the nonwoven material represents a fundamental difference to conventional SMC materials based on cut fibers. Unhindered fiber transport during compression molding is consequently not possible. To minimize the influence of mechanical fiber entanglement, investigations are carried out along the entire process chain. The nonwovens are characterized regarding their elongation at break and tear strength. The homogeneity of the nonwovens in terms of weight per unit area and isotropy is also of interest.

Regarding the SMC semi-finished product production step, the focus is on the handling and impregnation of the nonwovens. An automatic, speed-controlled unwinding ensures that the fabric is fed into the system without tension. This enables the use of very low-strength nonwovens with little mechanical entanglement of the individual fibers. Rheological characterizations support the development of semi-finished products. The impregnation

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The IGF project „VliesSMC" (No. 21124 BG) of the research associations DECHEMA Society for Chemical Technology and Biotechnology e.V. and Forschungskuratorium Textil eV is funded by the Federal Ministry for Economic Affairs and Energy through the AiF as part of the program to promote industrial community research (IGF) funded by a resolution of the German Bundestag.

Fig. 1: Nonwovens production at STFI (Source: STFI/D. Hanus)

Fig. 2: SMC line at Fraunhofer ICT (Source: Fraunhofer ICT)

quality is ensured by a complete monitoring of the system parameters as well as microscopic examinations of the semi-finished products and cured materials.

To evaluate the fiber transport during compression molding, flow tests are carried out to determine the maximum flow distance. Using in-mold sensors, pressure and material progress in the mold are monitored.

The VliesSMC materials are mechanically characterized and compared to conventional SMC. Furthermore, investigations of the achievable surface quality are carried out. A project-accompanying committee, which includes material and equipment manufacturers as well as processing companies, ensures that the developments are relevant to industry and that they can be directly implemented.

Project partners:

Fraunhofer ICT

stfi

In Cooperation with:

DECHEMA Gesellschaft für Chemische Technik und Biotechnologie e.V.

Forschungskuratorium textil

AiF iGF

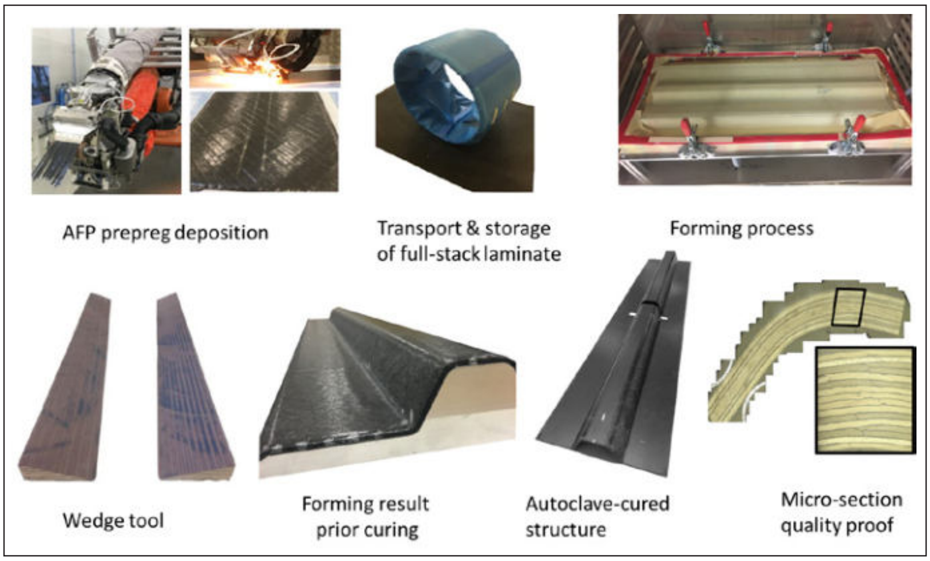
DLR – DEUTSCHES ZENTRUM FÜR LUFT- UND RAUMFAHRT
GERMAN AEROSPACE CENTER

„OMEGA-STRINGER FROM THE ROLL"

Author: Dr. Erik Kappel

Large-scale prepreg-made composite structures, such as wing covers and fuselage skins, are made in automated fiber placement (AFP) und tape laying (ATL) processes today.

In contrast, making profile-like composite stiffeners, and in particular hat-shaped-stringers, is dominated by manual processes, due to the fact that the small cross-section dimension of a few centimeters, with its angled shapes, cannot be created with reasonable deposition rates with today's bulky AFP/ ATL heads. When it is recalled that multiple kilometers of stiffeners are required for a single A350 aircraft, the demand for innovative processes with elevated production rates becomes obvious.



As prepreg laminates are deposited flat, AFP technology is applied effectively. By considering multiple stringer laminates in a common deposition process, the full deposition rates (kg/h) of the AFP technology can be exploited.

"Omega -stringer from the roll" circumscribes a novel process, which addresses the aforementioned scenario directly. It covers prepreg deposition, forming and curing.

The innovate key-piece of the process is the recipient-pressure-based controlled forming of full-stack prepreg laminates with the cheap single-diaphragm-forming process, which is often denoted as hotforming. Single-diaphragm forming is already applied in industry, where it is considered being suited for forming on male tools only.

Combining recipient-pressure controlled forming, with the novel patented wedge-tool ("Keileinleger" in German) underneath the membrane, allows for the simultaneous forming of positive and negative curvatures, thus allowing for making hat-shaped stringer shapes.

Using flat laminates in the process is accompanied by beneficial secondary aspects in terms of investment cost and manufacturing-tool occupation. Experiments show that full AFP-made stringer laminates can be wrapped up to a roll, re-frozen, stored, unfrozen, unwrapped, formed and finally cured without critically impeding the inner laminate architecture.

Thus, a temporal and spatial separation between material deposition and autoclave curing becomes possible, which allows for minimizing occupation of the costly manufacturing tools, as the ply-wise laminate tailoring does not take place on the curing tool itself. On the other-hand, different actors can be responsible for lay-up and curing. Thus, AFP infrastructure is not a mandatory prerequisite for potential part manufacturers any more, while others can focus on efficient prepreg deposition only.

Recent studies at DLR's Institute of Composite Structures and Adaptive Systems (FA) verify that flat full-stack stringer laminates can be formed successfully to an aerospace hat-stringer shape with the proposed process. Micro-section analyses, performed with samples from a cured stringer, further prove the flawless inner laminate architecture, which underlines the process's capability for composite stiffeners within the aerospace industry and beyond.

FRAUNHOFER INSTITUTE FOR CHEMICAL TECHNOLOGY – ICT

COMPOSITES

MADE FROM REACTIVELY PROCESSED POLYAMIDE 6 ON THE WAY TO SERIES PRODUCTION READINESS

In order to reduce environmentally polluting emissions, new materials and processes are increasingly being used in components which, on the one hand, save weight and, on the other, are easier to recycle. Fiber-reinforced plastics with a thermoplastic matrix made of polyamide 6 offer one possible way of achieving this.

Author: Michael Wilhelm

ROBUST PROCESSING ENSURED

The reactive processing of ε-caprolactam to polyamide 6 has been intensively investigated over the last 15 years. The major challenge was the high sensitivity of the matrix to environmental influences, above all moisture, which usually led to problems during polymerization and thus to an unstable process. Through the work at the Fraunhofer ICT, however, the researchers have now succeeded in determining, quantifying and thus comprehensively understanding the moisture-induced side reactions. Thus, a targeted compensation and optimization of the processing is possible.

This enables a further reduction of the cycle time and thus an increase in production efficiency with high quality and fewer scrap.

For this innovation, the researchers were awarded the AVK Innovation Award 2020 in the category „Research and Science".

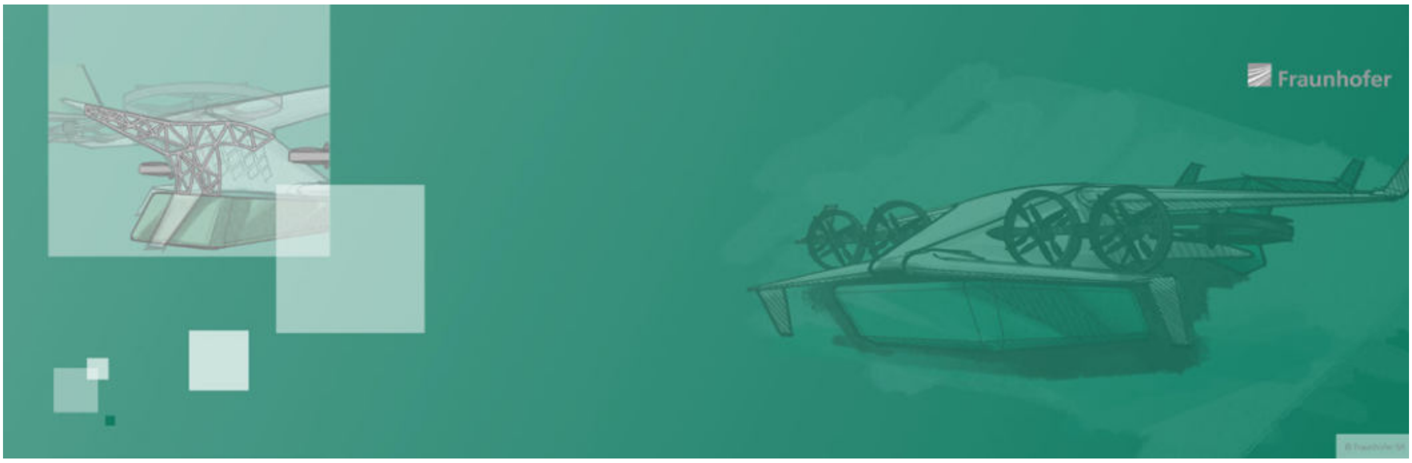


Fig. 1: ALBACOPTER - Fraunhofer internal research project focusing on „Urban Air Mobility" © Fraunhofer IVI

Fig. 2: T-RTM leaf spring - Contributes to sustainable mobility!
© Fraunhofer ICT

DIFFERENT PROCESSING METHODS

The thermoplastic matrix, based on ε-caprolactam, can be processed in different ways, both discontinuously in thermoplastic resin transfer molding (T-RTM) and continuously in thermoplastic in-situ pultrusion.

In a South African consortium, led by Aerosud Aviation, Fraunhofer ICT is using the T-RTM process to transfer components for an aerospace application from the current manual processing of thermoset prepreg to automated series production.

One example of in-situ pultrusion with reactive ε-caprolactam melt is being developed in the Fraunhofer internal joint project „ALBACOPTER“. The lead project, which started in January 2021 and focuses on „Urban Air Mobility“, has a duration of 4 years and aims to develop an Experimental Vertical Take-Off and Landing Glider. The load-bearing drone structure is created by thermoplastic hollow profiles connected with load-path reinforced node elements. In addition to modularity and scalability, the profile design targeted in the project also offers the potential for cost-effective implementation, as the pultrusion process is considered highly economical.

A SUSTAINABLE AND COST-EFFECTIVE ALTERNATIVE

The reactive processing of thermoplastics shows some significant advantages. Already in terms of material costs, the monomer ε-caprolactam as matrix material offers a significant cost advantage compared to thermoset resins, which are currently mainly used for fiber-reinforced plastics. Significant advantages also arise after the life cycle of the components: Components with thermoplastic matrix are much easier to recycle compared to those with thermoset matrix. On the one hand, they can be mechanically recycled by being shredded, recompounded and reused as glass fiber-reinforced injection molding material. On the other hand, chemical recycling is also possible, in which the polymer chains are broken down again into their monomer units. Both recycling approaches are currently being investigated at the Fraunhofer ICT.

FRAUNHOFER INSTITUTE FOR CASTING, COMPOSITE AND PROCESSING TECHNOLOGY – IGCV

ONE SHOT FULLY INTEGRATED THERMOPLASTIC FRAME

Authors: Kevin Scheiterlein, Kilian Seefried

Fig. 1: Close-up view of the »nip point« during the TAFP process with laser activation © Fraunhofer IGCV

State-of-the-art aircraft frames are built with thermoset resin systems necessitating time and cost consuming autoclave curing cycles. The substitution of these materials by unidirectional tapes with thermoplastic matrices offers potential to use out-of-autoclave, highly automated and therefore cost-efficient manufacturing technology. Due to the integration of joining-steps into the stamp forming process, integral design is possible and further assembly becomes obsolete. This study presents aspects of all stages of the corresponding process chain and highlights key findings.

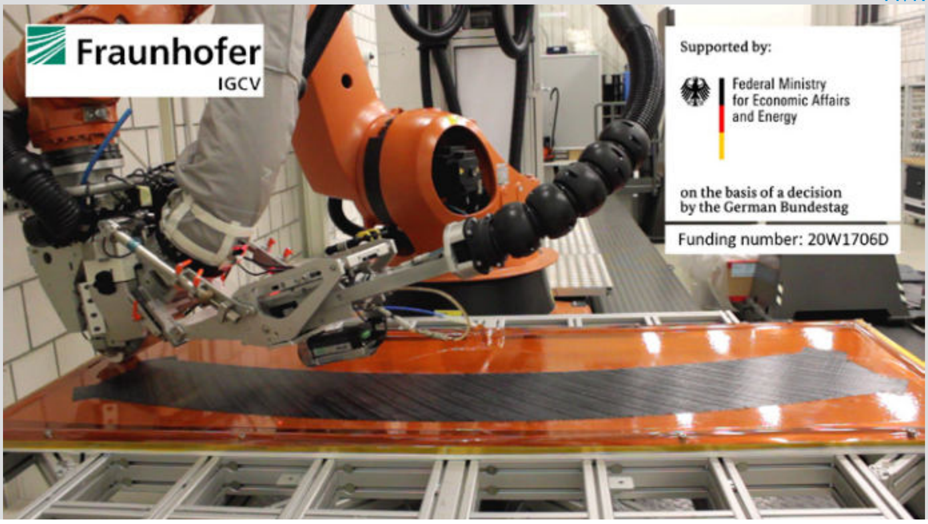


Fig. 2: Two-dimensional thermoplastic automated fiber placement (TAFP) process at Fraunhofer © Fraunhofer IGCV

Manufacturing of high integrated frame structures using thermoplastic automated fiber placement (TAFP) combined with stamp forming and co-consolidation to generate a cost- and time-efficient process chain is the topic of the „One Shot Fully Integrated Thermoplastic Frame"-project which is located in the aviation research program of the federal government for business and energy (funding code 20W1706C). The partners of the consortium are automotive center Südwestfalen GmbH, Fraunhofer IFAM, Fraunhofer IGCV, Leibniz-Institut für Verbundwerkstoffe GmbH and Premium-Aerotec GmbH as consortium leader.

CF-PEEK is the innovative thermoplastic tape-material, which is used in this project. The tapes are layed up by the TAFP-process, using a laser as heating source. To get a reliable process it is necessary to define a suitable process window allowing a good compromise of layup velocity and inner quality in respect to the following stamp forming process. Therefore, different manufacturing trails were performed and the quality of the preforms evaluated by various testings. Another aspect was the architecture of the layup-paths, which equals the fiber orientations. Manufacturing engineering investigations of possible guide curve designs for every single tapepath increased the surface cover ratio (important parameter due to the typical gap and overlap imperfections in TAFP) in respect to the tolerated angular deviation. Straight fibers with discrete angular directions were replaced by a constantly morphing, curved fiber architecture, which leads to the formation of longitudinal instead of commonly known triangular defects.

After the 2D layup of the preforms, they were molded into desired shape by stamp forming, whereas one-shot process development comprises two routes to integrate the stiffening and connecting elements, Stamp-forming plus co-consolidation and stamp-forming plus over-molding. Possible correlations between pre-consolidation and final part quality were studied. In-line tolerance management based on additive manufacturing technologies is used in the assembly of the final parts.

By the continuous development of the involved technologies, the technology readiness level of the entire process chain was increased within the collaborative research. The successful manufacturing of the corresponding demonstrator parts proved this evolution. Key findings may also be useful for other high-performance applications in aerospace industry and beyond.

About Fraunhofer IGCV

Fraunhofer IGCV stands for application-oriented research with focus on efficient engineering, networked production and smart multi-material solutions. Our unique selling proposition lies in interdisciplinary solutions for casting, composite and processing technology in the German industry. Our 120 scientists drive innovations on the level of manufacturing processes and material sciences, machines and process chains as well as factory and enterprise networks.

FRAUNHOFER INSTITUTE FOR PRODUCTION TECHNOLOGY – IPT

RECYCLING PROCESS

FOR PRODUCTION WASTE FROM FIBER-REINFORCED PLASTIC MATERIALS FOR AN EFFICIENT CIRCULAR ECONOMY

Fiber-reinforced plastic tapes (FRP tapes) are high-quality starting materials for a wide variety of applications. However, the recycling rate is low. Previous FRP recycling strategies show weaknesses in energy and resource efficiency. Therefore, a novel process is being developed in the „TapeZyklat“ project, which enables an economic reuse of these materials.

Author: Martin Schwane

Fig. 1: The aim of the „TapeZyklat“ project is to develop a recycling process for an economic reuse of production waste from FRP tapes for an energy- and resource-efficient use in the sense of a circular economy

The use of FRP tapes makes it possible to produce highly resilient components that are characterized by their particularly low weight. If such lightweight structures are used in automotive or aerospace applications, resources and energy can be saved during its use phase. However, the manufacturing process of FRP tapes is very energy-intensive, especially when carbon fibers are used. Resource-efficient use of these materials is therefore a prerequisite for improving sustainability. But significant offcut already occur during the production of components made from FRP tapes, for which sustainable recycling processes are needed. Existing processes, however, make little use of the fiber properties that are responsible for the good mechanical properties, are very energy-intensive or even harmful to the environment.

In order to reduce these deficits with regard to the sustainable use of FRP tapes, the Fraunhofer IPT is developing a recycling process in „TapeZyklat“ with which tape waste can be economically reused. This is done by processing production residues from FRP tapes into new types of semi-finished products. These semi-finished products can

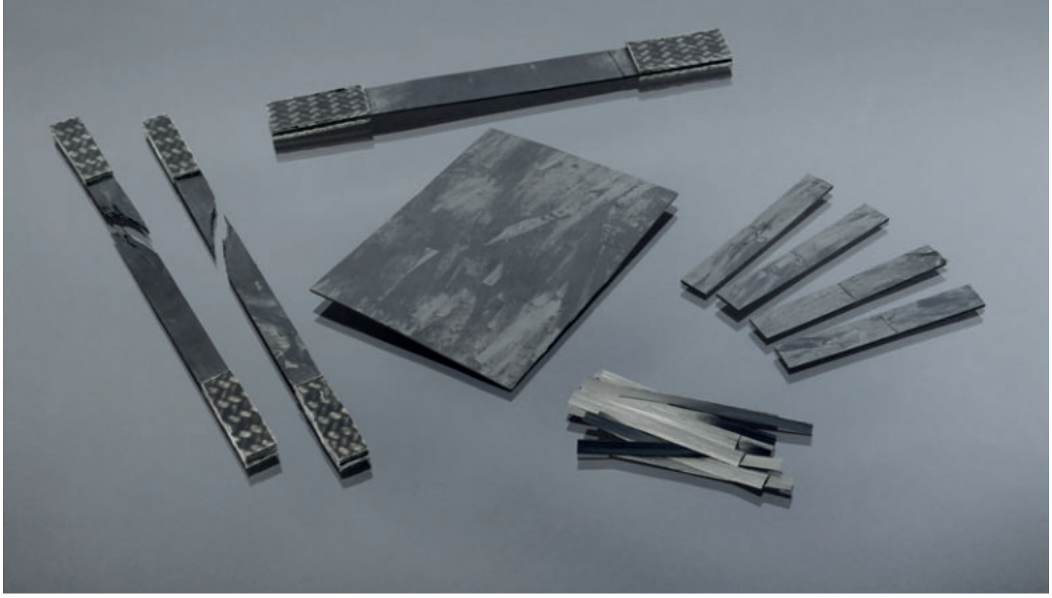


Fig. 2: Thermoplastic tape waste is processed into new semi-finished products and parts

then be further processed into new components using con-ventional manufacturing processes such as tape laying or thermoforming. The Fraunhofer IPT is working together with the project partners Lösing GmbH Schneideservice and M.TEC Ingenieurgesellschaft für kunststofftechnische Produktentwicklung mbH. While Lösing specializes in cutting FRP material to size, M.TEC uses simulations to enable the new material to be used in a way that is suitable for part design and produc-tion. The recycling process is being developed using a prototype plant at the Fraunhofer IPT. One ad-vantage of the process is that the fibers and plastic of the tapes are not separated and joined directly to form a new semi-finished tape product (rTape), which improves the energy balance compared to other recycling processes. In addition, improved formability in thermoforming processes compared to conven-tional tape is achieved through targeted calibration of the fiber lengths. Extensive investigations at the Fraunhofer IPT and simulations by M.TEC will ensure the desired mechanical properties of the novel semi-finished product. Experimental validation is carried out through the production of demonstrator components.

The Fraunhofer IPT offers interested companies customized processes to recycle production waste from FRP materials using the newly developed recycling process for sustainable and resource-efficient reuse.

EFRE.NRW Investitionen in Wachstum und Beschäftigung

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LEIBNIZ-INSTITUT FÜR VERBUNDWERKSTOFFE – IVW

CORE COMPETENCE LOAD CARRYING CAPACITY

STRUCTURAL FIBRE-REINFORCED CORES FOR USE IN AVIATION INDUSTRY

Authors: Thomas Rief, Nicole Motsch-Eichmann

Optimal lightweight design for fiber-reinforced composite (FRP) components requires a high degree of flexibility. The conventional manufacture of complex hollow structural components, such as a landing flap, with metallic mandrels is accompanied by manufacturing restrictions. Due to the necessary demolding of the mandrels, undercuts, curvatures and thickness variations can only be manufactured at great expense, if possible at all. As a result, there are insufficient degrees of freedom regarding structures design to allow optimized lightweight construction. One way to exploit these degrees of freedom is the use of structural FRP-cores. These FRP structures, designed as hollow bodies, remain in the component, carrying structural loads. This fact eliminates the need for demolding and opens up a wide range of design options. In a first step, structural cores are manufactured according to the specifications and are subsequently integrated into the component.

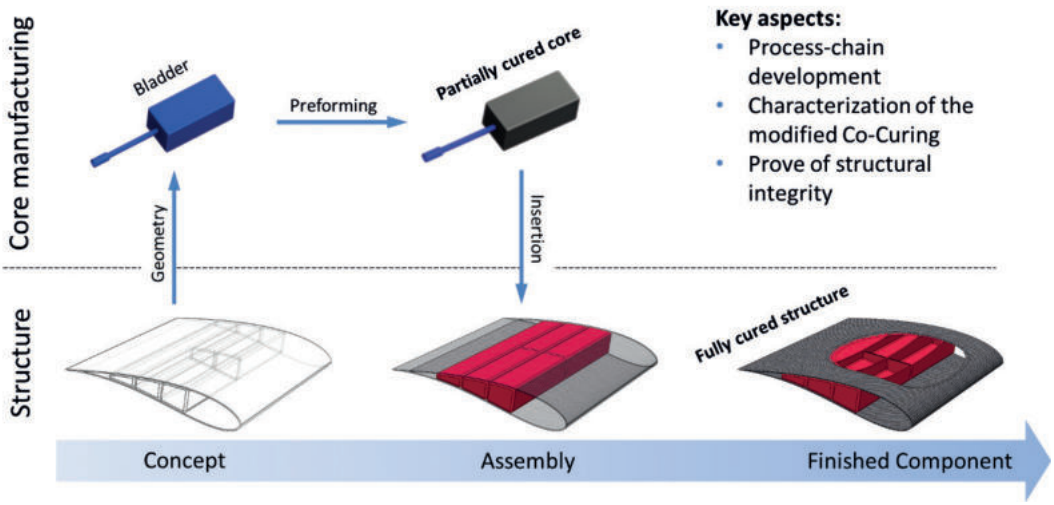

Fig. 1: Process chain with structural FRP-cores using the example of a landing flap - from concept to finished component with additional stiffening elements

LuFo project NextMove focused on implementing such design and on demonstrating its load-carrying capacity. A concept based on bladders was selected for production. With a given geometry, preforms of the cores can be produced and infiltrated in the first process step. In the subsequent reaction, the cores are partially cured. This offers mechanical stability combined with a good bonding to the surrounding components of the integral structure. After partial curing, the cores can be integrated accordingly and the overall structure can be overinjected. In the research project, this was implemented for a multicell box, in which structural FRP-cores with the same geometry can be used. In the process, an existing mold for a conventional design is modified for the use of three adjacent structural cores.

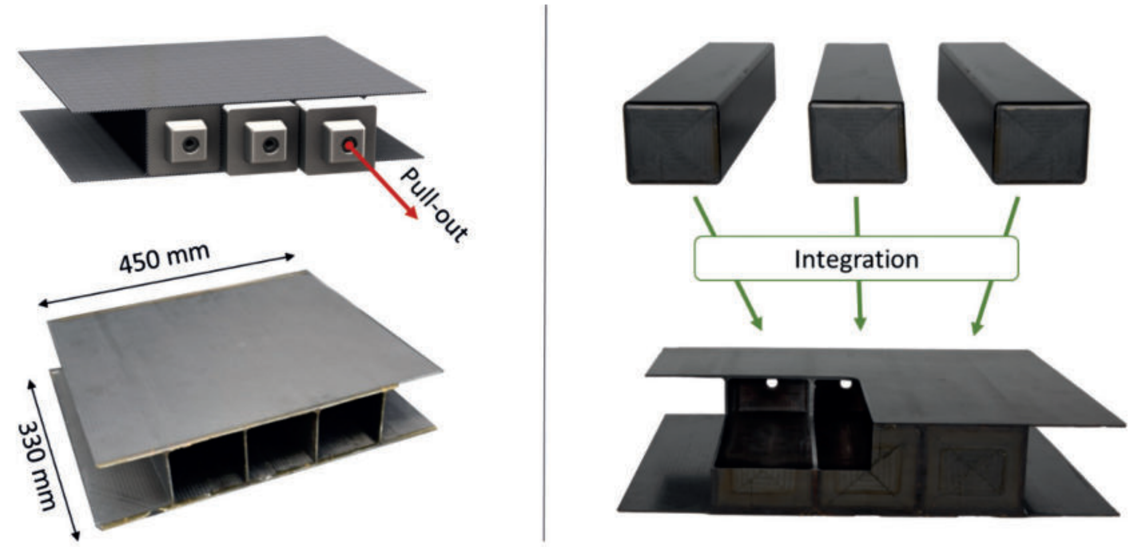

Fig. 2: Multicell box demonstrator: Reference design with mandrel extraction process (left) and new design with integrated structural cores (right, sectional view)

A comparison with a reference structure, manufactured using the conventional method, is carried out on the basis of T-joints extracted from the structures. By testing under tension and bending, the connection to the face sheets can be investigated. This connection is crucial for load transfer into the structurally supporting cores. Here, the new design with integrated structural cores provides comparable characteristic values to the reference, whereby the structural integrity is provided.

A manufacturing method with structurally load-bearing cores thus provides the user with new design options that enable optimized lightweight construction. The project thus represents the step into a new efficient manufacturing methodology that opens up extensive freedom regarding design of complex FRP components.

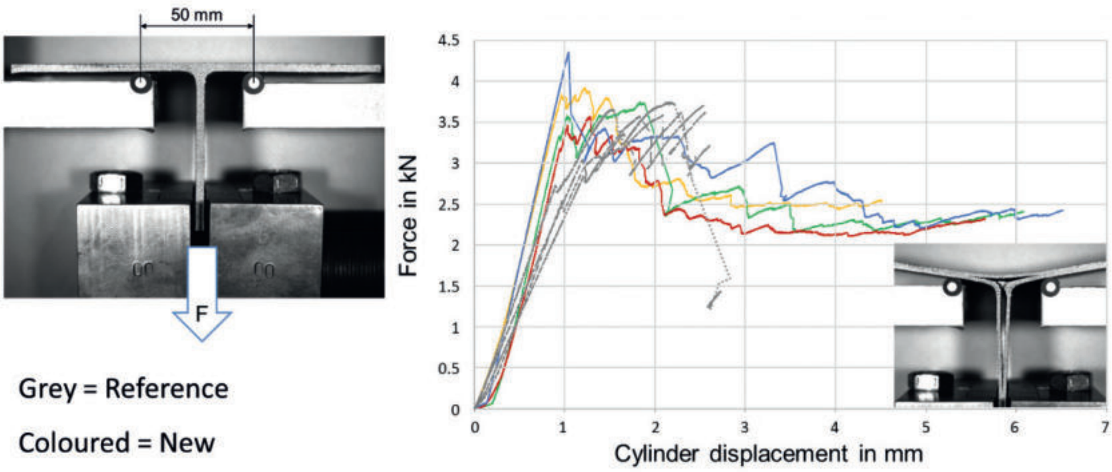

Fig. 3: Verification of structural integrity - test on T-joints under tension. Compared to the reference (in grey), the load-bearing capacity can be demonstrated

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Next Move

As a part of the aerospace research program, NextMove joint project was funded by the German Federal Ministry for Economic Affairs and Energy.

LEIBNIZ-INSTITUT FÜR VERBUNDWERKSTOFFE – IVW

NEW F² COMPOSITOR TAPE

Laying Portal System at IVW

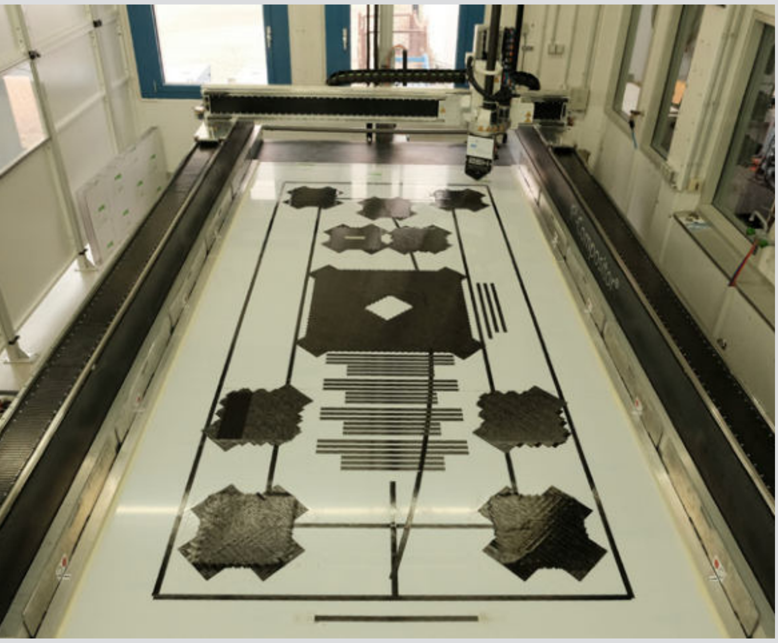
A highly modern and precise tape-laying portal system for (unidirectional) fiber-reinforced thermoplastics was put into operation at Leibniz-Institut für Verbundwerkstoffe in Kaiserslautern, the world's fastest of its kind.

Authors: Dr. Jens Schlimbach, Sven Hennes

IVW is one of the pioneers in the field of robot-assisted thermoplastic tape laying. As early as 1999, this technology was developed for industry-related applications, which was – at that time - an ultra-modern robot system. Long before the first commercially available thermoplastic tape laying machines were available on the European market (around 2006), the hardware developed at IVW (control and regulation technology, several generations and concepts of fully automated tape laying heads, different heating sources, etc.) was used as the first functioning unit by industry partners.

Recently, there has been increased interest in thermoplastic tape laying, since the technical and economic potential can now be fully exploited through higher quality tapes at lower prices as well as the suitability for series production of downstream processes. After upgrading its hardware with a new, ultra-modern tape laying robot in 2016, the expansion of tape laying capacities with an ultra-fast portal system has been expanded, in order to overcome current technology limits and so, expand the technology considerably in the future. One of the essential factors for the economic use of this technology is eco-efficiency, i.e. having the highest possible output with the lowest possible material and energy consumption.

This tape laying portal system should be available for the production of high-precision near-net shape 2D laying images and preforms in order to scientifically investigate the influences of different heating methods, different



F² compositor with different preform layups

Features:	
Feature	**Value**
layup area	3.500 mm x 1.500 mm
layup speed	1 - 4 m/s
output	up to several tons/h
tape widths	½ „“ to 50 mm
materials	Thermoplastic tapes: GF-/CF-/Kevlar-/NF- reinforced • PP, PE, PA, ... • PPS, PEEK, PEAK, ... Binder tapes rCF tapes
heating source	hot gas torch laser (experimental)

material combinations for extremely high output rates and to further develop the process technologically with new approaches. This so-called F² compositor from Automation Steeg & Hoffmeyer (ASH), Mainz, Germany, is characterized by a laying area of 3.5 x 1.5 m and a maximum laying speed of up to 4 m/s, i.e. 240 m/min, which corresponds to output quantities from several 100 kg to tons of deposited composite material per hour. All common fiber-reinforced thermoplastic tape materials and so-called binder tapes in widths between 12 and 50 mm can be used for layup. Tape guides for 12, 12.7 (1/2 “), 20 and 50 mm are currently available; other widths can be produced as required.

A programmable logic controller from Beckhoff is used to control the functions of the attached end effectors. Communication between PLC and system is handled by an EtherCat G bus system.

The functions and parameters are visualized using the TwinCat HMI solution, a software environment from Beckhoff, which enables programming of a PLC as well as visualization.

With this tape laying portal, IVW is planning new projects that will further increase the efficiency of additive manufacturing, based on the tape laying process, and qualify for future applications – in transport industry, for instance.

FRIMO WCM

Nasspressen von Struktur- und Sandwichbauteilen

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Beim Nasspressen werden zunächst trockene Faserzuschnitte aus Glas-, Kohlenstoff-, oder Aramidfasern mit einem reaktiven Polyurethan- oder Epoxidharz imprägniert und anschließend automatisiert in eine Presse eingelegt. Dort erfolgt unter Druck und Temperatur die Formgebung und die Matrixwerkstoffe härten aus.

Die im Vergleich zum RTM-Verfahren geringen Pressdrücke, erlauben die Integration von leichten Sandwichkernen, wie beispielsweise vorgefräste Papierwabenkerne (Paper-Honeycomb), komplexe dreidimensionale PUR-Schaumkerne oder auch vorkonfektionierte PET-Schnittschäume. Neben maßgeschneiderter Werkzeug- und Pressentechnik entwickelt FRIMO für Sie auch individuelle Automationslösungen zur Vorfertigung Ihrer Sandwichkomponenten.

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- Sandwichvorbereitung
- Bauteilbeschnitt & Konfektionierung
- Qualitätssicherung, EOL-Testing Sandwichkernfertigung
- Werkzeug-& Anlagentechnik für PUR-Schaumkerne
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