EDITION APRIL 2025

AVK COMPOSITES REPORT 11

CONTENT

CONTENT

COMPOSITES REPORT 11

Dear reader,

The topic of sustainability is currently one of the most important economic challenges for companies, including in the composites industry. Expectations of sustainable production and product solutions are becoming ever greater, both from a regulatory perspective and on the part of (end) customers, also in order to meet the requirements for recyclability. Due to their often very long service life alone, composite components have many advantages over shorter-lived materials. However, the raw materials used and the recycling options and routes at the end of the product's useful life must also be included in a comprehensive assessment of sustainability. Companies are aware of the importance of this topic, and many are working on developing innovative, more sustainable solutions. Within the AVK and the European umbrella organization (EuCIA), there are numerous activities relating to both sustainability and composites recycling (working group meetings, recycling study, LCA tool, ...).

This issue of the Composites Report presents ways to improve the use of resources in processing methods (keyword “resource-efficient lightweight construction”). You will also find articles on natural fiber-reinforced and bio-based sustainable materials. There are numerous technical options for recycling in particular: the magazine presents solutions for recycling natural fiber materials, carbon fiber recycling and the topic of life cycle assessment. With these articles, AVK supports the spread of sustainable solutions in the composites industry and thus the future viability of our materials.

Kind regards,

Dr. Elmar Witten,
AVK Managing Director

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FRAUNHOFER INSTITUTE FOR CHEMICAL TECHNOLOGY (ICT)

CIRCULAR-READY and biobased MATERIALS for the sports industry

Authors: Anna Krüger, Sascha Kilian, Janne-Constantin Albrecht, Sebastian Zürn

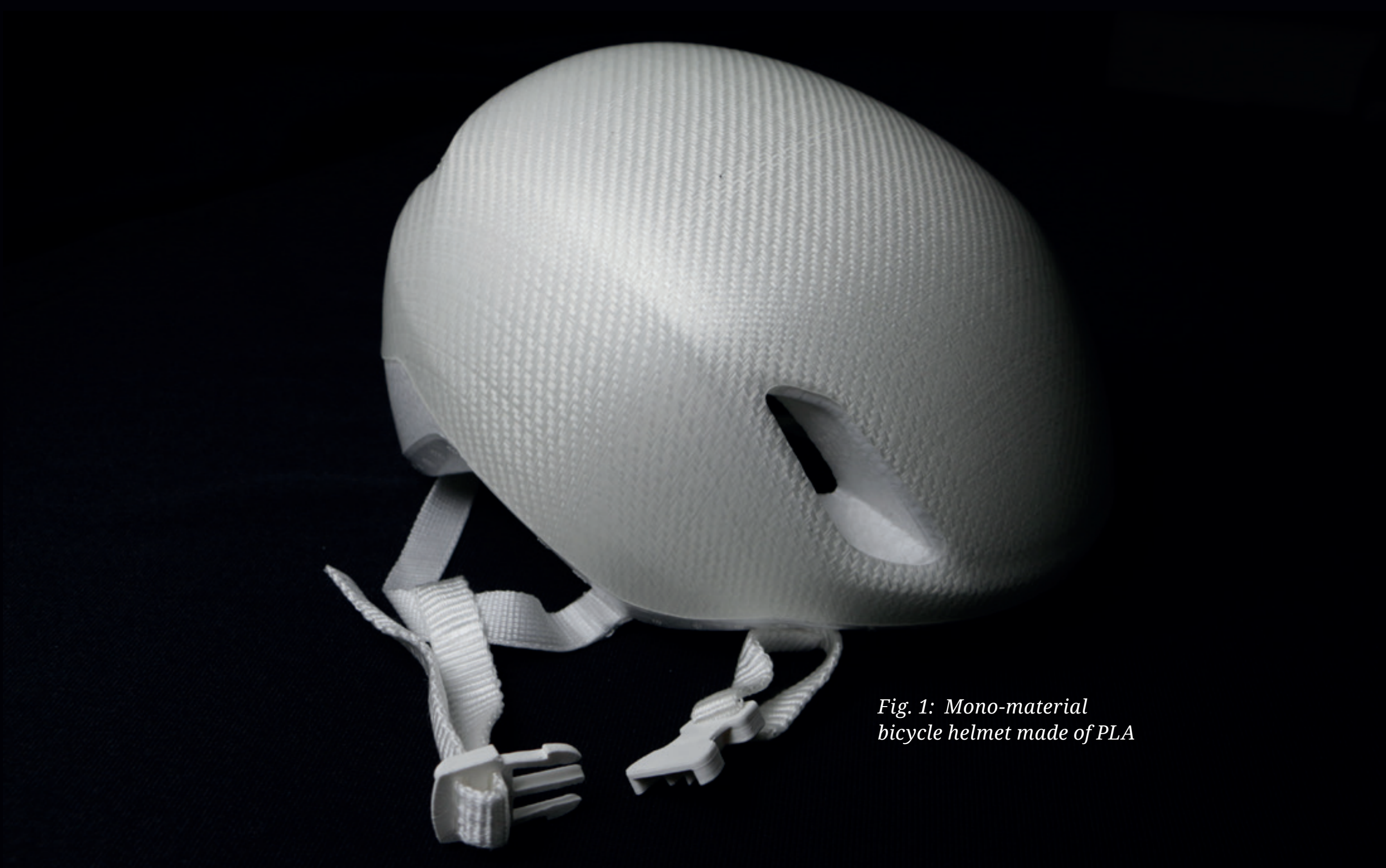

Fig. 1: Mono-material bicycle helmet made of PLA

Bicycle helmets are currently being developed in a multi-material design: a shock-absorbing EPS core, possibly a fiber-reinforced, stiffening and protective shell made of PC, clips, and sun visors made of PET are combined with straps made of nylon fabric. Recycling the helmets would only be possible with a high disassembly effort, which cannot be implemented technically and economically on an industrial scale. Therefore, helmets are thermally recovered, for example, in residual waste incineration plants at the end of their product life. However, customer demand for circular and bio-based products is steadily increasing, especially in the sports and outdoor sector. Thermoplastic, self-reinforced plastics (SRP) offer a promising alternative to traditional solutions. By using the same base polymer as fiber and matrix material, material recycling back into the same application is enabled. The self-reinforcement is based on the stretching of the fibers and the resulting high degree of molecular orientation. These innovative materials combine the advantages of highly abrasion-resistant fibers to avoid dissipative losses, high energy absorption, and pronounced circularity. Through partial consolidation of an SRP textile, direct integration of stiffening ribs into the fabric is made possible (see Fig.1). A combination with foams, films, compact materials, and nonwovens, all based on the same polymer, creates a modular system of material morphologies. Considering the specific component and process requirements, these can be freely combined. The materials and processes developed at Fraunhofer ICT enable high flexibility regarding reinforcement, installation space, load introduction, haptics, and other properties of the components. Already, complex components in a mono-material approach made of bio-based plastics can be manufactured on conventional processing equipment, as demonstrated by a PLA-based bicycle helmet in Figure 2. The shell was made from a complexly shaped self-reinforced PLA covering. Straps, clips, and size adjustment systems are also based on PLA. The EPLA in the core is a bio-based solution for substituting EPS. EPLA not only offers comparable mechanical properties to EPS but can also be processed with identical equipment technology. Likewise, the formation of three-dimensional, structural parts with this particle foam developed at Fraunhofer ICT is possible. EPLA can be used with densities ranging from 30 kg/m³ to 150 kg/m³, and a broader density spectrum is being investigated. The switch to a PLA mono-material bicycle helmet allows for a reduction of the CO_2eq of the helmet by 36% compared to conventional helmets.

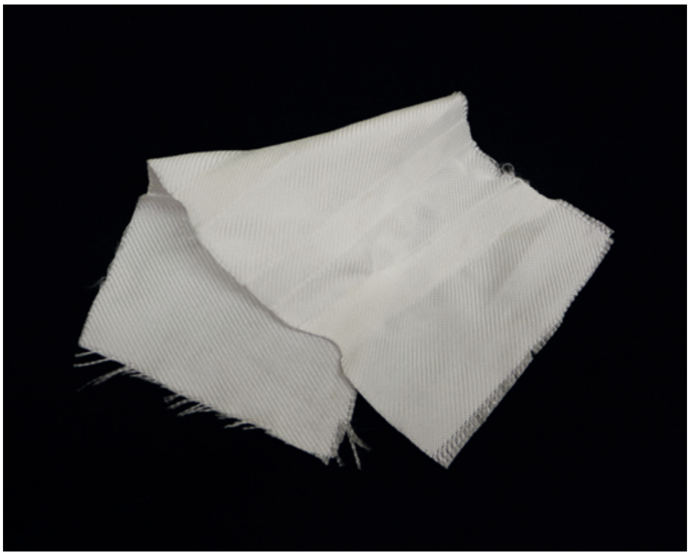

Fig. 2: srPLA fabric with directly integrated stiffening ribs through partial consolidation

As shown in Fig. 3, the impact properties and thus the protective effect of the helmet could be adjusted to a comparable level to conventional helmets through targeted morphology selection. In its varying morphologies, PLA can be used not only for helmets but also for textiles, backpacks, and protectors through the developed processes. It is also suitable for use in semi-structural applications.

The goal of the bio-based morphology lightweight design presented here is to demonstrate lightweight, circular, and resource-saving solutions for sports equipment. The development and application of SRP represent a significant step towards a more sustainable transformation of the sports industry.

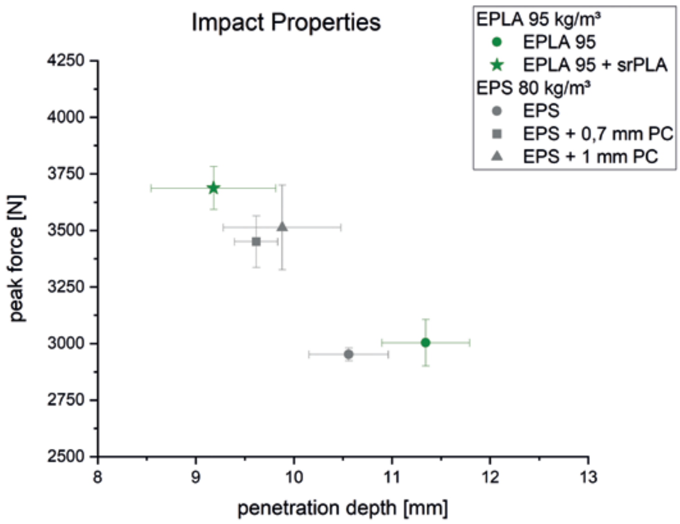

Fig. 3: Impact properties of EPLA in combination with srPLA compared to conventional helmet materials made of EPS and PC.

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LASER ZENTRUM HANNOVER

RE-USE

Strategy for sustainable utilisation of semi-finished thermoplastic composite parts

Author: Hagen Dittmar

Endless-reinforced carbon fibre composites are a sought-after construction material in almost all lightweight construction applications. However, the manufacturing process is still complex and production capacity especially for carbon fibres is low, so that high prices are incurred for the carbon fibres or composite semi-finished products made from them.

In the manufacture of composite components, single-layer carbon fibre tapes or fabric layers are usually used, which are then stacked with changing fibre orientation according to the requirements of the respective application until the designed thickness and load capacity is reached. This stacking requires the semi-finished fibre products to be cut to size close to the final contour and often leaves behind offcuts that can rarely be used again. These offcuts are usually collected, shredded and mixed as filler, for example in asphalt or concrete. They are also often incinerated for energy recovery.

In the Re-use project (03LB3068), the mechanical engineering company KMS Technology Center, the Vereinigte Elektronikwerkstätten and the Laser Zentrum Hannover are working together with Airbus to develop a system (cf. Fig. 2) and a process for producing long-fibre-reinforced CFRP semi-finished products.

In the process, uniform chips are produced from the offcuts, which only have reinforcing fibres of the same length. For this purpose, a system is being developed that can be loaded with non-overlapping, single-layer offcuts. An intelligent camera system recognizes the shape and size of the semi-finished product remnants and their position on the work surface. It also determines the fibre orientation of the remnants and then determines a cutting pattern that produces the largest possible number of chips. The coordinates of the cutting pattern are transmitted together with the semi-finished product remnants on the work surface to a laser station, which separates the offcuts into chips using a laser cutting process for carbon fibre composites.

As part of the project, chips with different types of binding and edge lengths between 10–20 mm are produced in this way, cf. Fig. 1. Laminates are pressed from these long-fibre chips. To do this, the chips are stochastically poured into the mould based on their weight. Test specimens are obtained from the long-fibre reinforced laminates in order to characterise the used chips.

In this way, the raw materials used in the production of endless-reinforced thermoplastic carbon fibre composites and the energy consumed in the process shall achieve greater sustainability in high-quality products.

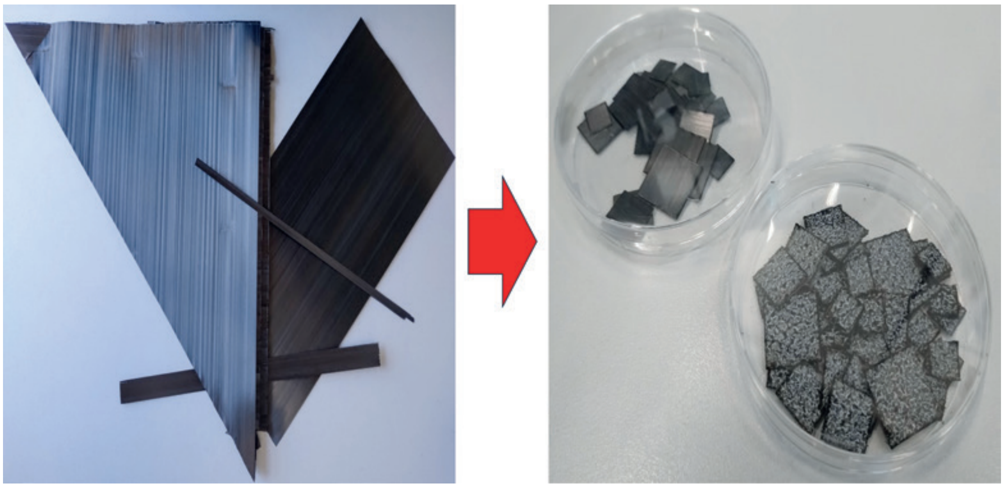

*Fig. 1:
Carbon fibre semi-finished product remnants and chips of different types.*

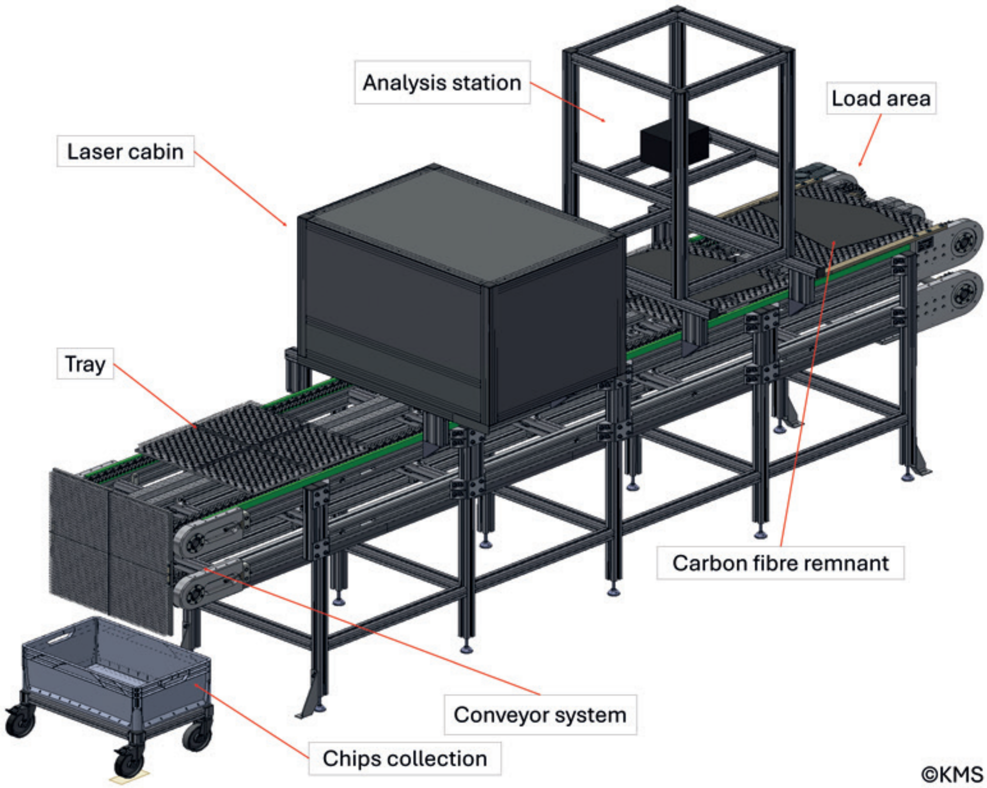

Fig. 2: Re-use machine schematic

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NATURE*DEEPDRAW*

Sustainable Organosheets for Vacuum Thermoforming

Authors: Agata Ryzewska, Santino Wist, Tim Vosmer, Thomas Gries

The NatureDeepDraw research project focuses on developing an innovative, natural fiber-reinforced, thermoplastic semi-finished product (organosheet) optimized for use in vacuum thermoforming processes.

Currently, carbon and glass fiber-based semi-finished products are predominantly used for this type of forming. However, their widespread application in serial production presents a challenge due to the high susceptibility to defects. This issue is attributed to their insufficient plastic deformability and limited drapability. Deficiencies in these properties lead to pronounced deformation mechanisms when replicating complex geometries (e.g., convex shapes). Excessive forces acting on the material layers or individual fiber bundles ultimately result in material defects such as wrinkles, gaps, fiber break or thinning (Fig. 1).

Natural fiber-reinforced plastics (NFRPs) rank third in terms of the most significant material groups by volume, following carbon and glass fiber-reinforced plastics. A key advantage of natural fibers lies in their deformable yarn structure, which makes them more adaptable to deformation and thus simplifies draping. Additionally, they offer important performance characteristics crucial for textiles – they provide high strength combined with low weight. The combination of these properties with fully biodegradable resins opens the possibility of creating innovative, recyclable materials for thermoforming processes, thereby achieving the goals of our project (Fig. 2).

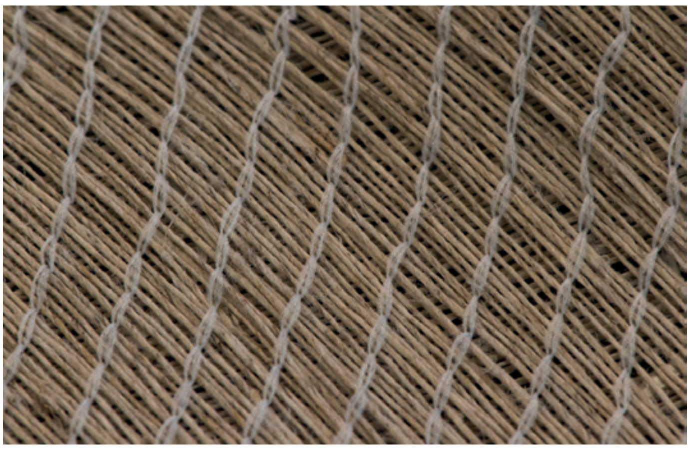
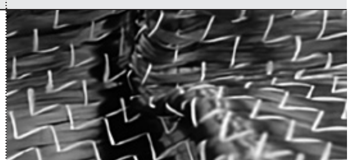


Fig. 1

A central aspect of the project is the use of the potential of natural, renewable raw materials in innovative composite manufacturing processes. The developed material is produced using flax, kenaf, or hemp in a vacuum thermoforming process. Damaged or defective components resulting from the process are reintroduced into the initial stage of the process chain, creating a recycling loop. Our research demonstrates hat NatureDeepDraw provides

DRAPING ERRORS	ILLUSTRATION
WRINKELS	
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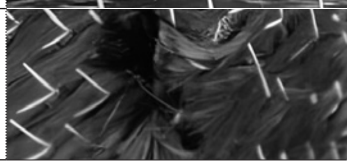
FIBER BREAK	

Fig. 1: Illustration of the draping errors

a key approach for the industry, particularly for small and medium-sized enterprises (SMEs). The insights gained allow SMEs to avoid costly investments in new equipment while efficiently producing high-strength, sustainable materials. This innovative concept combines economic advantages with ecological responsibility, sustainably enhancing the competitiveness of companies.

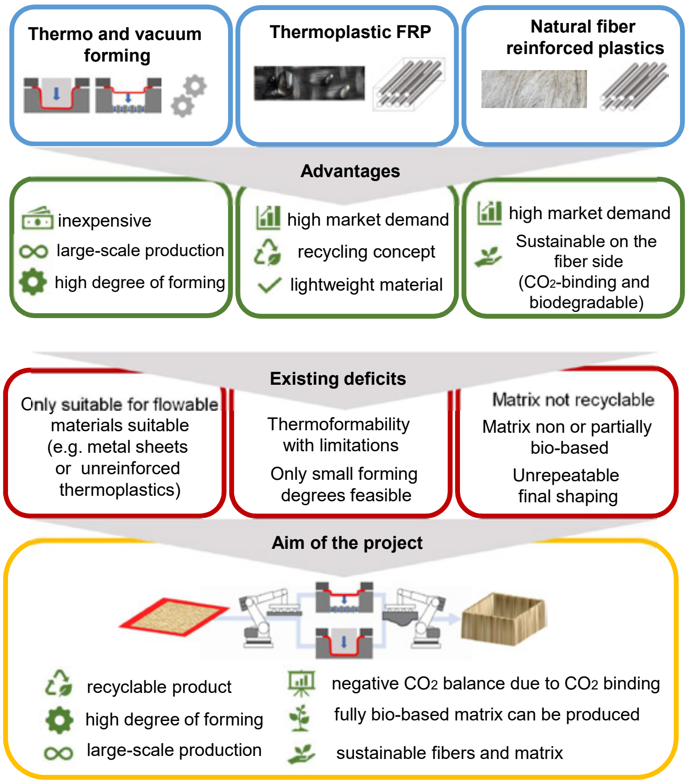


Fig. 2: Derivation of the project approach from deficiencies in the state of the art

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We thank the Bundesministerium für Wirtschaft und Klimaschutz (BMWK) and the DLR Projektträger for funding this research project.

DLR Projektträger

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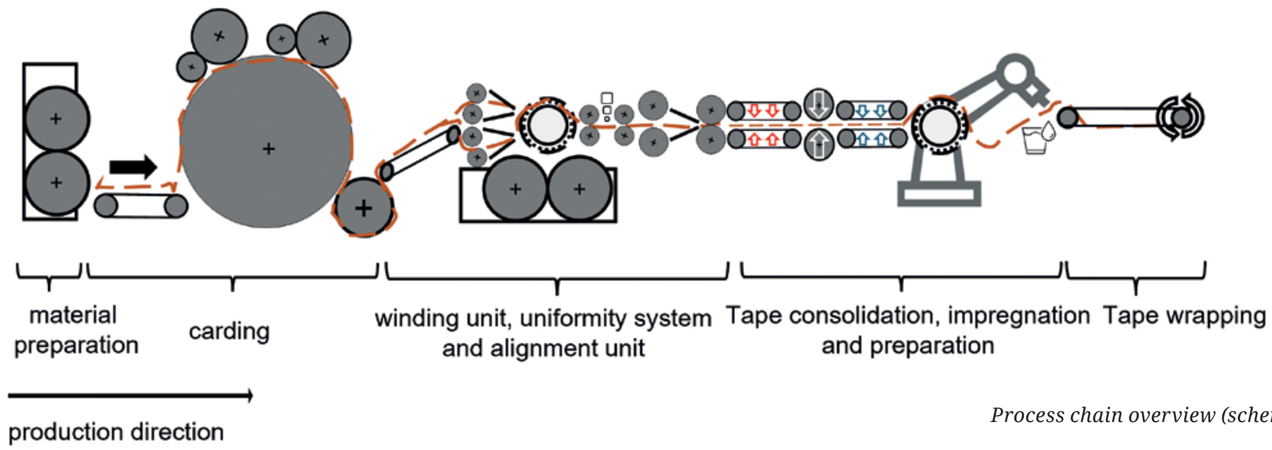
INSTITUT FÜR TEXTILTECHNIK AUGSBURG, TECHNISCHE HOCHSCHULE AUGSBURG

Manufacturing process for highly oriented TAPES FROM PYROLYZED CARBON FIBERS

A continuous process chain

Authors: Felix Teichmann, Christoph Klemm, Simon Krauß (Institut für Textiltechnik Augsburg), Mesut Cetin (Technische Hochschule Augsburg,)



Process chain overview (schematic)

Fiber-reinforced composites have established themselves as key materials for the most demanding applications over the past decades. They consist of a combination of fibers and a matrix, where the fibers provide strength and stiffness, while the matrix protects and bonds the fibers. This synergy enables the creation of materials that are both lightweight and mechanically highly resilient. A critical step in the production of fiber-reinforced components is the manufacture of textile fiber semi-finished products, which serve as the starting material for component fabrication. Fabrics, braids, or unidirectional tapes offer defined material properties that can be specifically tailored to the requirements of the product. Tapes, in particular, consisting of parallel-aligned fibers, allow precise tailoring and optimal alignment with the load paths within the component. By utilizing modern manufacturing technologies such as robot-assisted placement processes, tapes enable not only the creation of complex structures but also the achievement of highly efficient mechanical component properties. These characteristics make tapes a vital element in the development of high-performance fiber-reinforced components.

Different RecyTapes

During the recycling of carbon fibers (rCF), the ordered alignment of the fibers is lost. This random orientation significantly limits their applicability, as it prevents the carbon fibers from fully realizing their potential. The ITA Augsburg is addressing this challenge in the GReTa project (German Engineered Renewable Wind Turbine Blade - 03LB3087E) by reorienting these random fibers to produce oriented semi-finished products with properties comparable to those made from virgin fibers. The project focuses on the wet winding process, in which the dry fiber tape is passed through a resin bath and then wound around a rib structure. The rCF tape used in the project comprises 95% recycled carbon fibers by weight and 5% binder fibers, which ensure the tapes' processability.

The entire process chain is designed for high productivity, with the goal of manufacturing a 22-meter-long demonstrator by the end of the project.

At the beginning of the process chain, rCFs are mixed with binder fibers and homogenized during fiber preparation. The fiber blend is then processed using a carding machine to separate and mix the fibers further. This step produces a fiber web, which inherently exhibits mass fluctuations due to the process. To address this, the web is divided at the carding machine's output and formed into separate slivers. These slivers are redirected and fed into a mass-regulated drafting unit. The redirection introduces a longitudinal offset between the slivers, which, in combination with the drafting unit, enhances the mass uniformity of the sliver. The homogenized fiber sliver is subsequently fed into the fiber alignment unit, where it undergoes precise orientation. In the final step of the process chain, the aligned sliver is consolidated into a tape. During this step, the edges are smoothed, and the tape is fixed in shape using binder fibers, which are melted and cooled under pressure.

The process operates continuously at a current speed of 5 m/min, producing tapes with widths of ¼ or ½ inch and surface weights ranging from 150 to 350 g/m². Pyrolyzed carbon fibers provided by a project partner are utilized as the recycled material. Beyond the specific fiber mixture used in the project, thermoplastic tapes with fiber volume contents (FVC) of up to 40% can also be produced. The mechanical properties of the recycled fiber tapes currently achieve approximately 40% and 60% of the tensile strength and modulus, respectively, compared to comparable virgin fiber products. By the end of the project, the goal is to achieve 80% of these mechanical properties at an FVC of 50% and a production speed of 9 m/min.

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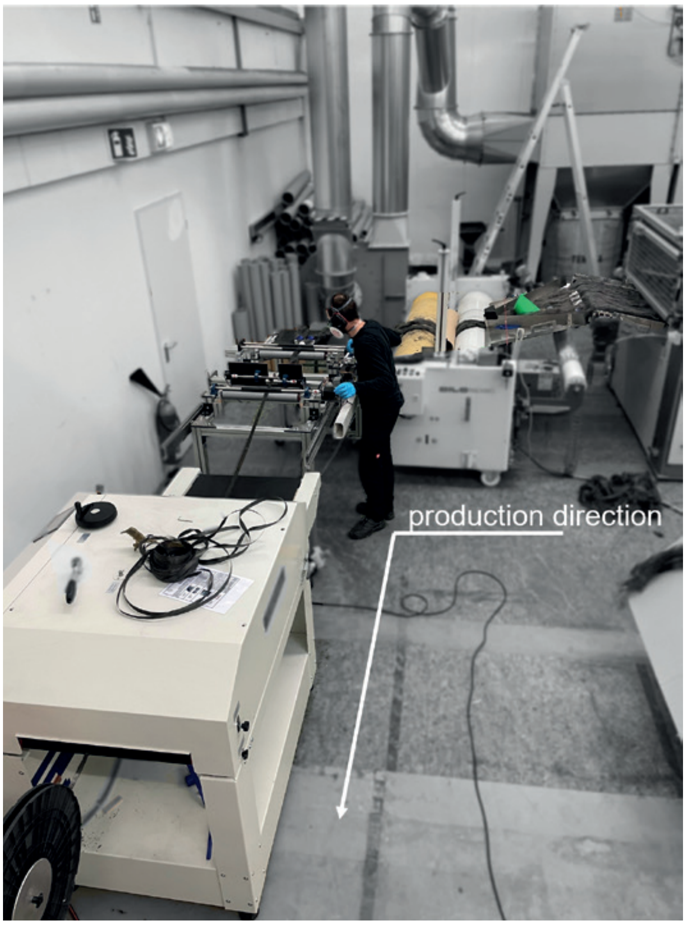

process chain in practice

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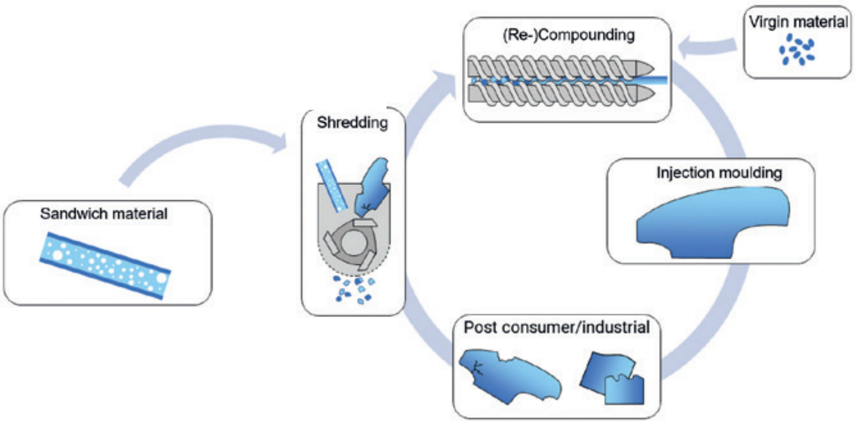
Innovative recycling strategies for natural fibre sandwich materials:

EFFICIENT REUSE

with Versatile Applications

Author: Dipl.-Ing. Florian Tautenhain



The compression moulding process plays a decisive role in the production of moulded parts used in key industries such as the automotive and construction industries. The use of thermoplastic fibres combined with natural fibres or sandwich structures consisting of a foam core and nonwoven cover layers is well established – technologies that represent the state of the art. At the end of the lifecycle of these composite materials, thermal recovery is often the standard approach. However, a promising alternative comes into play: material recycling. By combining mechanical pre-shredding with adapted dosing and compounding technology, a recycling cascade becomes a realistic approach, enabling highly efficient material utilisation. Initial results already prove that even sandwich materials with low bulk density can be successfully processed into injection-mouldable recyclates. This is a major step towards a more sustainable and resource-efficient future.

MATERIAL PROCESSING AND GRANULATION

The pre-shredding of the sandwich components is carried out using a cutting mill. The material is then fed into the compounding system via a volumetric dosing unit. Compared to the gravimetric dosing, which was also investigated, the volumetric method offers a continuous and precise material feed. One challenge lies in the low bulk

Fig. 1: NF/PP-PET-Sandwich material

Fig. 2: Compounding tests left: NF/PP-PE flakes with low bulk density; right: Compounder with feed screw (red) for material dosing

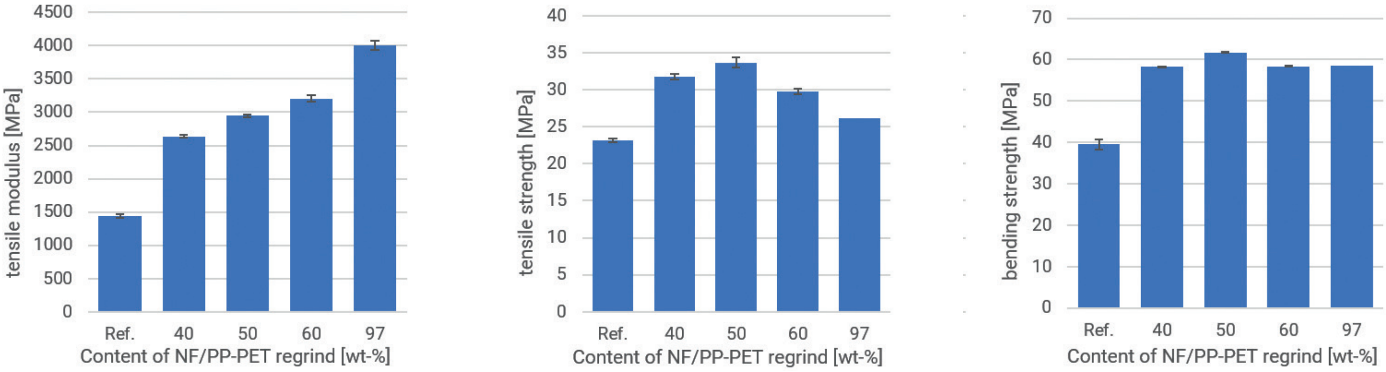


Fig. 3: Comparison of the mechanical properties of PP with different content of NF/PP-PET regrind
left: Tensile modulus from tensile test according to DIN EN ISO 527-2; centre: Tensile strength from tensile test according to DIN EN ISO 527-2; right: Flexural strength from flexural test according to DIN EN ISO 178

density and the tendency to clog, which complicate process control. Various dosing methods were implemented, including a conical feed screw, flexible container geometries, and massage paddles. These measures stabilised material feeding and enabled reliable process control. For granulation, the NF/PP-PET sandwich materials were blended with adhesion promoters such as Scona TPPP 8112 GA and polypropylene virgin material (40–60%), which significantly improved process continuity. At the same time, the material composition influenced the homogeneity of strand extrusion and the expansion of the foamed PET core.

MECHANICAL PROPERTIES OF THE RECYCLED GRANULATE

Mechanical tests show that the tensile and flexural modulus increased continuously with a higher regrind content. A high proportion of regrind content led to significant improvements in stiffness. Tensile and flexural strength reached their maximum at a medium regrind content, while impact toughness remained stable over a wide range, but was reduced compared to pure PP material.

CONCLUSION

The investigations demonstrate that optimised dosing methods and targeted material additives enable the successful continuous recycling of NF/PP-PET sandwich materials. The produced regranulates are suitable for injection moulding, with largely preserved mechanical properties. Future research could focus on developing additives to enhance impact toughness. Overall, these technologies offer promising opportunities for sustainable recycling and innovative applications in plastic processing.

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FHNW HOCHSCHULE FÜR TECHNIK UND UMWELT

RECYCLED CARBON FIBERS

as a sustainable solution in the sports sector

Author: Prof. Dr.-Ing. Marc Siebert

Abb. 1:

Recycled carbon fibers (rCF) can currently only be processed in the form of short fibers for injection molding or for production of nonwovens. This product class offers distinctive material properties that are well above those of unreinforced plastics, but at the same time well below those of high-performance CFRP laminates. The lack of performance simply corresponds to the very low fiber volume content, which is currently limited to around 35% for an isotropic fleece. There is therefore a widespread opinion in the composite industry that this shall be the limit of rCF semi-finished products in terms of technical feasibility and recycling costs.

Contrary to this belief, the Recywind project aims to improve rCF semi-finished products in terms of their mechanical properties so that they can fully replace virgin fiber material in structural applications. Only then can true circularity be achieved for CFRP-based composite materials. This vision is supported by the company V Carbon GmbH in a long-term collaboration with the Institute for Plastics Technology – IKT at the University of Applied Sciences Northwestern Switzerland in Windisch. Two rCF semi-finished product formats were developed for this purpose: 1. staple fiber tape, which has a flat, wide cross-section and is suitable for flat, thin-walled compo-

Fig. 1: Reclaimed 2nd life carbon fibre after solvolysis treatment

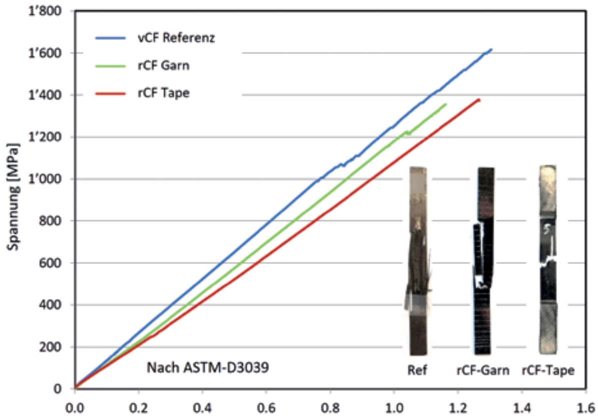

Fig. 2: Load displacement curves of rCF-tape/yarn UD-specimens vs. virgin reference

Fig. 3: Manufacturing of tubular sections via dry filament windin

nents and 2. staple fiber yarn with a round cross-section, which is suitable for winding structures and bulky parts. Together with the bicycle frame builder SPIN and CG TEC GmbH, a racing bike frame was designed and built to demonstrate the applicability of 2nd-life material in a structural component. In the bicycle industry, there is still no real recycling target, so the demonstration of CFRP recycling and circularity has a particular impact here.

Via mechanical testing rCF-specific knock-down factors were derived. To be able to evaluate the process-specific requirements on a broad basis, four manufacturing processes were examined: 1. Wet wrapping with subsequent autoclave infusion, 2. roll wrapping with UD prepreg, 3. the tube blowing process with fabric prepreg and 4. wet pressing with dry fabric. All individual components were bonded with in-situ sleeves in a "tube-to-tube" assembly process. The frame has been tested for static steering head stiffness and achieves the required minimum value. With the support of partners Schmolke, Carbovation, DT-Swiss and Schwalbe, a full bicycle was built and successfully tested by several people on variable terrain.

There is no alternative to the economic and ecological processing of rCF, as its value is simply too high to be incinerated or downcycled, or to be sent to landfill. Therefore, rCF should be considered as another raw material source. It is noteworthy that the use of rCF in the CFRP manufacturing process can lead to a reduction in energy consumption of up to 80% compared to the use of virgin CF. Significant energy savings are estimated 50–130 kWh per kg CF. This is a turning point for the CFRP industry and any step towards reducing the carbon equivalent footprint per kg of CFRP will be beneficial.

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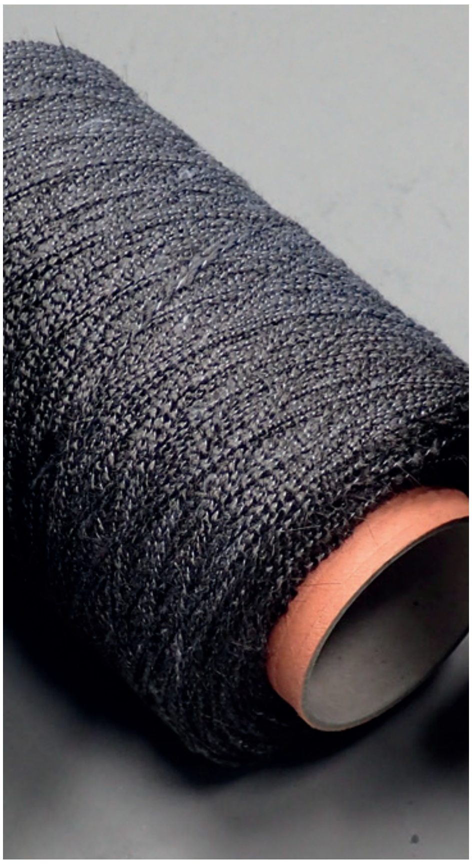
New Project "HiCarR" Launches to Revolutionize Carbon Fiber Recycling by Creating an Advanced High-Fidelity Card Sliver

Authors: Miriam Preinfalck, Julian Kupski

Due to the large volumes of composite waste generated and the significant carbon footprint of carbon fiber products, the urgent necessity of recycling carbon fibers is no longer controversial today. Unfortunately, the possible uses of recycled carbon fibers (rCF) are significantly limited compared to virgin carbon fibers (vCF). This is because the two main advantages of vCF – length and orientation – are lost during recycling, leaving rCF shortened and in a disordered, entangled state.

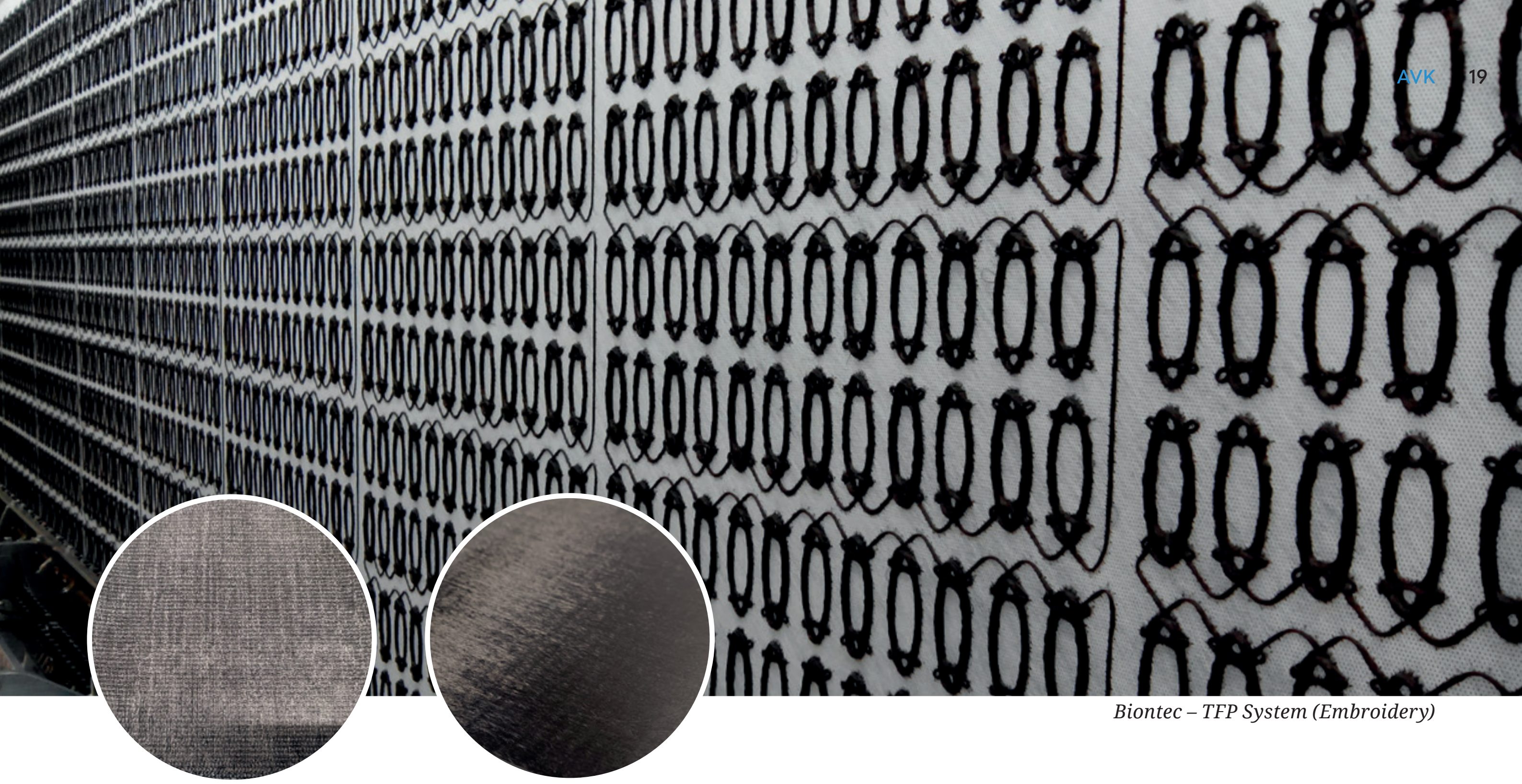
In recent years, there have been several efforts to convert rCF into re-oriented semi-finished products. In this context, the carding process has been identified as the most critical step in producing high-quality intermediates. Studies have shown that fluctuations in sliver mass are difficult to correct in downstream processing steps, but the drafting of inhomogenous rCF card slivers tends to lead to the formation of package defects.

In the Cornet project HiCarR, the research institutes Institute of Polymer Engineering (IKT) of University of Applied Sciences and Arts Northwestern Switzerland (FHNW) and the German Institutes of Textile and Fiber Research (DITF) together with the companies BIONTEC – Bionic Composite Technologies AG and Ensinger Composites Schweiz GmbH are tackling this challenge, working collaboratively on the development of an optimized high-fidelity card sliver and demonstrating its quality through innovative processing routes. The aim is to create a superior rCF card sliver suitable for further processing



rCF Yarn

rCF Card Sliver



Biontec – TFP System (Embroidery)

Embroidered Test Panel

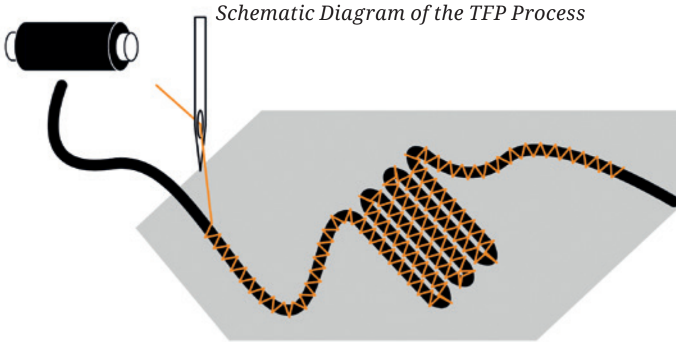
Test Plate Made of Embroidered Yarn

into high-quality semi-finished products, making them a viable alternative to virgin carbon fibers. The project follows two main approaches to optimize the card sliver: firstly, the development of optimized materials, and secondly, the improvement and adaptation of rCF carding technology.

In terms of material development, customized polymer fibers and sizing agents are being developed to enhance the compatibility between rCF and polymer and to minimize fiber damage during processing to ensure the highest possible material quality. Regarding the advancement of carding technology, the roller carding process is being optimized to produce a high-quality card sliver with respect to mass uniformity, fiber orientation, and minimal fiber shortening. This involves examining both the process parameters and the machine setup.

Finally, two benchmark applications will be produced to validate the quality of the semi-finished products. The first demonstrator will be manufactured using an innovative approach combining wrap yarn spinning, tailored fiber placement (TFP) preforming and complex shape closed mould consolidation. The second demonstrator will be a 3D-complex component made from woven yarn fabric, designed to showcase the deep-drawing capability of the developed semi-finished products.

Schematic Diagram of the TFP Process



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FRAUNHOFER-INSTITUT FÜR HOLZFORSCHUNG (WKI)

LIFE CYCLE ASSESSMENT

in polymer injection molding simulation

Authors: Christina Haxter (Fraunhofer-Institut für Holzforschung, Wilhelm-Klauditz-Institut WKI), Raphael Zimmermann (GreenDelta GmbH), Frederik Block (SIMCON kunststofftechnische Software GmbH), Marco Neudecker (Hochschule Hannover, IfBB – Institut für Biokunststoffe und Bioverbundwerkstoffe), Kevin Ullmann (Hochschule Hannover, IfBB – Institut für Biokunststoffe und Bioverbundwerkstoffe), Timo Weggebakker (bekuplast GmbH)

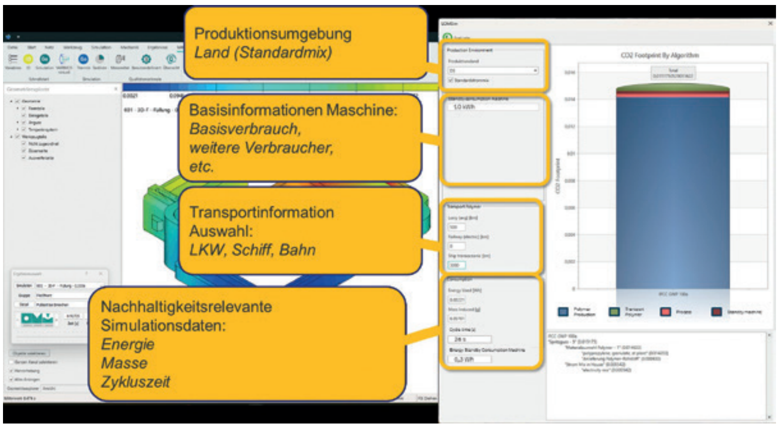
Injection molding is an important processing method in the globally expanding polymer industry as it is used in many industries and applications. The main advantages are the high freedom in the design, as well as the high number of pieces produced. An important aspect, especially for industrial use of the process, is process control, as the various parameters have a significant influence on the quality of the components and process stability, but also on energy consumption.

To reach the sustainability goals of this energy-intensive industry, energy efficiency must be increased. Life cycle assessment (LCA) is used to measure these goals. An LCA was usually only carried out shortly before or after the development of new components and processes. Potential optimization approaches derived from such LCAs cannot be incorporated into the design of machines, components and processes, or only at great cost and time. Using a predictive LCA approach instead would offer considerable advantages.

Such an LCA approach in conjunction with injection molding simulation software is developed in the project LCA4Sim with the partners SIMCON, GreenDelta, bekuplast, IfBB and Fraunhofer WKI. In the project, the CADMOULD software links injection molding process parameters directly with LCA results so that well-founded decisions to increase sustainability and energy efficiency can be made as early as the design phase via the interface to the openLCA software. Optimization with VARIMOS helps find a balance between quality, costs and environmental impacts. Modeling environmental impacts, like global warming potential, allows for the early detection and targeted resolution of weaknesses in product and process design. This way, the creation of predictive LCAs is simplified and made practically feasible.

A parameterized foreground model was developed based on the UVEK database and covers the life cycle stages from resource extraction to the production of the injection-molded part. By connecting to openLCAs IPC server, the parameters of the model can be defined in CADMOULD. Entering the parameters triggers an impact calculation in openLCA, the results of which will then be displayed in CADMOULD.

The project version is currently in the internal test phase and has already been made available to the project partners of LCA4Sim. The product has yet to be implemented, but work is progressing in collaboration with the necessary stakeholders.



Test version of the CADMOULD user interface: Software solution for predictive LCA during the design phase of an injection molded part and manufacturing process in LCA4Sim, ©SIMCON.

The LCA4Sim project was thus able to show for the first time that the programmatic combination of process control and predictive LCA is possible in the context of injection molding.

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INSTITUT FÜR TEXTILTECHNIK DER RWTH AACHEN UNIVERSITY (ITA)

CONCEPT DEVELOPMENT

for sandwich floor panels with increased sustainability for the aviation sector

Authors: Rebecca Emmerich, Thomas Gries, Adli Dimassi, Christoph Klemm

Within the 'EcoFloor' project, a new concept for aircraft floor panels is being developed and investigated. The conventional layered structure of virgin carbon fibre fabrics and non-crimp fabrics the top layers and honeycomb cores is being replaced by layers made of alternative materials. A layer structure consisting of a polyester foam core, a cork intermediate layer and cover layers made of recycled carbon fibres (rCF) is being used.

The aim of this layer structure is to fulfil the requirements for aircraft floor panels in civil aircraft. Various bonding systems are also being investigated. The requirements concern not only technical criteria, such as tensile and bending loads, but also long-term goals of the aviation industry, such as increasing the sustainability of the raw materials used and minimising the overall environmental impact. To this end, the sub-concepts are evaluated with a life cycle analysis. In addition, a recycling concept is being developed to ensure economically and ecologically sustainable recycling. The aim of this concept is to efficiently separate the different layers. The focus is on processing the outer layers in order to preserve the structural integrity of the recycled carbon fibres and enable their reuse as high-quality semi-finished products in load-bearing applications.

At ITA, the focus is on investigating the production of top layers made of rCF. Both slivers and yarns are used as input materials for this purpose. These are used to produce multiaxial fabrics and woven fabrics from rCF yarns. The rCF slivers used (90–95 wt.-% rCF, 10–5 wt.-% co-polyamide) are developed and manufactured at ITA-A. The produced textiles were analysed with regard to the achievable mechanical properties in the composite. The research focus of FIBRE is on the production of sandwich composites and the investigation of insert integration. The vacuum infusion process with the duromeric, bio-based resin system Furolite 106A25 2ST, TransFurans Chemicals bv, Geel (Belgium), is used to manufacture the panels. (see Fig. 1)

Acoustic tests carried out by ZAL GmbH, Hamburg, have already shown that the adapted layer structure improves the acoustic damping properties compared to the benchmark. The production and further processing of the yarns and tapes represented significant obstacles.

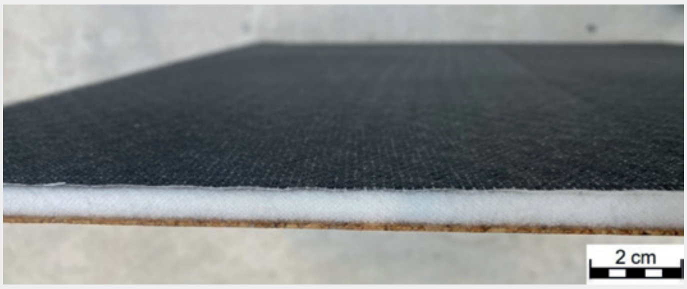

Fig. 1: sandwich floor panel

The rCF are available as short fibres. Therefore, the textiles have a voluminous structure with a rough surface after processing compared to primary fibre textiles. In the selected processing method, this results in low fibre volume contents of a maximum of 30 vol.-%. In the final months of the project, the focus will be on increasing the fibre volume content, fully characterising the mechanical properties and carrying out an ecological evaluation. The project with the funding code 20E2101C is funded by the Federal Ministry of Economics and Climate Protection as part of the Aviation Research Programme VI.

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INSTITUT FÜR TEXTILTECHNIK DER RWTH AACHEN UNIVERSITY (ITA)

Sustainable Fibre Composites:

THE BioYarnCoat

Innovation in Thermoplastic Processing

Authors: Lars Wollert, Maryam Sodagar, Thomas Gries

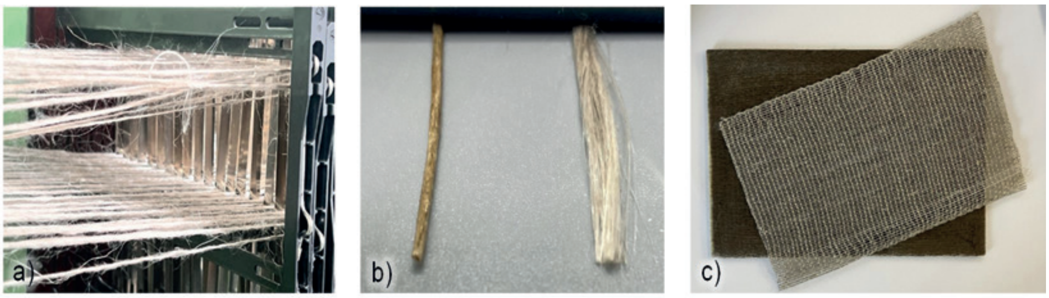

Fig. 1:
a) not impregnated flax yarn during weaving;
b) impregnated and not impregnated flax yarn;
c) 100 % biobased thermoplastic organo-sheet

The growing demand for sustainable composite materials has increased interest in natural fibres due to their renewability, biodegradability, and lower carbon footprint. However, high fibre hairiness, moisture absorption, and weak interfacial bonding with polymer matrices have limited their industrial use, leading to fibre shedding, machine wear, and reduced mechanical performance. To overcome these challenges, in the IGF project "BioYarnCoat" conducted at the Institut für Textiltechnik (ITA) of RWTH Aachen University, a thermoplastic impregnation method for natural fibre yarns has been developed.

The project focuses on melt-impregnation technology for flax fibre yarns with 100% biobased polyamide 11 (PA11), enabling fully biobased fibre-reinforced composites. A key innovation is the control of fibre twist during impregnation, which significantly enhances fibre alignment and impregnation quality. Proper orientation improves mechanical properties, making the material suitable for high-performance applications.

One major improvement is the drastic reduction in fibre hairiness, which minimizes fibre shedding and contamination during textile processing. This results in smoother, more durable yarns, reducing machine maintenance and improving production efficiency.

Mechanical performance has also been significantly enhanced. The tensile strength has increased tenfold compared to dry yarn, reaching 171.25 ± 5.5 MPa, while the elastic modulus has improved to 21.03 GPa. Additionally, moisture absorption has been reduced by 35% increasing long-term storage stability by preventing dimensional changes and degradation.

Another key achievement is the reduction of porosity to just 0.3%, combined with an optimized fibre volume content of 60%, improving mechanical integrity and durability. These enhancements make the material highly competitive with synthetic fibre composites.

The impregnated flax yarns have been successfully tested on industrial weaving machines, including the DORNIER P2 (as weft yarn) and Jakob Müller AG NFJK2 (as warp yarn). These trials confirm compatibility with existing textile manufacturing, ensuring scalability for industrial production.

The BioYarnCoat project represents a major step in biobased composite technology, addressing key processing challenges and enabling broader industrial applications. Future work will optimize fibre-matrix adhesion, explore alternative biobased thermoplastics, and scale up production.

With sustainability as a priority, innovations like BioYarnCoat at the Institut für Textiltechnik of RWTH Aachen University offer high-performance biobased alternatives, paving the way for a greener and more efficient composite industry.

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- Bond-Laminates GmbH
- Material 4 Print GmbH & Co. KG
- Teijin Carbon Europe GmbH
- Fehrer Automotive GmbH
- Büfa GmbH und Co. KG
- Fibrecoat GmbH
- Institut für Textiltechnik Augsburg gGmbH
- Institut für Unternehmenskybernetik e. V. an der RWTH Aachen
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FROM THE IDEA TO THE COMPONENT

Digital product development process for the design of tailored fibre placement components

Authors: Rebecca Emmerich, Lars Wollert, Thomas Gries, Diego Aguirre Guerrero, Univ.-Prof. Dr.-Ing. Georg Jacobs, Tobias Schalm, Prof. Dr.-Ing. Kai-Uwe Schröder

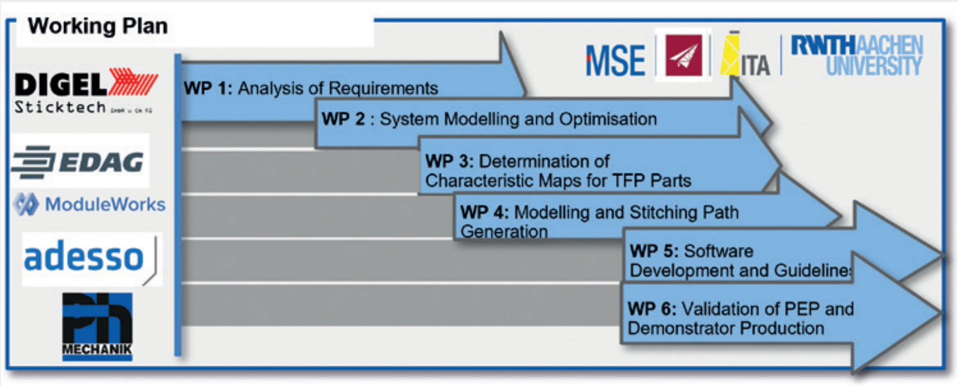

Fig. 1: Working Plan

Tailored fibre placement (TFP) technology is a variant of technical embroidery in which reinforcing fibres are placed variably and axially on an embroidery base using a CNC-controlled embroidery frame. This allows textile preforms for fibre composite components to be produced with the fibres aligned along the main stresses in the component. Despite a technology maturity level of 9, the optimised component design and embroidery pattern generation represent a hurdle for industrial application. This applies in particular to small and medium-sized series. The development of components using TFP usually requires a large number of iterations.

The aim of the 'DigiPEP' research project was to develop and validate a digital product development process for TFP components. This should help to enable material- and resource-efficient lightweight construction using TFP technology. A digitally networked product engineering process (PEP) has been developed to optimise the structural design of TFP components in terms of cost, weight and performance. In addition to three institutes at RWTH Aachen University, five companies were involved in the project (Ph-MECHANIK GmbH & Co. KG, adesso SE, Digel Sticktech GmbH & Co. KG, ModuleWorks GmbH, EDAG Engi-neering GmbH). (see Fig. 1)

The solution approach is based on the methodology of model-based systems engineering (MBSE). The linked value chain (design, structural mechanics, textile and production technology) is aggregated in the form of a system model and mapped from individual digital sub-models. The sub-models include structural optimisation, strength and stability analyses and path planning for production. To this end, a Business Process Model and Notation (BPMN)

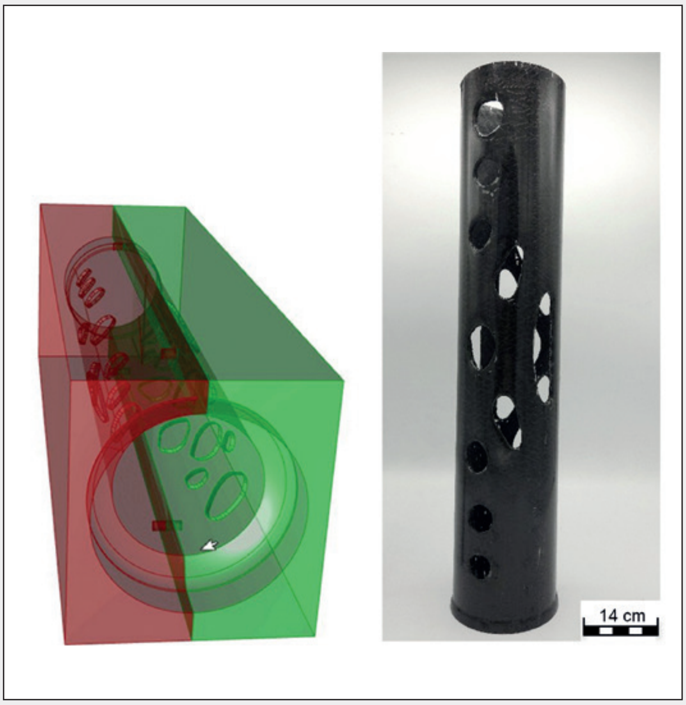

Fig. 2: left: Concept of the Tool Shape, right: Final Demonstrator

was first created and various models were developed to support product development. These include CAD concept design, topology optimisation and optimisation of fibre paths. In addition, material cards for CFRP-TFP materials were created and specific models for automated path planning were developed. A robot segment was selected to demonstrate the digitalised process chain. It was determined that mould development should also be taken into account in subsequent projects. (see Figure 2)

The software solution developed will enable the design and manufacture of material-efficient components in future, taking all relevant parameters into account. This represents a contribution to the achievement of sustainability goals, including the reduction of greenhouse gas emissions. Once completed, the software solution will be available to the project partners and further development is planned as part of a follow-up project.

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DIN 35255 „Qualitätsanforderungen an Composite-Prozesse“

Ist die kommende DIN 35255 wirklich „neu“?

Eindeutig ja: Die DIN 35255 legt für die Composite-Technologie **weltweit erstmalig umfassend**, d.h. von der ersten Produktidee bis zum fertigen FVK-Bauteil die Qualitätssicherungs-Leitlinien sowohl für Composite-Produkte als für Composite-Prozesse fest.
Andererseits: In anderen Technologiebereichen – die Schweißtechnik und die Klebtechnik sind zwei international erfolgreiche Beispiele derartiger QS-Normen – existieren vergleichbare Normensysteme längst. **Die DIN 35255 überträgt diese Erfolgs-Stories jetzt auf die Composite-Technologie.**

Wie ist im Composite-Bereich die Verbindung zwischen dem Produktsicherheitsgesetz (ProdSG), dem „Stand der Technik“ und dem Begriff „Spezieller Prozess“ nach ISO 9001?

Gemäß Produktsicherheitsgesetz (ProdSG) gilt für alle Technologien: Ein Produkt – egal welches, egal woraus, egal wie und wofür hergestellt – darf nur dann auf den Markt gebracht werden, „wenn es bei bestimmungsgemäßem oder vorhersehbarem Gebrauch die Sicherheit und Gesundheit von Personen nicht gefährdet“. Um dieses zu gewährleisten, ergibt sich der juristische Zwang, den **Stand der Technik** umfassend umzusetzen und nachzuweisen, sowohl für die Entwicklung und Herstellung von Composites und Composite-Bauteilen, für deren Instandhaltung und Reparatur als auch für die Nachweisführung der jeweiligen Produkt- und Prozesssicherheit.

Wenn jedoch dieser geforderte „Stand der Technik“ prozess- und produktspezifisch **nicht rein zerstörungsfrei** durch begleitende bzw. nachträgliche Überwachung respektive Messung oder zerstörungsfreie Prüfverfahren am Produkt (Produktsicherheit) oder in der Fertigung (Prozesssicherheit) nicht mit einhundertprozentiger Sicherheit verifiziert werden kann, handelt es sich gemäß ISO 9001 um sog. **spezielle Prozesse**. Folglich ist die Composite-Technologie ein solcher „spezieller Prozess“ – eine Analogie zur Schweißtechnik, zur Klebtechnik und zu zahllosen weiteren Verfahren!

Wie ist bei „speziellen Prozessen“ der gesetzlich geforderte „Stand der Technik“ zu realisieren und welche Funktion hat dabei die DIN 35355?

Für „spezielle Prozesse“ fordert die ISO 9001 vom Beginn der Produktentwicklungsphase über die Prozesse in Fertigung, Instandhaltung und Reparatur bis zum Produktlebensende ein **Qualitätsmanagementsystem mit der Hauptfunktion einer durchgängigen Fehlervermeidung.** Hierfür konkretisiert – direkt vergleichbar zu den entsprechenden Schweiß- und Klebnormen – die „neue“ DIN 35255 die vorgegebenen ISO 9001-Leitlinien und spezifiziert ein bestehendes QMS auf den Bereich der Faserverbundwerkstoffe.

Die DIN 35255 legt **branchenübergreifend** sowohl **die Anforderungen** an eine qualitätsgerechte Entwicklung und Ausführung von Faserverbundbauteilen als auch die allgemeinen organisatorischen, vertraglichen und fertigungstechnischen Grundlagen für die Entwicklung, Herstellung, Instandhaltung und Reparatur **fest.** Sie enthält dafür die aus den Schweiß- und Klebnormen bekannten Kernelemente:

- - **Klassifizierung nach** hohen (C1)
  - mittleren (C2)
  - geringen (C3)
  - und ohne (C4)
  Sicherheitsanforderungen

- objektiver **Nachweis der** jeweiligen technologischen **Personalkompetenz** (Kompetenzlevel 1 – 3) *siehe www.faserverbund-in-bremen.de*)
- **Nachweisführung** der Produkt- und Prozesssicherheit

und **vervollständigt** auf diese Weise in allen Bereichen von Industrie und Handwerk ganzheitlich **den geforderten Stand der Technik** für die fachgerechte, fehler(quellen)vermeidende Planung, Organisation und Umsetzung faserverbundtechnischer Prozesse und Produkte sowie für die prozess- und produktspezifische Sicherheitsnachweisführung.

Der FVK-verbindliche „Stand der Technik“ besteht folglich aus der Verknüpfungvon ProdSG, QMS und DIN 35255.

Stand der Technik -> Produktsicherheitsgesetz + QMS + DIN 35255

Durch Umsetzung der DIN 35255 gestaltet der Anwender in diesem Sinne Composite-Produkte und -Prozesse **robust und reproduzierbar.**

Weitere Fragen zur DIN 35255 und deren Umsetzung beantworten DIN-Arbeitskreisleiter Stefan Simon (Leiter Weiterbildungszentrum Faserverbundwerkstoffe – WZF im Fraunhofer IFAM / stefan.simon@ifam.fraunhofer.de) und Frank Stein (Leiter Zertifizierungsstelle TBBCert des Fraunhofer IFAM / stein@tbbcert.de).

UNIVERSITY OF STUTTGART, ITFT, ICD, ITKE, INTCDC

HYBRID-FLAX-PAVILION

Novel hybrid building system using natural fibers

Authors: Daniel Christopher Bozó[1,4], Pascal Mindermann[1,4], Monika Göbel[2,4], Christoph Zechmeister[2,4], Harrison Hildebrandt[2,4], Rebeca Duque Estrada[2,4], Tzu-Ying Chen[3,4], Jan Knippers[3,4], Achim Menges[2,4], Götz T. Gresser[1,4,5]

The Hybrid-Flax-Pavilion serves as a central exhibition building on the revitalized banks of the Argen River at the Landesgartenschau Wangen im Allgäu 2024 (Fig. 1). Developed by the Cluster of Excellence "Integrative Computational Design and Construction for Architecture" (IntCDC) at the University of Stuttgart, it pioneers a wood-natural-fiber hybrid construction system in a real application scenario as an alternative to conventional building methods. Combining cross-laminated timber with robotically wound flax fiber reinforced components, the pavilion exemplifies resource-efficient building systems using bio-based materials with regional ties, lending new life to flax, a material historically central to the local textile industry.

The roof, an innovative hybrid construction, integrates 20 timber-fiber components alternating with cross-laminated timber plates to form a 380 m² column-free space. These components, designed through computational design methods, balance tensile strength in filament wound components with compression in timber, optimizing material use while addressing high snow loads typical of the alpine region. The assembly of the 44 prefabricated elements took just eight days, showcasing the efficiency of computational design and robotic prefabrication. The design process involved interdisciplinary specialists, integrating structural analysis, material, and fabrication constraints, and architectural vision. The system enables future reuse through the sorted separation of components, advancing principles of circular construction.

The coreless filament winding process, adapted for flax fibers, enables a precise fabrication with limited formwork. Robotically created prototypes provide feedback to the design process, streamlining the design-to-fabrication workflow and bridging the gap between research and industry (Fig. 2).

The aim of the current research project "HNFVBauSys2" (Hybrid Wood-Natural Fiber Composite Building System 2nd funding phase) is to further develop the existing hybrid construction method.

To this end, the structural integrity of individual components is being monitored using fiber-optical sensors (Fig. 3). The knowledge gained from the long-term structural health monitoring will be implemented in existing processes to enable the conservation of resources through constructive optimization and the evaluation of designs. In addition, the effects of an increased demand for fiber plants from the construction sector will be holistically evaluated and a life cycle analysis of the construction project will be carried out. The results provide important insights for the construction industry and make a significant contribution to sustainability and efficiency in the construction sector.

Fig. 1: Hybrid-Flax-Pavilion at the Landesgartenschau 2024 in Wangen im Allgäu © ICD/ITKE/IntCDC University of Stuttgart

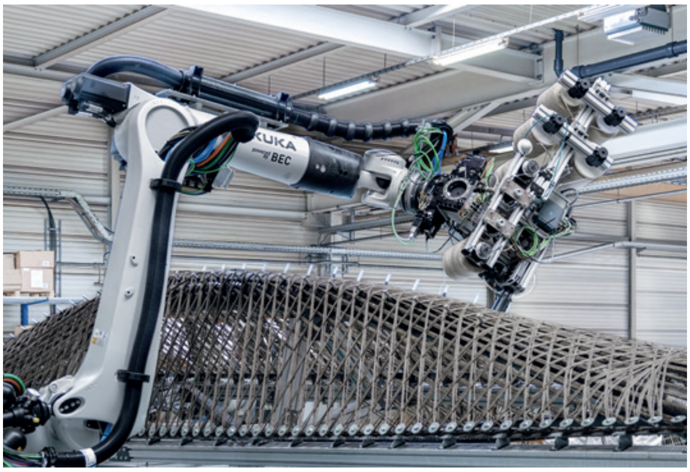

Fig. 2: Robotic prototype manufacturing using the coreless filament winding process © ICD/ITKE/IntCDC University of Stuttgart

Further project partners: Julia Weißert, Philip Leistner, Institute for Acoustics and Building Physics (IABP), University of Stuttgart and Alina Rossa, Franziska Schünemann, Institute of Economics, Chair of Bioeconomy, University of Hohenheim.

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Bioökonomie Baden-Württemberg

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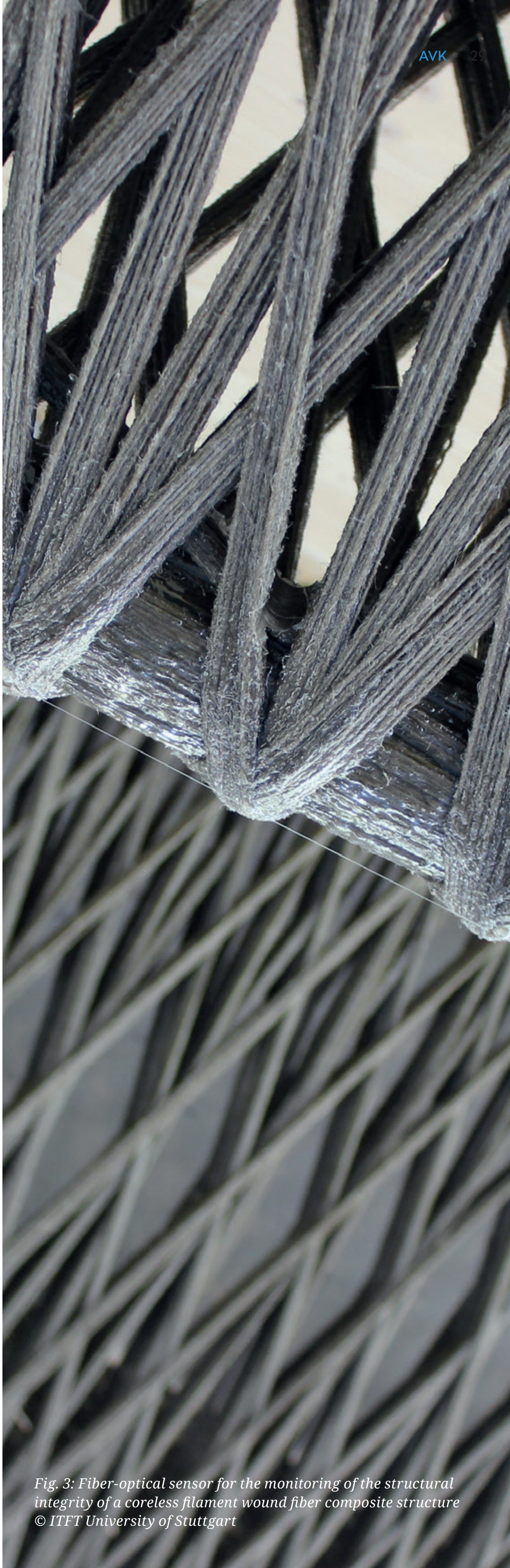


Fig. 3: Fiber-optical sensor for the monitoring of the structural integrity of a coreless filament wound fiber composite structure © ITFT University of Stuttgart

Final ReForm tool

TU CHEMNITZ

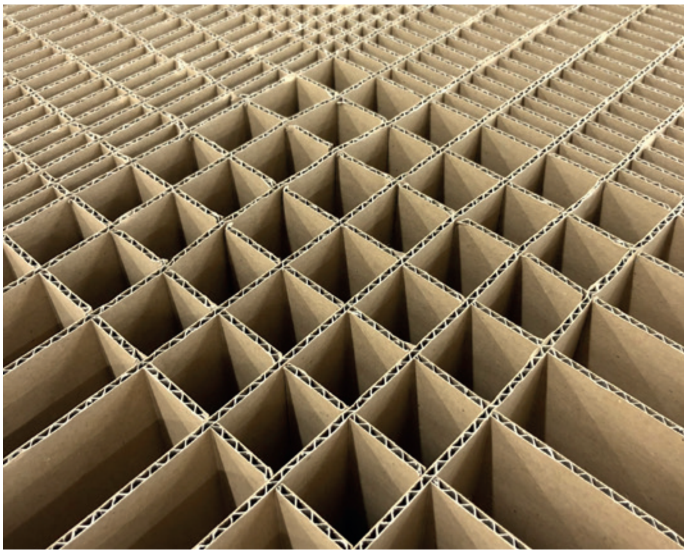
Resource-efficient molds made from RENEWABLE RAW MATERIALS for the production of fiber composite components

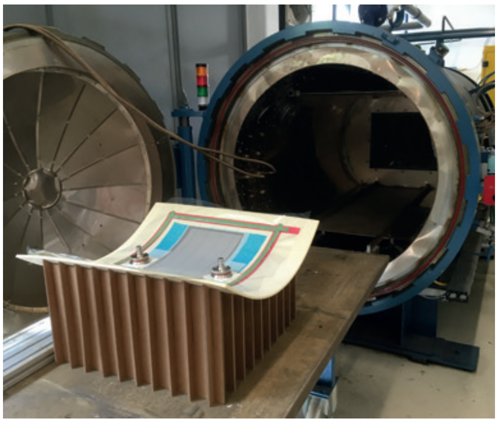
Author: Patrick Evers, Scientific employee

Fiber composite components are frequently manufactured in small series or as prototypes for one-offs. Depending on the manufacturing process and the desired component properties, open mold or closed mold tools are required to exactly reproduce the final geometry of the finished component. Despite the high quantities involved, mold manufacturing for laminating, infusion and casting processes accounts for approximately 50% of the total component costs and significantly contributes to resource consumption. In specific application areas, such as yacht construction, the multiple use of molds is severely limited due to the unique custom-made products prioritized by the end user, resulting in extremely high costs and making the process economically unfeasible.

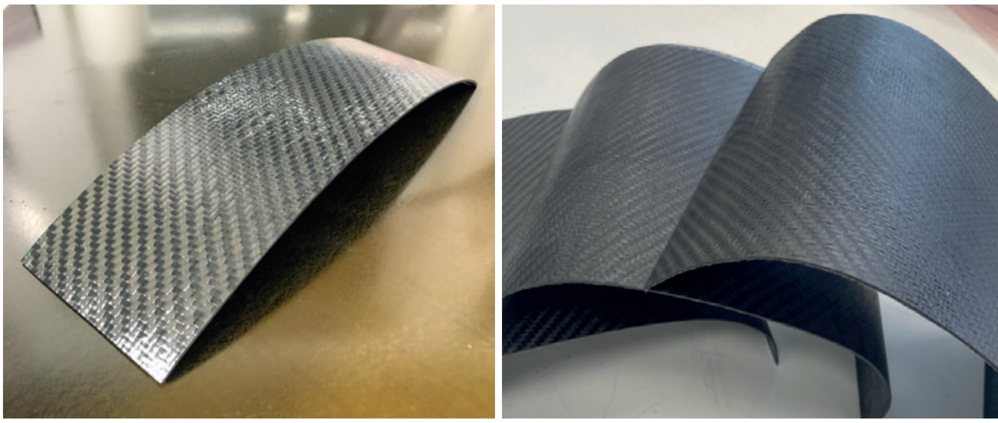
The aim of the "ReForm" research project was to develop a novel and sustainable concept for the generation of resource- and cost-efficient molds made from renewable raw materials. In addition to the optimized recycling aspect, the innovative use of cellulose fiber-based components is characterized by a considerable reduction in tool weight and thus decreasing transport and handling efforts.

The approach involved the use of corrugated cardboard as a material in the form of a stuck cardboard structure, which reproduces the 3D component contour by joining





Production tests at the DLR Institut of Lightweight Systems



Component production

2D cardboard webs using precise contour plotting. By reducing the distance between this structure, a more detailed design for heavily stressed segments can be implemented. In combination with a flexible mat simple geometries can be produced using the hand lay-up laminate process. For more complex structures or vacuum applications, the tool was subsequently optimized in several iteration steps in close cooperation with DLR Institut of Lightweight Systems and richter & heß VERPACKUNGS-SERVICE GmbH. The complexity was increased by stacked corrugated cardboard webs and the required vacuum tightness was achieved by applying a thin layer close to the final contour.

Overall, the process reliability was demonstrated through initial composite components using the sustainable tool. The molding tools are characterized by sufficient dimensional stability, even at high temperatures and under pressure. With an additional perforation line close to the surface of the corrugated cardboard webs, it is possible to return 95% of the tool to the established cardboard recycling process after its use phase.

In further research projects, the evaluation and transfer of the current development results into new solutions for suitability in serial applications will take place.

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