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Research Article

Sustainable Lightweight Bio Hybrid Construction for Future-Oriented Mobility

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Abstract

As part of the "Renewable Resources" funding program of the German Agency for Renewable Resources (FNR), the Fraunhofer Application Centre HOFZET® is working with Porsche AG and the Four Motors racing team to develop biogenic hybrid composites, i.e. bio-based matrix systems in combination with bio-based and/or synthetic reinforcing fibers, for use in the mobility sector. These are a sustainable alternative to the previously used carbon fiber-reinforced materials. "Sustainable lightweight bio-hybrid construction for future-oriented mobility" is the follow-up project to the successful "Bioconcept-Car", which was also funded by the FNR 2011-2013 at the Institute for Bioplastics and Biocomposites at Hannover University of Applied Sciences and Arts, the partner institute of the HOFZET® Application Centre.

Keywords: Bio-Composite; Hybridization; Automotive; Carbon; Natural Fibers; Life Cycle Assessment

Abbreviations

BMEL: German Federal Ministry for of Food and Agriculture; DIN: German Standards Institute; FNR: National Agency for Renewable Resources in Germany; FRP: Fiber-Reinforced Plastics; HFRP: Hybrid Fiber-Reinforced Plastic; NFRP: Natural Fiber-Reinforced Plastics.

Introduction

The present project comprises the development of biogenic hybrid composites, i.e. composites of bio-based matrix systems and/or bio-based reinforcing fibers/fabrics used in combination with carbon or glass fibers as solution for applications in sustainable mobility. Instead of a simple substitution, an advantageous combination of biogenic materials and industrially available high-performance materials is to be achieved. The tasks will initially be carried out in small batch production, while the economic indicators will be monitored. In the first phase of the project, hybrid fiber-reinforced polymer composites will be produced and subsequently tested under real conditions with a dedicated automobile. Subsequently, automotive components are selected for a specific application-oriented material development and hybrid composites are produced from them. These parts are also used for supplementary tests under real conditions. Finally, transfer scenarios are designed for series production.

In the automotive industry, especially in motor racing, fiber-reinforced plastics (FRP) have established themselves alongside steel, aluminum and plastics. FRPs consist of a homogeneous plastic carrier component, the so-called matrix, and the continuously or discontinuously embedded fibers as reinforcing components. These composite materials are particularly important in lightweight construction and are increasingly replacing materials such as steel and aluminum due to their high quality, density-specific properties [1-4]. When two or more types of reinforcing fibers are combined in a matrix in an FRP, this is referred to as hybrid fiber-reinforced plastic (HFRP) (Neitzel., *et al.* 2014). Hybridization fuses the properties of two fiber types in a single component, whereby the ratio of fiber-specific advantages and disadvantages can be chosen specifically to obtain the desired material properties. Hybridization can be achieved either by layering semi-finished products of different fiber types or by using different fibers in a textile layer (hybrid fabric).

Figure 1: Hybrid multilayer structure © Fraunhofer WKI/Ole Hansen.

Figure 2: Hybrid fabric structure © Fraunhofer WKI/Carsten Aßhoff.

The majority of fiber composite technologies in the automotive industry are covered by conventional reinforcing fibers such as carbon and glass fibers due to their good mechanical properties. The steadily growing public demand for sustainable, resource-saving and recyclable materials demands not only appropriate mechanical properties but also focusses on aspects such as a good CO_2 balance or durability. In particular, the hybridization of conventional reinforcement fibers with natural fibers promises a good compromise between mechanical properties and environmental compatibility: High-performance fibers such as carbon or glass fibers induce high strength and stiffness, which decisively determine the mechanical properties of the fiber composite material. The very cost- and energy-intensive production with a correspondingly poor CO_2 balance and the exclusively conventional availability of petroleum-based carbon fibers can be partially compensated by the proportionate substitution with natural fibers.

Natural fibers offer a number of special properties compared to conventional (high-performance) reinforcing fibers [5]:

- Lower density
- Lower splintering behavior under crash load
- Advantageous acoustic damping properties
- Lower raw material costs
- Lower production-related energy consumption and thus better CO_2 footprint
- Physiologically easier handling
- Almost CO_2-neutral and residue-free thermal recycling

The aim of the project is to develop hybrid high-performance materials and components and to investigate their technical, economic and ecological potential in the context of sustainable mobility. In addition to classical material development, the focus is on technology assessment of hybrid materials from the point of view of the automotive industry, which also includes the analysis of raw material and production costs, recyclability and ecological criteria.

To this end, the researchers at Fraunhofer HOFZET® produce a proportionally bio-based composite material that meets the component specifications of the selected components. In this way, they determine not only the technical parameters for component design, but also the information required for feasible series production. If, for example, the complete substitution of carbon fibers by bio-based fibers is not possible for every part, synergies are exploited through intelligent material combinations to provide functionally at least equivalent materials and components with improved ecological performance. Bottlenecks of bio-based fibers in the area of mechanical properties are compensated by functional integration and load path-optimized hybrid structures. Also, corresponding concepts concentrate – with regard to saving resources and improving the CO_2 balance –on the highest possible (re-)use of production residues.

Materials and Methods

The project is divided into three work packages: Technical, ecological and economic evaluation, which systematically build on each other (Figure 3). During the project, selected components will be mounted on a Porsche Cayman GT 4 (981) as a test vehicle and evaluated over the racing season. The investigations on a racing vehicle combine the advantage of extreme loads with the use of a vehicle that is also available in the same geometry as a road vehicle. In cooperation with Porsche AG, the development can also be carried out under real-world conditions of an automobile manufacturer.

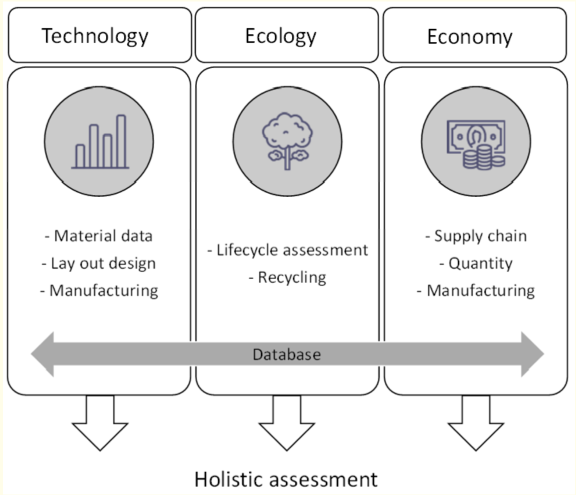

Figure 3: The three columns issues: Technology, ecology and economy form the project objective - a holistic evaluation basis © Fraunhofer WKI/Ole Hansen.

The mechanical characterization according to the corresponding standards of the automotive sector and the comparison of different manufacturing processes show the potential of a possible series production. For ecological and economic considerations, additional data over the entire life cycle of a component are determined for the preparation of a life cycle analysis (LCA). In addition, price ranges as a function of the order quantity are being collected, which supplement the performed market research with real values. The evaluation basis created from these results enables industry, politics and customers to design a component from e.g. ecological aspects and to estimate the resulting influences on technical and economic factors.

The main difference between natural fibers and conventional fibers is the limited length of natural fibers, due to its natural origins, compared to glass or carbon fibers which can be produced in the form of endless filaments. Because of the spinning process, the natural fibers are more or less twisted together as yarn, which is why the yarn has different mechanical properties than the individual fibers. Depending on the structure and load of the different components, different woven textiles are used. They differ in fiber type, architecture, grammage, but also e.g. in the purchase price. For example, plain weave fabrics show a high degree of undulation (waviness of the fibers as a result of weaving), which is why they have a high resistance to displacement, but low drapability and lower mechanical properties than other types of weave. This applies to both petrochemical and bio-based fibers.

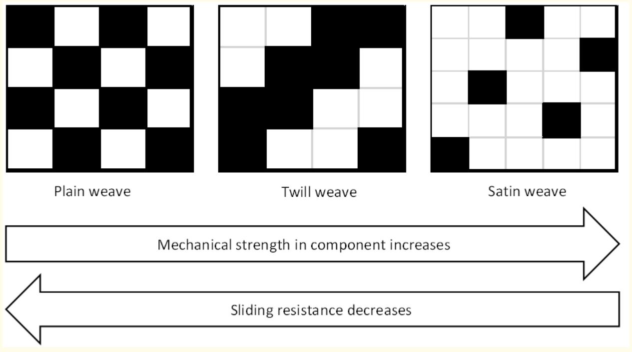

Figure 4: Influence of fabric architecture on bond strength and sliding attachment wedge of the fabric © Fraunhofer WKI/ Jana Winkelmann.

The selected textiles are cut out according to given patterns via CNC machinery (Computerized Numerical Control) in order to guarantee the best possible draping and displacement resistance. The vehicle components are composed of two or more individual parts, which are manufactured and glued separately. For this purpose, the blanks are placed in negative molds, sealed vacuum-tight and saturated with a liquid matrix. After the matrix has hardened, the component can be removed from the mold and processed further. Using the example of the door of a Porsche Cayman GT 4 (981), the influence of hybridization of natural fiber-reinforced plastics (NFRP) with carbon fibers on various factors is compared.

Relevant requirements for the door include sufficient buckling stiffness in the door leaf and sufficiently high stiffness in the door frame. If this is not the case, the pressure differences inside and outside the vehicle can cause the door frame to protrude outwards during the race. Defined stiffness and strength for such critical areas form the basis of the material design. Depending on the component requirements, the respective layer structure also varies within the door, which is why test specimens from critical areas of the door were manufactured as two-dimensional laminates and characterized according to standards of DIN (German standards institute). This enables an easy and quick comparison of different laminates for an optimal design.

Results and Discussion

Based on the test specimens, project researchers determined the weight, the price (related to one square meter of dry laminate, ordering a minimum of 2,000 m^2) and different technical parameters for varying natural fiber contents. The values in the test specimen with a pure natural fiber content were set as 100 percent (Figure 5 to 7). Figure 5 shows that it is possible to use 100 percent natural fibers in the outer door leaf, with a lower raw material price and almost identical mechanical characteristics. Only the component weight is minimally increased.

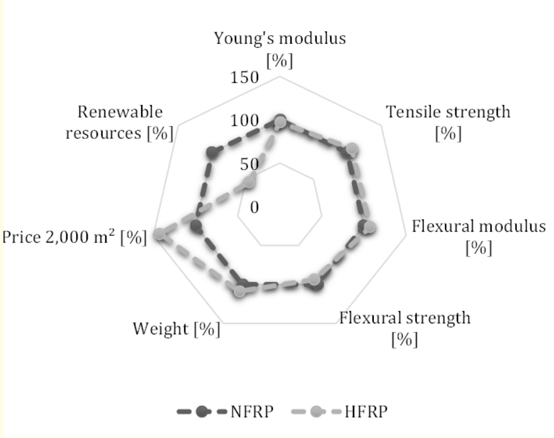

Figure 5: Influence of hybridization (HFRP) on selected parameters of the outer door shell compared to a natural fiber-reinforced plastic (NFRP) © Fraunhofer WKI/Ole Hansen.

The situation is different for the inner and outer door frames. The graphs in Figures 6 and 7 show a significant increase in the values of different mechanical properties due to hybridization. The price and weight of the HFRP components remain at a similar level to the NFRP component, in contrast to the case described above for the outer door leaf. Even at a smaller share of natural fibers, its ratio is still over 40 percent.

The use of a bio-based matrix system could help to increase the amount of renewable raw materials. Tests with such materials have not yet been carried out in the project, but they have great potential for better force transfer from the door frame to the door leaf under load.

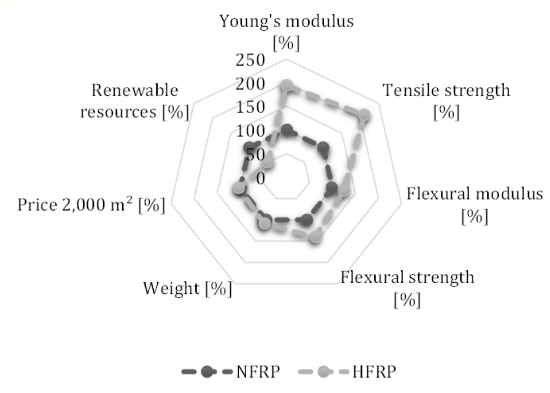

Figure 6: Influence of hybridization (HFRP) on selected parameters of the outer door frame compared to a natural fiber-reinforced plastic (NFRP) © Fraunhofer WKI/Ole Hansen.

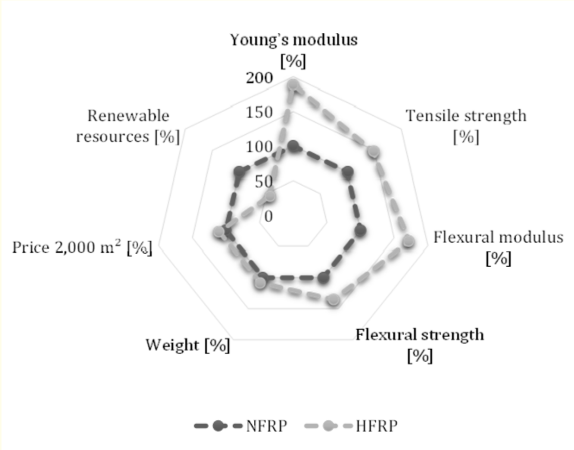

Figure 7: Influence of hybridization (HFRP) on selected parameters of the internal door frame compared to a natural fiber-reinforced plastic (NFRP) © Fraunhofer WKI/Ole Hansen.

Conclusion

A total of four components (doors, front cover, rear wing and the wheel arch liner) were considered within the framework of the project and manufactured using renewable raw materials. The door and the rear wing as dynamically loaded components are subjected to a holistic evaluation. The current results clearly show the potential of hybridizing NFRPs with carbon and were generated with hybrid multi-layer composites. In order to further increase the amount of renewable raw materials in composite applications, hybrid fabrics made of natural and carbon fibers are currently being designed to meet the mechanical requirements. These are particularly suitable for one-dimensional force flows, e.g. in door frames. At the same time, potential series production of these optimized structures is being successfully scaled-up with a view to various manufacturing processes required for automotive components.

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Bibliography

1. Bergmann HW. "Konstruktionsgrundlagen für Faserverbundbauteile". Berlin : Springer (1992).
2. Flemming M and Roth S. Faserverbundbauweisen. Eigenschaften; mechanische, konstruktive, thermische, elektrische, ökologische, wirtschaftliche Aspekte. Berlin: Springer (2003).
3. Endres HJ. Bioverbunde, Technik und Umwelt vereint. Kunststoffe Zeitschrift (2012).
4. Habermann C and Endres HJ. The Project: Sustainability Racing – The Vision: Mobility of the Future. [Buchverf.] A. Subic, R. Trufin (Hg.) J. Wellnitz. International Conference ICSAT 2013 (2014).
5. Carus M. (Hg.). Studie zur Markt- und Konkurrenzsituation bei Naturfasern und Naturfaser-Werkstoffen (Deutschland und EU). Unter Mitarbeit von Gahle, C., Pendarovski, C., Vogt, D (2008).

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