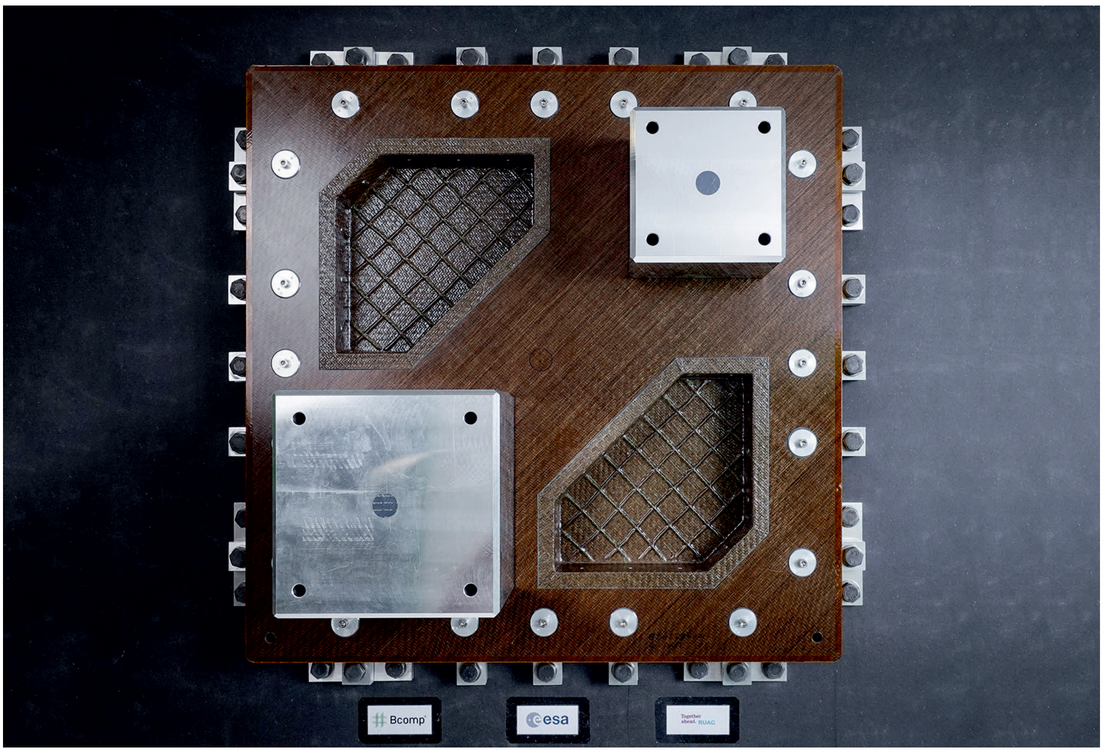
Composites Are Trendsetters in Lightweight Design

Fiber-Reinforced Composites Drive Innovation in the Transport and Construction Sectors

Climate change and the transport revolution are demanding smart fiber-reinforced composite solutions. In sectors such as the marine industry, infrastructure, and rail vehicle construction, many different fire protection concepts are competing. The composites industry is paying increased attention to recycling.



The first natural fiber-reinforced satellite panel permits safe space exploration and completely burns up on re-entry into the earth's atmosphere © BComp

Through loss of production and sharply declining investment activity, the composites sector is also being affected by the great uncertainty of the coronavirus crisis. A significant proportion of suppliers and processors – particularly in the aviation industry – have been seriously hit. This is also made clear by the Composites Development Index determined by Composites Germany, Berlin, Germany, from a survey of the member companies of its three main sponsoring trade associations AVK (Federation of Reinforced Plastics), Frankfurt am Main, Germany, Leichtbau Baden-Württemberg (Development Agency for Lightweighting), Stuttgart, Germany, and the VDMA Working Group on Hybrid Lightweight Construction Technologies, Frankfurt am Main. The business situations of these companies have been assessed as becoming increasingly negative for over a year now [1], with a continuing downwards trend. With the current economic instability, reliable further forecasts are also very difficult to make.

Nevertheless, very dynamic developments in individual fiber-reinforced composite segments can be expected in future. It is notable that, after many years, carbon fiber-reinforced plastics (CFRP) have replaced glass fiber-reinforced plastics (GFRP) as trend setters, although a downturn of approximately 13% in the European CFRP production volume is forecast for 2020 [2]. The hope is that, even in this exceptional time, positive trends will emerge, for example towards more sustainable applications, processes, and materials.

Highly topical issues at the present time include public transport – where materials have an important role to play in both lightweight design and fire safety – and conservation of resources, whether through long-lasting fiber-reinforced composites or modern fiber recycling.

Besides developing modern drive concepts, there is also great interest in reducing the amount of car and truck »

Fig. 1. Spaceframe for a metro rail vehicle front end made from braided tubes. To reduce the weight, comprehensive changes in geometry were undertaken © Far UK

traffic per se. Transport of goods and people should, for example, be switched from road to rail and local public transport in towns and cities strengthened. For these developments, products based on fiber-reinforced composites are much in demand. Carbon fibers are being increasingly used in these lightweighting applications. Load path-aligned fiber orientation is a must here. The construction industry is also proving quite crisis-resilient with many composite developments. In the transport sector, Far UK, Nottingham, United Kingdom, has designed a modular prototype for a railcar front end (**Fig. 1**) [3] as part of a project entitled "Brainstorm – Braided Novel Beam Structures with Opportunities in Railcar Manufacture".

Cost-Effective Braiding Processes

To achieve weight reductions as required for "very light rail" (VLR), which means a maximum weight of 1 t per running meter, the team carried out far-reaching geometrical optimizations. The spaceframe chassis is based on hybrid rovings made from thermoplastics and glass or carbon fibers. The spaceframe tubes, produced by a cost-effective braiding process, have a consistent outside diameter but tailored wall thickness according to the local load. The advantage of these tubes that are adhesive bonded and welded together is that in the event of damage, localized replacement of a single element is possible.

Another transport example is a force flow-optimized roof structure for rail vehicles developed by the Institut für Fahrzeugkonzepte (Institute for Vehicle Concepts) at the Deutsches Zentrum für Luft- und Raumfahrt: DLR) (German Aerospace Center), Stuttgart. This is a 65 mm thick sandwich structure with outer layers made from CFRP and a foam core that also performs insulation functions (**Fig. 2**) [4]. The roof consists of five different segments symmetrically arranged with respect to the vehicle center and each divided into two longitudinal beam sections and a covering layer section. Through tailored layer structures and fiber orientation, the individual segments are adapted to the local load conditions. The roof can be produced using vacuum infusion, for example. The faWaSiS joint project associated with this development is also focusing on a structural health monitoring system to detect and evaluate damage during operation [5]. This lightweight fiber-reinforced composite roof structure is already implemented in a whole train, the Cetrovo metro vehicle, which is made almost entirely from CFRP components [6].

Fire-Retardant Thermoset and Thermoplastic Composites

Meeting fire safety requirements continues to be a key criterion in many plastics applications. Composites with a thermoset matrix are frequently used to advantage here. For many years now, Saertex GmbH & Co. KG, Saerbeck, Germany, has supplied modular fire protection systems for composites, comprising reinforcing and core materials as well as resins and protective layers [7]. A sandwich concept specifically tailored to the hull design of large ships is currently being developed (**Fig. 3**). This sandwich structure incorporates the "Enex" aluminum trihydroxide (ATH)-based reinforcing layer that has a cooling action in the event of fire. Thanks to this localized effect, infusion processes with unfilled epoxy resin can be used. A 3D-reinforced foam maintains the cohesion of the structure through integrated glass bridges. Laterally arranged glass-metal hybrid fabrics that permit the hull elements to be welded on conventionally are a major plus for ship assembly.

Thermoplastic fiber-reinforced composites also meet high fire retardancy requirements. Maezio UD tape, produced by Covestro AG, Leverkusen, Germany, is a carbon fiber-reinforced polycarbonate with very good mechanical properties as well as low flammability [8].

Even if spectacular new developments suggest otherwise, cost-effective, successfully established glass fibers continue to reinforce most fiber-reinforced composites. However, carbon fibers with their high tensile strength and stiffness have made a remarkable advance in some sectors, such as the automotive

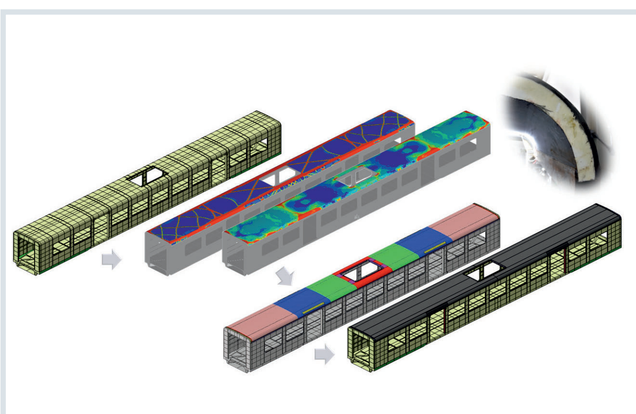


Fig. 2. Methodical development process for a fiber composite-based rail vehicle roof. The improved topology results in favorable load paths. Free-size optimization determines the thickness of the fiber layers © DLR

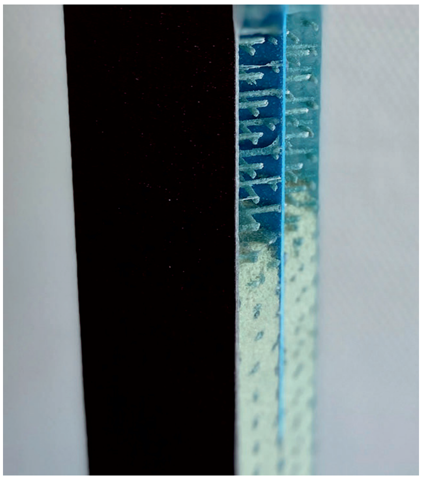


Fig. 3. The core of an integrated sandwich structure for vacuum infusion is a 3D-reinforced foam with an "Enex" fire-retardant inner layer © Saertex

Fig. 4. The TextureWall component for mobile homes has an authentic plaster look. It is weatherproof and UV-resistant and therefore has a very long life © Lamilux

and wind power industries. Many manufacturers also rate basalt fibers highly on account of their high tensile strength combined with good availability [9, 10]. Natural fibers have long found application in automotive interiors, where they are used in the form of compression molded fiber mats with thermoplastic or thermosetting binders. For some years now, new areas of application have been emerging, particularly for higher-performance natural fiber-reinforced composites. Regenerated cellulose fibers are a high-quality, non-abrasive alternative to glass fibers (**Box**).

Natural Fibers for Satellites

Continuous natural fiber-reinforced satellite structures offer the advantage of burning up completely on re-entry from space – a current requirement of the European Space Agency (ESA) in the context of "Design for demise". Thanks to the so-called PowerRibs reinforcement, visible in the **Title figure** in the recessed component areas, the structure has sufficient strength to transport sensitive equipment safely under high rocket launch forces [11]. High mechanical damping capacity and low thermal expansion ensure the competitiveness of this flax fiber-reinforced epoxy as compared with CFRP.

There is currently movement in the construction sector, where more traditional materials have tended to be used. The drivers for this are affordable living space concepts and the demand for increased building efficiency. The TextureWall from Lamilux Heinrich Strunz Holding GmbH & Co. KG, Rehau, Germany, is a fiber-reinforced plastic sheet with an authentic plaster-like surface texture [12]. This UV-resistant, weatherproof Lamilux variant for facade cladding of halls, prefabricated houses, mobile homes and containers is available in a continuous roll and has an attractive, durable plaster look (**Fig. 4**).

Foam Cores Processed Differently

The ThermoBracket facade cladding bracket from Fisco GmbH, Zusmarshausen, Germany, is an innovative development for mounting back-ventilated curtain wall facades [13]. It comprises a GFRP core based on a fire-retardant biopolyurethane (PU). The GRP core is surrounded with EPS foam. The bracket is fixed to the building wall to support the cladding sub-structure. Since it is only attached after the wall insulation has been installed and has very low thermal conductivity, the wall insulation is very effective, allowing the thickness of the insulating material to be significantly reduced.

The combination of fiber-reinforced outer layers with a lightweight foam core is also an efficient lightweighting solution for structural components in auto manufacture. Ultrastiff sandwich components can be produced at low pressures and temperatures in processes such as HP-RTM (high-pressure resin transfer molding) by combining cost-effective polyethylene terephthalate (PET) cores with outer layers made from continuous fiber-reinforced PU. The PU resin system Loctite Max 2 from Henkel AG & Co. KGaA, Düsseldorf, Germany, cures in a few minutes at temperatures less than 70 °C so enabling serial production of such components [14, 15]. »

Natural Fibers for Fiber-Reinforced Plastics

Büfa Thermoplastic Composites, founded in 2019 by the Oldenburg/Germany-based chemical company Büfa, is the only European distributor to supply cellulose fibers. They are used among other purposes as a reinforcing material for organosheets and long fiber-reinforced thermoplastics (LFT) [22]. Like other natural fibers they have a density of only 1.5 g/cm^3 and also have very good ductility. Since cellulose fibers are less damaged in compounding processes, thermoplastic composites reinforced with these fibers can be recycled significantly better than those based on glass fibers.

© Cordenka / BÜFA Thermoplastic Composites

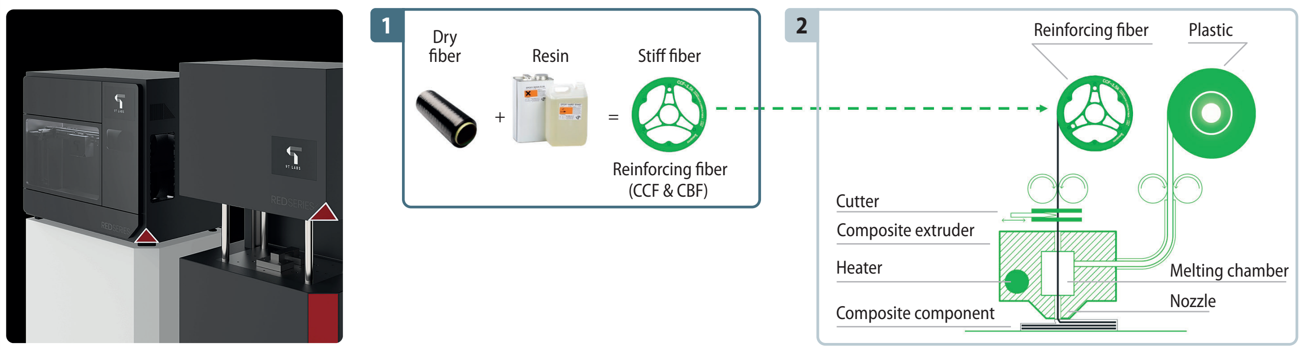


Fig. 5. Two concepts for quasi-pore-free, additively manufactured fiber-reinforced composites. The 3D printer with "fusion module" for post-consolidation gives users an uncomplicated entry into serial production (left). Coextrusion of thermoplastics with pre-impregnated fibers leads to composites with very good mechanical properties; CCF = composite carbon fiber, CBF = composite basalt fiber (right) Left: © 9T Labs, right: source: Anisoprint; graphic: © Hanser

Also for sandwich components, Hexion, Columbus, OH/USA, has launched, for the first time, fiber-reinforced, foamable thermoset materials for both injection molding and extrusion. Thanks to stabilizing additives and a chemical blowing agent tailored to the curing kinetics, Hexion has succeeded in producing lightweight, fire-retardant Bakelite FoamSet foams and skin-core foam structures [16].

At the Neue Materialien Bayreuth research institute, Bayreuth, Germany, various sandwich concepts have been tested for three-dimensional preformed composites made from thermoplastic tapes or foams [17]. For in-situ particle foam, for example, the core is produced directly between any desired configuration of three-dimensional preformed outer layers or hollow profiles. In this process, prefoamed thermoplastic beads are filled and sintered to provide a tight material bond between the core and outer layers.

Pore-Free 3D Printing

Additive manufacturing of replacement parts and prototypes has long been established. This trend has been accelerated during the coronavirus crisis because the process offers rapid availability of medical device components. 3D printing is being used for serial production. In additive manufacturing of structural plastic components for high mechanical loads, continuous fiber reinforcement is a must. Besides an optimum fiber structure, minimal pore density is crucial for the approval of serial components. Two young companies are achieving this in different ways for fused filament fabrication (FFF). 9T Labs, Zürich, Switzerland, post-consolidate the additively manufactured CRP component under pressure and heat (**Fig. 5, left**) [18]. In this process, as well as proprietary polyamide (PA) or polyetherketoneketone (PEKK) filaments, it is also possible to use customer-specific compositions. Anisoprint, based in Luxembourg, first impregnates the carbon or basalt fibers pore-free with a liquid resin system [10]. This reinforced filament is then coated in the composite fiber coextrusion (CFC) process above its softening temperature with any desired thermoplastic that melts below 270 °C (**Fig. 5, right**).

Recycling of Aircraft Components

With fiber-reinforced plastics (FRP), too, there is growing interest in recycling. Whereas glass fiber-reinforced plastics, notably from decommissioned wind turbine rotors, are frequently recycled in cement works by both raw material reuse and thermal energy recovery, carbon fibers are simply too expensive not to recycle in a closed loop. Boeing, Chicago, IL/USA, for example, is currently in partnership with ELG Carbon Fiber, Coseley, United Kingdom, to recycle uncured and cured CFRP production scrap for manufacturing electronic and automotive equipment [19]. For some years now, CFK Valley Stade Recycling GmbH & Co. KG, Wischhafen, Germany, has also been recycling production scrap and end-of-life composites by pyrolysis [20]. The waste derives increasingly from rotor blade belts but also comes from many other sources such as collection systems of bicycle dealers. Through its partner company carboNXT GmbH, Wischhafen, consolidated recycled-fiber nonwovens, chopped fibers and thermoplastic and thermoset molding materials are sold [21].

As the current product developments show, intelligently tailored fiber-reinforced composite systems are penetrating virtually all relevant sectors. 3D printing makes it possible to produce completely new composite designs. Overall, these developments offer very good prospects for surviving the next few economically difficult years. ■

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Service

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