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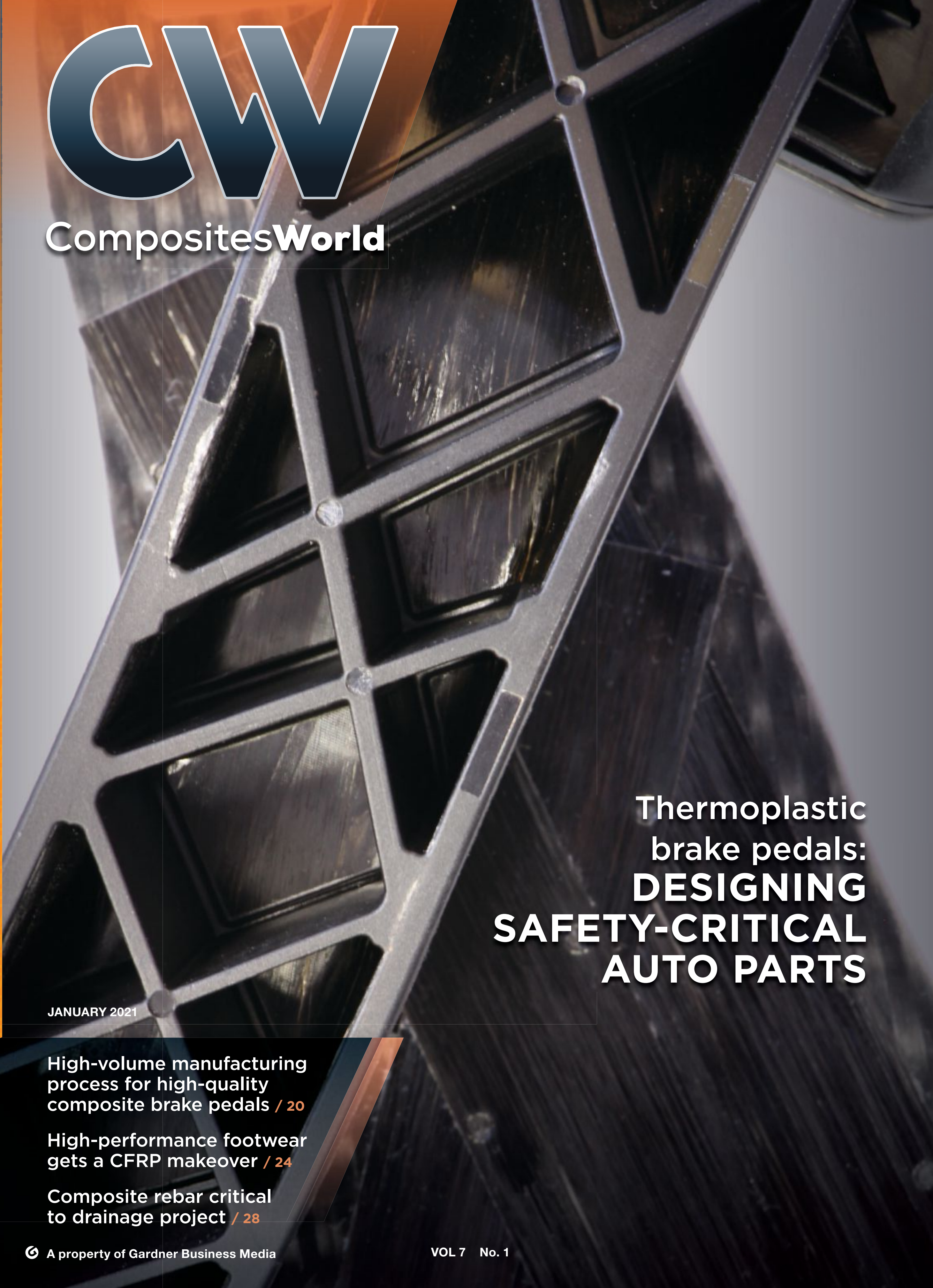

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Thermoplastic brake pedals: DESIGNING SAFETY-CRITICAL AUTO PARTS

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ON THE COVER

The first all-thermoplastic composite brake pedals produced by Boge Rubber & Plastics Group use three different types of composite — organosheet (right), UD thermoplastic tapes (laser-tacked onto organosheet, middle) and short-glass overmolding compound (top ribbed structure) in fiberglass-reinforced PA6 or PA6/6. See pp. 20, 44.

Source | Boge Rubber & Plastics Group

FOCUS ON DESIGN

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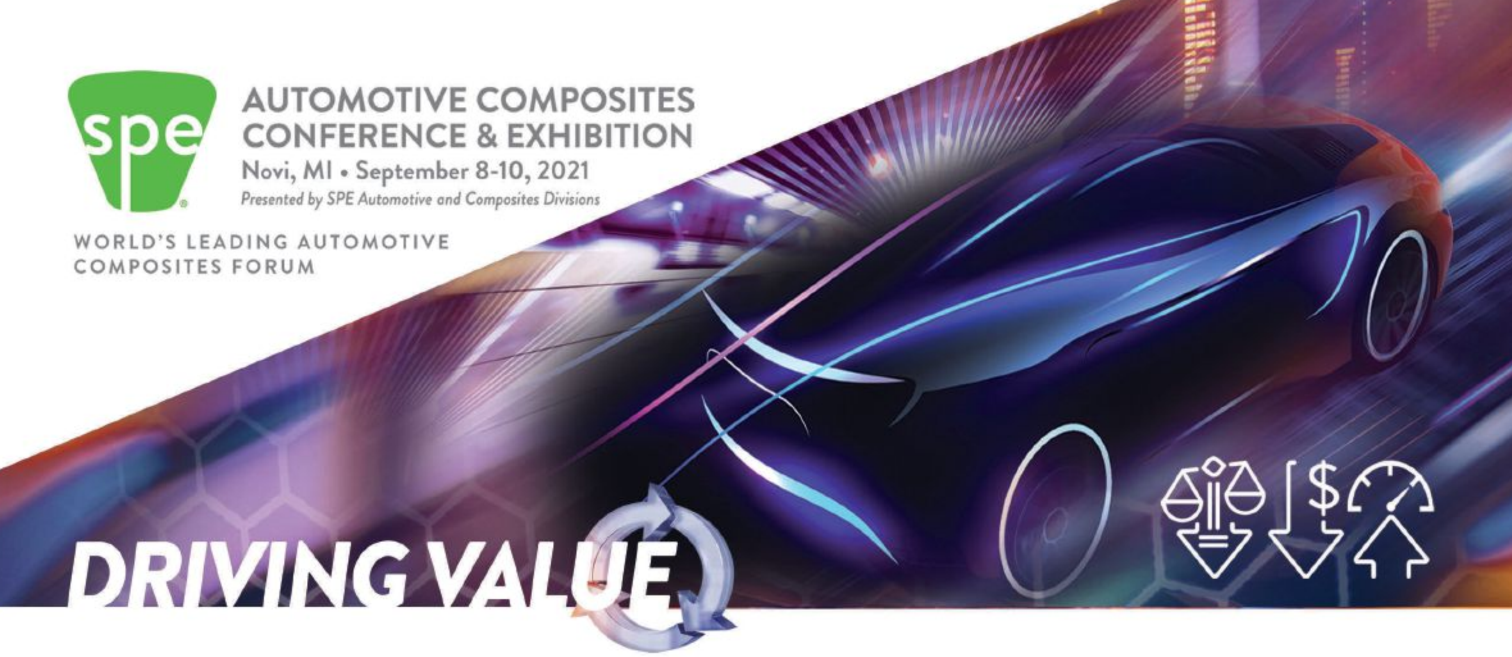

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Although it is objectively true that 2020 is, on balance, one of the worst years of the last century lived by humans, it will be quite a while before we understand thoroughly how history will judge the Year of the Pandemic.

However, now that the year is officially in the rearview mirror, and now that the distribution of vaccines is providing us a *slight* glimpse of what might be the *faintest* glimmer of a light at the end of the COVID-19 tunnel, we might start thinking about what 2020 has wrought, and what it means for the composites industry.

> The darkest, biggest cloud of 2020 is the aerospace industry.

First, we should acknowledge the asynchronous nature of the economic downturn caused by the pandemic. Unlike a traditional recession, which strikes broadly and uniformly, the brakes applied to the composites industry by COVID-19 were not felt homogeneously.

The wind energy industry, for example, after a short lull in the spring, soon returned to pre-COVID-19 form and is expected to end 2020 in record-setting fashion. The American Wind Energy Assn. (AWEA, Washington, D.C., U.S.) reported in October 2020 that the third quarter of 2020 saw the U.S. install 2,000 megawatts (MW) of wind power — a record for any third quarter in the U.S. Further, the U.S. was on pace to install more wind power in 2020 than any previous year, with installations through the third quarter up 72% compared to the same period in 2019. Much of this activity likely was spurred by the Production Tax Credit (PTC), which expired on Dec. 31, 2020, but that should not diminish our admiration for what the entire wind industry supply chain accomplished in very difficult circumstances.

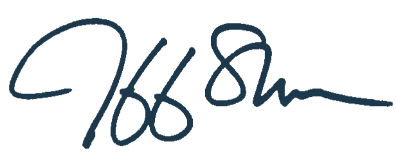
Similarly, with the downturn in air travel, and with governments limiting indoor gatherings, many people sought outdoor activities for leisure pursuits and to safely escape the pandemic. Thus, recreational vehicle (RV), recreational marine, bicycle and fishing rod sales increased significantly. The RV Industry Assn. (RVIA, Reston, Va., and Elkhart, Ind., U.S.) in September 2020 reported that shipments of RVs were expected to have surpassed 400,000 wholesale units in the U.S. by the end of 2020 (a 4.5% increase over 2019) and see continued growth in 2021 to more than 500,000 units.

The National Marine Manufacturers Assn. (NMMA, Chicago, Ill., U.S.) reported in October 2020 that powerboat retail sales had increased 8% year to date (YTD) compared to the same period in 2019. Sales of personal watercraft (PWC), pontoons and freshwater fishing boats were up 2%, 9% and 10% respectively YTD.

The pandemic also clarified and possibly accelerated some trends in the automotive industry that were already at work. The most notable is the global shift away from internal combustion engine (ICE) vehicles and toward electric vehicles (EVs). The International Energy Agency (IEA) says overall passenger vehicle sales in 2020 are expected to drop about 15% compared to 2019, but that EV sales will be flat. And Bloomberg NEF says the EV average sale price will drop below the average ICE vehicle price by 2025, and that EV sales will exceed ICE vehicle sales by 2037. *CW* columnist Dale Brosius outlines the EV opportunity for the composites industry in greater detail on p. 8 of this issue.

If wind, recreation and EV sales are the silver lining, then the darkest, biggest cloud of 2020 is the aerospace industry, which, by value, is the most important end market served by the composites industry. Passenger air travel has been so diminished by the pandemic that one can say, with substantial confidence, that things can only get better. But even that will take time, led first by a recovery in domestic air travel, followed by a return to "normal" international air travel by around 2025. Aviation Week, in a mid-December forecast, said to expect new global commercial aircraft deliveries to increase to about 1,350 in 2021, followed by incremental annual increases through 2030. Still, an estimated output of 1,750 by that year takes us back to 2017 levels only, and a far cry from the 2018 high-water mark of 1,800+ aircraft. Still, it's an encouraging return to growth.

The big question facing the aerospace industry now is if and when a new aircraft program might be announced. And who might announce it. I will address that next month. In the meantime, happy 2021, and stay safe.



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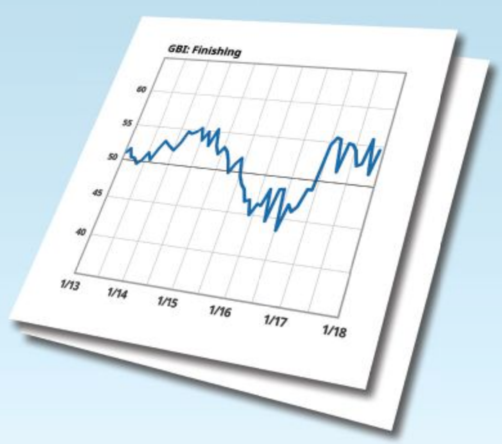

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Fatigue testing of composites

»Fatigue testing involves the application of cyclic loading to a test specimen or a structure. Unlike monotonic tests in which loading increases until failure, the applied load is cycled between prescribed maximum and minimum levels until a fatigue failure occurs, or until the predetermined number of loading cycles have been applied. If failure does not occur within the prescribed number of loading cycles — ranging from thousands to millions depending on the application of interest — the test result is referred to as a *run-out*.

Results from multiple fatigue tests, performed using several different cyclic stress levels, typically are plotted as the amplitude of the alternating stress, S_{amp}, (Fig 1b, bottom) versus the number of cycles to failure, N, and are commonly referred to as an *S-N diagram* (Fig. 1a, top). All of the fatigue tests included in the plot are performed using the same *ratio* of minimum stress to maximum stress within a loading cycle, referred to as the cyclic stress ratio, or *R*. For tension-tension fatigue testing, R-ratios of R = 0.1 are commonly used, whereas for reversed tension-compression fatigue tests, an R-ratio of R = -1.0 is typical. Fatigue testing is also used to investigate stiffness and strength reductions in composite materials and structures resulting from prior cyclic loading. For these determinations, testing is performed under cyclic loading for a prescribed number of cycles, followed by monotonic loading to failure.

Flexural fatigue testing is among the most common specimen-specific fatigue tests for composites.

Fatigue testing may be performed at multiple points during the design of a composite structure, featuring different sizes and complexities of test articles. Small-specimen and simple, element-level tests are used to determine the fatigue behavior of composite materials and laminates, as well as to investigate the sensitivity of environmental conditions, stress concentrations and existing damage to fatigue performance. Larger and more complex structural element, subcomponent and full-scale structure fatigue tests are also commonly performed as part of a building block approach for composite design[1]. Since higher-level fatigue testing varies greatly across a broad spectrum of applications, I will focus this column on small-specimen level fatigue test methods for composite materials that tend to be common to many applications.

In contrast to metal fatigue, in which failure may be produced by a single crack or a small number of cracks that coalesce, the formation and propagation of fatigue damage in polymer matrix composites (PMC) is more complex, often involving multiple types of damage. In multidirectional composite laminates, fatigue damage often initiates at matrix cracking, followed by the formation and growth of delaminations, and eventually fiber fracture.

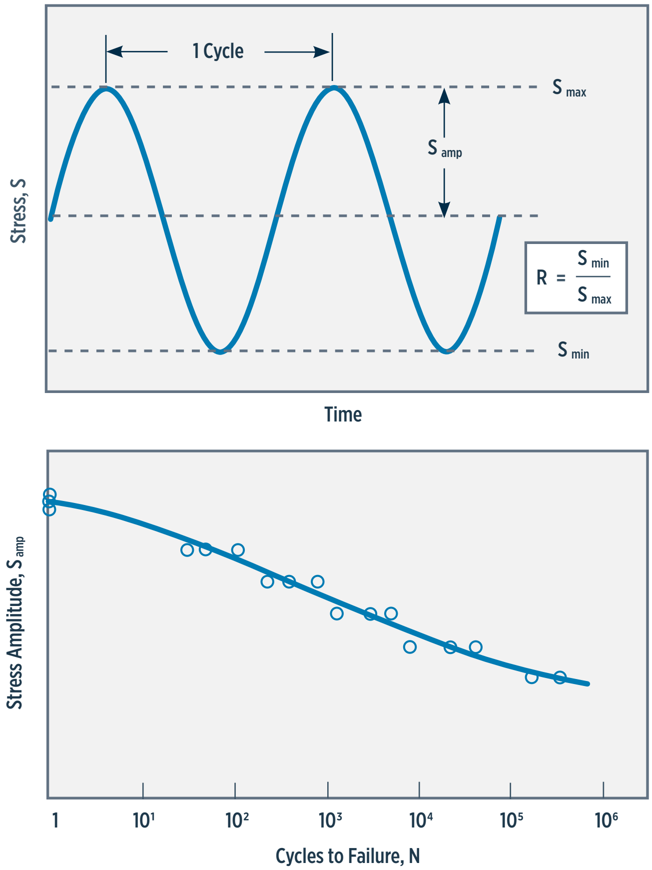

FIG. 1 Fatigue test results

Standard method used for displaying fatigue test results. Fig 1a (top) depicts an S-N diagram, and Fig 1b (bottom) shows standard fatigue testing terminology.

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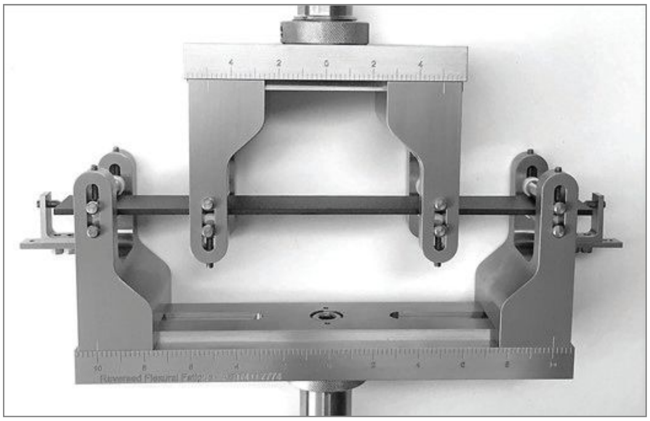

FIG. 2 Flexural fatigue test configuration

Flexural fatigue test configuration for composites. Source | Wyoming Test Fixtures

Therefore, it's common to perform fatigue tests using multidirectional laminates intended for use in the composite structure rather than unidirectional (0° or 90°) laminates. Additionally, the types of specimen-level fatigue tests as well as the fatigue loading (such as tension-tension versus tension-compression) is often guided by the primary loadings expected for the particular application of interest.

Compared to the relatively large number of standardized mechanical tests for PMC under monotonic loading, currently there are relatively few that focus on fatigue loading. ASTM D3479[2] was first standardized in 1996 for tension-tension fatigue testing. The tabbed specimen geometries specified are the same as for monotonic tension loading in ASTM D3039[3] and the scope is limited to constant-amplitude fatigue testing under either load or strain control. The primary test result is the fatigue life (number of cycles to failure) corresponding to the specific stress amplitude, R-ratio and environmental condition used in testing.

Somewhat surprisingly, there are *no* current standardized test methods for fatigue testing of a PMC under compression or in-plane shear loading. Although not standardized to date, many test methods used for monotonic testing of PMC may also be used for fatigue testing with relatively minor modifications. Under some conditions, additional constraints are required as part of the test fixturing to prevent the test specimen from moving relative to supports or loading surfaces. Additionally, cyclic loading can produce wear and premature failure at specimen loading surfaces. Finally, for reversed tension-compression fatigue testing, special attention is required to eliminate "slack" in the load train of the test machine when passing through zero force.

Flexural fatigue testing is among the most common specimen-level fatigue tests performed with composites, and among the simplest to perform. Currently, there is no standardized method for flexural fatigue testing of PMC. However, ASTM D7774[4], which focuses on fully reversed (R = -1) flexural fatigue testing of unreinforced plastics may be used as a guide for when applying the existing ASTM D7264[5] flexure test method for PMC to flexural fatigue. Specialized test fixturing is required that includes additional restraints as well as dual loading rollers for reversed loading (Fig 2). Additionally, an ASTM standard practice is currently under development for short-beam fatigue testing of PMC, providing guidance for modifying the monotonic short beam strength test method in ASTM D2344[6] for constant-amplitude cyclic loading.

Within the ASTM D30.05 Subcommittee on Structural Test Methods, two standard practices have been developed for fatigue testing. The first, ASTM D7615[7], provides guidance for performing open-hole or "notched" testing of composite laminates under cyclic tension or compression loading. The open-hole test specimens and test fixturing used in cyclic testing are identical to those prescribed for monotonic tension (ASTM 5766[8]) or compression (ASTM D6484[9]) loading. The second standard practice, ASTM D6873[10], addresses the bearing fatigue response of composites, using the four bearing test procedures (Procedures A-D) described in ASTM D5961[11] for monotonic loading. Special considerations for cyclic bearing testing include the removal of fiber-matrix debris resulting from damage associated with hole elongation. In these, as well as other composite fatigue test methods, the static strength reduction associated with fatigue damage may be determined by discontinuing cyclic loading following the prescribed number of fatigue cycles and subsequently loading monotonically to failure.

Finally, specimen-level fatigue testing may be performed to investigate the propagation of existing damage under fatigue loading. ASTM D6115[12] provides a test methodology to determine the number of fatigue cycles required for the onset of delamination growth under constant amplitude Mode I (opening) cyclic loading using the Double Cantilever Beam (DCB) specimen. Additionally, while not standardized to date, cyclic Compression-After-Impact (CAI) testing may be performed following the test methodology provided in ASTM D7137[13] to assess the effects of pre-existing impact damage on the fatigue resistance of composite laminates. CW

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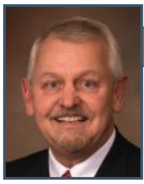

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What is the role of composites in electric vehicles?

»The 2020 U.S. presidential election is over (although not without considerable drama) and Joe Biden will be sworn into office on January 20, 2021. He will inherit an ongoing pandemic that will, we hope, ameliorate over the following months with the administration of vaccines, putting the U.S., along with the rest of the world, on a path back to a "new normal."

Biden also brings with him an ambitious climate change agenda, one focused on increasing investments in clean energy and the transformation of ground transportation away from internal combustion engine (ICE) vehicles and toward battery electric vehicles (EVs). These initiatives include financial incentives for consumers to buy EVs, the installation of 550,000 charging stations across the U.S. and replacement of ICE vehicles by EVs in government fleets.

> The sooner we move away from seeing composites as simply a way to reduce mass, the better.

Biden is not the first leader to propose such an agenda. In November 2020, U.K. Prime Minister Boris Johnson announced aggressive goals to ban the sale of gasoline- and diesel-fueled cars by 2030, and hybrid vehicles by 2035 (previously 2035 and 2040, respectively). Johnson also wants to provide consumer incentives and add charging stations across the U.K. Other European countries have set similar bans on ICE vehicles ranging from 2025 to 2040. In Asia, Japan is targeting 50-70% hybrid and EV sales by 2030, and China, already the world leader in EV sales, is targeting a mix of 50% electric, plug-in hybrid and fuel cell vehicles, and 50% hybrid vehicles by 2035, with no pure ICE vehicle sales.

Obviously, to accomplish all of this requires the development and manufacture of millions of hybrid and zero-emission vehicles. While Tesla has long been considered an automotive industry disruptor, inspiring startups including Rivian and Lucid Motors, the world's largest OEMs are rising to the challenge. In November, Volkswagen increased its planned investment in EVs to $41 billion by 2025, and will offer 70 fully-electric models by 2030, with more than 20 already available today. At the same time, General Motors (GM) raised its commitment to invest $27 billion to develop 30 EV models globally by 2025, with at least 20 of those available in the U.S. GM also withdrew support for a Trump administration lawsuit against the State of California, which is setting its own more restrictive automotive emissions standards. Political expediency? Perhaps.

Clearly, electric vehicles are the future. Bloomberg NEF forecasts cost parity between EVs and ICE vehicles by 2025, and that sales of EVs, plug-in hybrids and fuel cell vehicles will surpass ICE vehicle sales by 2037, reaching 55 million vehicles annually by 2040. Due to the impact of the pandemic on global vehicle sales, Bloomberg believes ICE vehicle sales will never again reach 2019 levels due to increased penetration from these cleaner models.

So what does this mean for composites? Most electric vehicles on the market today have a range of 250 to 400 miles (400 to 640 kilometers), and "range anxiety" is a real thing, especially since charging stations are not as ubiquitous as gasoline stations. Plus, batteries are very heavy, so increasing range requires adding weight. This makes lightweighting using composites a great opportunity, right?

We've seen this play out before in ICE vehicles, going back to the 1980s and often since. The line "automakers have taken powertrain technology as far as it can go, so now have to rely on lightweight composites to improve fuel efficiency" was disproven with multi-speed transmissions, fuel injection, cylinder deactivation and other lightweighting alternatives. A similar story is happening in battery technology; Bloomberg forecasts battery energy density to improve by approximately 50% by 2030, and costs per kilowatt-hour to fall by more than half in the same time frame. As battery costs fall and energy density increases, extending vehicle range will be as simple as adding batteries.

For composites, the automotive market may be shifting from ICE vehicles to EVs, but the path to adoption has yet to follow. Earning a position in the material mix on a vehicle platform still comes down to meeting production rates and reducing costs, providing value through parts consolidation, multifunction integration (embedded wiring or sensors, for example), or reducing capital and tooling costs. One high-profile application appears to be battery enclosures, particularly given the fire, thermal and electrical requirements that can be met by composites, especially if such enclosures can take advantage of the anisotropic behavior of composites to provide torsional stiffness to the body structure. And, as EVs enable the move toward an autonomous future, the ability for composites to provide more complex shapes will open opportunities for designers to differentiate platforms and provide improved consumer experiences. The bottom line? The sooner our industry moves away from seeing automotive composites as simply a way to reduce mass, the better. CW

ABOUT THE AUTHOR

Dale Brosius is the chief commercialization officer for the Institute for Advanced Composites Manufacturing Innovation (IACMI), a DOE-sponsored public-private partnership targeting high-volume applications of composites in energy-related industries including vehicles and wind. He is also head of his own consulting company, which serves clients in the global composites industry. His career has included positions at U.S.-based firms Dow Chemical Co. (Midland, MI), Fiberite (Tempe, AZ) and successor Cytec Industries Inc. (Woodland Park, NJ), and Bankstown Airport, NSW, Australia-based Quickstep Holdings. He served as chair of the Society of Plastics Engineers Composites and Thermoset Divisions. Brosius has a BS in chemical engineering from Texas A&M University and an MBA.


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Composites activity expands for third straight month

November—51.8

» The Composites Index ended November at 51.8, signaling the industry's third consecutive month of overall expanding business conditions, made possible by a multi-month trend of expanding new orders, production and employment. The spread between production and new orders activity widened in part due to a relatively greater slowing of new orders activity, causing backlog activity to contract. As of November, export order readings had yet to return to their pre-pandemic levels, demonstrating both the severity and global impact of COVID-19.

Had it not been for an elevated supplier delivery reading in November, the Index would have registered its first overall contraction since August. Recent supplier delivery readings continue to signal extreme challenges to supply chains and logistics, especially considering that supplier delivery index values are closely tied to order-to-delivery times, with readings increasing as delivery times lengthen. The fourth quarter of 2020 will be made worse as seasonal package delivery demand and vaccine distribution compete for more of the transportation industry's already diminished capacity.

November 2020, as many know, was also the month in which the FAA cleared the Boeing 737 MAX to return to service. It may not be a coincidence that aerospace activity for the month reported its first expansionary reading since before the pandemic. Among all end markets tracked by Gardner Intelligence, composites fabricators reported the quickest expansion in the automotive and electronics markets. CW

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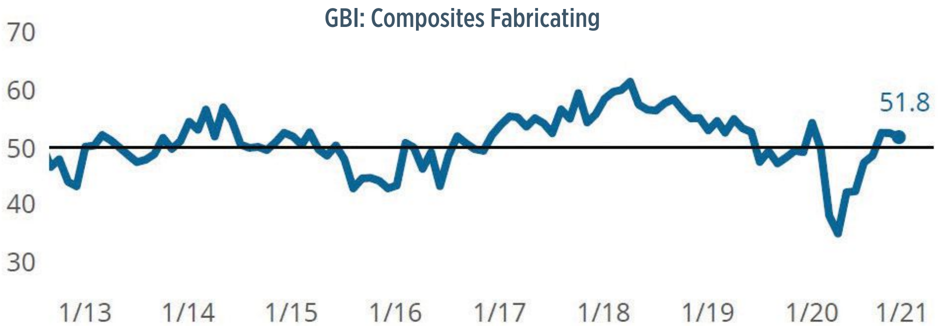
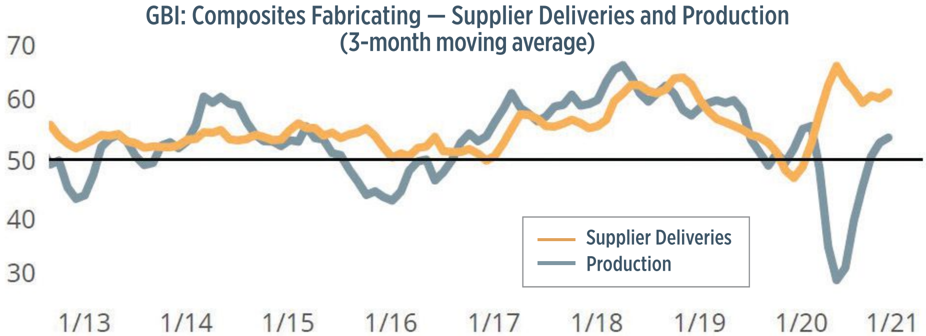


Composites Fabricating Business Index

Total business activity expanded for a third consecutive month in November 2020, helped by the slowing expansion in new orders and production activity. The supplier delivery reading elevated the Composites Index by over 2 points, keeping the overall Index above 50.



Transport companies face increasing demand with diminished capacity

Supply chains issues will be made worse in the fourth quarter of 2020 and beyond as seasonal shopping and vaccine distribution consume more of the shipping capacity that could otherwise be used to deliver materials to composites fabricators, and sustain production.

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GARDNER BUSINESS INDEX

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NASA and Wisk partner to extend urban air mobility capabilities, *CW* Senior Editor Ginger Gardiner gives an overview of the "FUTURE COMPOSITE MANUFACTURING - AFM & AM" symposium, Mighty Buildings disrupts home construction using large-format 3D printing, Joby Aviation chooses Toray Advanced Composites as its long-term carbon fiber supplier, *CW* interviews Lisa Ketelsen, CEO of Maezio at Covestro and more.

CONSTRUCTION

3D-printed homes aim to disrupt construction market

The recipient of the 2020 CAMX Unsurpassed Innovation Award, Mighty Buildings Inc. (Oakland, Calif., U.S.), was founded in 2017 with the goal of disrupting home construction using large-format 3D printing, advanced materials and automation.

Traditional home construction methods "are often labor-intensive, materially wasteful and energy-inefficient," says Sam Ruben, chief sustainability officer (CSO) and one of the company's four co-founders. This was particularly evident in California, which, as its population has grown, has faced a long-standing housing shortage and lack of affordable housing for low- to middle-income residents. In August 2020, the average price of a single-family home in California reached a record $706,900. At the beginning of 2017, California changed its state regulations to encourage the construction of accessory dwelling units (ADU) — standalone housing units built on the same property of a house or other primary dwelling. Seeing this new regulation as an opportunity, Mighty Buildings' founders applied to startup accelerator Y Combinator (Mountain View, Calif., U.S.). Accepted for the Winter 2018 cohort, the newly formed Mighty Buildings company began to leverage the founders' combined experience in 3D printing (CTO Dmitry Starodubtsev), business (CEO Slava Solonitsyn), robotics and automation (COO Alexey Dubov) and sustainability and housing policy (CSO Ruben) to develop the team and technologies.

Currently, Mighty Buildings offers six models: four smaller "Mighty Mods" ranging from a 350-square-foot studio to the 700-square-foot Duo B/I, which are built


Source | Mighty Buildings


Source | Mighty Buildings

at the company's production space and then installed onsite via crane; and three, two- to three-bedroom "Mighty Houses" built as panels that are shipped and assembled at the construction site. Prices for a turn-key Mighty Buildings structure range from $183,750 for the 350-square-foot Mighty Studio model to $409,500 for the 1,440-square-foot, three-bedroom, two-bathroom Mighty Cinco model.

According to Ruben, the team was inspired by innovations in UV-curable resins and wanted to expand this type of product to a much larger scale and transfer it to the construction market. The result is a printing material called Light Stone Material (LSM) and a 3D printing process called Photo Activated Component Extrusion (PACE). "We have created a proprietary printing material and technology which allow us to UV cure an extrudable gel that cures quickly enough to be able to support its own weight, unlocking the ability to print unsupported spans and organic shapes," Ruben says.

The original version of LSM is an unreinforced thermoset resin, which enables building single-story buildings and ADUs, but ultimately, Mighty Buildings plans to build up to 3-5 floors and above with the help of fiber reinforcement. A version of LSM reinforced with continuous glass fiber has been developed, and internal testing has shown that 3D-printed structures made with this material are "able to achieve a maximum ultimate load similar to that of a comparably-sized, steel-reinforced concrete beam, with more than four times less weight and an ultimate tensile strength that is nearly 20 times higher," Ruben says. LSM is also water and fire resistant, highly energy-efficient and is the first UL-certified 3D-printed building material. Mighty Buildings expects the reinforced composite material to pass requisite UL 3401 certification testing within the next year or so, to meet the company's goal of launching multi-story, multi-family buildings in 2022.

Production of each prefabricated building requires four steps: 3D printing, quality control, post-processing and assembly. Automation plays a large part each step of the way. "Currently, we are automating 40% of the construction process, and ultimately will be at 80%," Ruben says. In addition, Mighty Buildings is working with MSC Software (a division of Hexagon, Newport Beach, Calif., U.S.) to develop its own digital simulation and modeling platform. The PACE 3D printing process itself involves extrusion of an LSM gel at room temperature and polymerization via UV light at the end of the printhead. The PACE system boasts a print volume of 11 x 26 x 13 feet: "We're limited more by overland transport size than 3D printing volume of the machine." With the help of robotic arms, cured parts are inspected via 3D scanning and thermography, and then each structure is moved into a robotic finishing cell for post-processing. Finished modules are then transported and assembled at the construction site. Mighty Buildings' current process takes about two to three weeks to build a house, with the goal being less than a week start to finish.

Currently, all ADUs are sold direct-to-consumer, but a longer-term goal is to sell the process as a "production as a service" platform, so that homes can be built closer to demand in different areas around the U.S. and globally. The plan is to enable building of distributed "Mighty Factories" with small footprints in existing warehouse spaces, using and training a local workforce.

Read the full article online at **short.compositesworld.com/MB3Dhomes**

CARBON FIBER

South Korean carbon fiber recycling start-up scales up

Founded in 2017 by CEO Jin-Ho Jeong, CATACK-H (HwaSeong, South Korea) is a chemical treatment-based, carbon fiber composite recycling startup that currently serves the Korean region, but plans to expand as early as January 2021.

According to Hendrik Neuhaus, international operations manager, the company's process involves the use of chemical

Source | CATACK-H

solvents to break down epoxy-based resins in carbon fiber-reinforced plastic (CFRP) parts to recover fibers to reuse as a chopped or milled fiber product.

At its 65,000-square-foot facility two hours' drive south of Seoul, CATACK-H currently has the capacity to process 300 tons of carbon fiber fabrics per year, such as uncured prepregs, on a continuous processing line. The company plans to quickly scale this up to 1,000 tons per year with the installation of a second, 700 tons/year line for batch treatment of "harder" materials like cured prepregs and end-of-life (EoL) CFRP parts, expected to go online in January. Current capabilities are for thermoset-based composites, but according to Neuhaus, the company will soon also add processing technology for thermoplastic composites.

Beyond the HwaSeong plant, the company plans to open a new, larger Korean facility by *(continued on page 14)*

(continued from page 13)

summer 2022, with an additional 4,000 tons/year of processing capacity. So far, the company mainly processes scrap sourced from Korean manufacturers, but long-term plans include expansion for sourcing and for additional recycling facilities in Europe and North America.

Two strengths that set CATACK-H apart, according to Neuhaus, are the company's sustainable practices, and the high quality and high mechanical properties of the fibers it produces. "The technology is 100% eco-friendly with very little energy use," he says, "and doesn't cause any surface damage to the fibers, so the quality is very high."

Currently, CATACK-H strives for sustainability in three ways:

- According to Neuhaus, its materials are treated at relatively low temperatures (less than 210°F), requiring less energy compared to high-temperature recycling processes.
- In this process, resins can also be recovered and reused, alongside fibers. During treatment, the polymers' molecular structure is broken down into smaller units and condensed into another material which can be used, for example, as an ingredient in urethane foam.
- The chemicals CATACK-H uses for its treatment process can be reused for six to seven recovery cycles, and Neuhaus says the company is constantly working on improving this chemical formula even further to decrease processing time for even lower energy consumption.

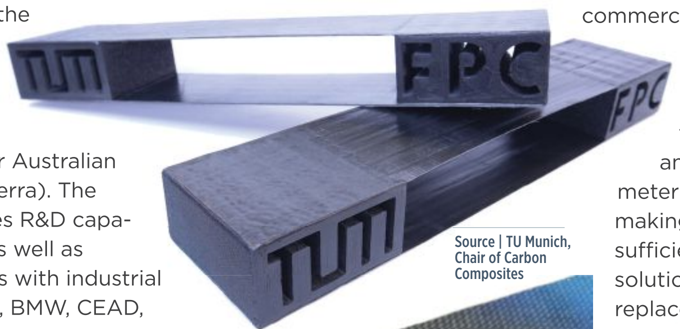
After recovering the fibers and resins from scrap materials, the company produces chopped and precision-cut carbon fiber and milled carbon fiber products, as well as thermoplastic pellets, 3D printing filaments and dry carbon fiber nonwovens (such as carbon paper). It also offers a resin remover powder. Neuhaus says future plans include production of recycled carbon fiber automotive components. "Beyond that, we continue to invest in technology and equipment to supply new types of materials and new forms of applications," he says.

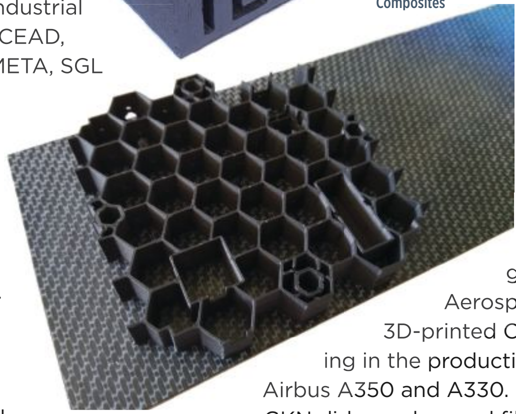
As the company scales up, it will require more waste material. Neuhaus says CATACK-H is looking for "any kind of epoxy-based CFRP," including dry carbon fibers and fabrics, uncured and cured prepregs, and finished parts. "We also have the technology to recycle carbon fiber/glass fiber pressure tanks (such as hydrogen tanks), and are researching how to recycle wind blades," he says. Companies interested in partnering with or in learning more about CATACK-H are encouraged to reach out to Neuhaus at neuhaus@catackh.com or visit catackh.com.

CARBON FIBER

Future composite manufacturing – AFP and Additive Manufacturing

In September 2020, *CW* Senior Editor Ginger Gardiner attended the virtual symposium "FUTURE COMPOSITE MANUFACTURING – AFP & AM," referring to automated fiber placement (AFP) and additive manufacturing (AM). This symposium was hosted by the Chair of Carbon Composites (LCC) at Technical University of Munich (TUM, Munich, Germany). The event also included TUM's research partner Australian National University (ANU, Canberra). The symposium reviewed composites R&D capabilities at both TUM and ANU, as well as completed and ongoing projects with industrial partners including AFPT, Airbus, BMW, CEAD, DLR, Fraunhofer, GKN Aerospace, INOMETA, SGL Carbon and Victrex.





Source | TU Munich, Chair of Carbon Composites

TUM collaboration with ANU began in 2010 with the AutoCRC project to develop compressed natural gas (CNG) storage tanks from thermoplastic composites. Joint R&D has continued since then, including formation of the Australian Research Council's center for Automated Manufacture of Advanced Composites (AMAC) and three major focus areas at ANU including materials enhancement (nano-scale materials and coatings for enhancement of functional properties of carbon composites, graphene-enhanced prepreg tapes for thermal and electrical conductivity); laser-AFP (project with Ford to develop composite-reinforced steel, digital control of heating bias, e.g. process stability for corners/3D geometries); and advanced diagnostics with X-ray CT.

The keynote "New Horizons by Merging AFP and AM" was presented by Prof. Dr.-Ing. Klaus Drechsler, who established the LCC in 2009 with funding from SGL Carbon (Wiesbaden, Germany). Drechsler gave a background on the LCC and its composites research, including a long history working with in-situ consolidation (ISC) using automated fiber placement.

He discussed the similarities between material extrusion (MEX), the most common process used for 3D printing fiber-reinforced composites, and AFP ISC, such as local, recurring heat treatment, layer-based design and orthotropic material properties and material placement along 2D and 3D programmed paths and thermal activation between layers.

Drechsler then discussed the future needs for composites and how combining AFP and MEX could provide solutions, including near-term in tooling, and longer-term in high-performance, lightweight structures that are cost-efficient and ecologically sustainable.

The next presentation after Drechsler's keynote was given by Maarten Logtenberg, executive director of CEAD (Delft, Netherlands). Highlights from Logtenberg's presentation included CEAD's development of hybrid solutions that integrate CNC milling, large heated print beds (1.2 x 3m and 1.2 x 2m) and heated rotary print beds. It is also pursuing even larger cells and 45-degree printing, as well as printing of fiber-reinforced tools for serial autoclave production of commercial aircraft parts.

Logtenberg noted that one of the main challenges for 3D-printed autoclave tools is thermal expansion, and tools much larger than 4 meters tend to expand too much, making it difficult to compensate sufficiently via tool design. The solution he put forward is to replace the chopped fiber reinforcement used mostly to date with continuous fiber deposited by systems such as AM Flexbot.

This path forward was seconded in the presentation, "Introduction of 3D-printed Track Intensifiers for Composite Flap Production," given by Thomas Herkner at GKN Aerospace in Munich, Germany. These 3D-printed CFRP intensifiers are used as tooling in the production of CFRP landing flaps for the Airbus A350 and A330. Although this successful program at GKN did use chopped fiber reinforcement, Herkner showed a roadmap for further development that included use of continuous fiber in 3D-printed tooling as well as, eventually, in the aircraft parts themselves.

Sebastian Nowotny at DLR discussed combining 3D printing with ISC AFP of thermoplastic composites, including 3D printing onto AFP laminates and AFP onto partially open 3D-printed structures. First experiments include 3D printing a core onto a premade CFRP skin and then AFP/tape laying on top of the 3D-printed core. Specimens were created and then subjected to tensile shear testing to evaluate skin-to-core bonding quality.

Christian Weimer, head of materials for Airbus Central Research and Technology, discussed continuous fiber printing as part of the evolving technology landscape, aimed at reduced weight with reduced costs and increased sustainability that must be achieved for composites to secure a place on future aircraft. He discussed the need for bio-derived fibers and resins in order to meet urgent climate and environmental sustainability goals.

The TUM symposium featured many more presentations, including summaries of work at ANU. All showed how composites are moving forward and how the LCC, working with partners worldwide, continues to envision what composites can achieve and to push our industry forward.

Read the full article at **short.compositesworld.com/TUMforum**

Episode 35: Lisa Ketelsen, Covestro

Our guest on episode 35 of CW Talks: The Composites Podcast is Lisa Ketelsen, head of thermoplastic composites and CEO of Maezio at Covestro (Shanghai, China). Ketelsen, who grew up in Germany, is based in Shanghai and manages Covestro's Maezio product line, which comprises carbon fiber tapes with a polycarbonate resin matrix.

Ketelsen talks about her career at Covestro, the evolution of the Maezio product line, Maezio's attributes and applications and how she sees thermoplastic composites evolving in the marketplace. This excerpt has been edited for clarity and length.

***CW*: Can you describe for our audience what Maezio is?**
LK: Well first of all, it's the brand name for a polycarbonate-based thermoplastic composite. We focus on unidirectional tape production, carbon fiber-based, as well as laminates.

***CW*: What is the greatest advantage that polycarbonate conveys to the applications that Maezio typically is used in?**
LK: The greatest advantages that our Maezio UD tape and sheet bring come from the resin, a very different resin in this case. You're right, PA and PP, other options, have been on the market for a long time. But polycarbonate combines the toughness and the stiffness with a good surface quality. It's easier to realize Class A surfaces. We do a lot of work on different coating solutions, different surfaces solutions. So if you're really looking for a combination of these things, then our materials come into play. There's also the advantage of the dimensional stability. In comparison to other polymers, for example, we don't have so much of a problem with moisture absorption. And the other part is that we can reach flame retardant properties.

***CW*: A frequent use of Maezio, at least in the last few years, has been as a carbon fiber insert [shank] in athletic shoes. And I think the most recent shoe that came in the market that uses this material is in the KT6 basketball shoe, which is manufactured by Anta. Why is this such an attractive application for Maezio?**
LK: Covestro actually has been in the footwear industry for quite a long time with a variety of materials. Thermoplastic composites then are sort of the next addition to that portfolio. Anta is really at the forefront of performance shoes. So why Maezio? I think the answer is what I talked about before, the high degree of tunability. We had a lot of iteration rounds together with Anta to really figure out what the optimum layup design for the shank is. So that we could precisely tune the stiffness to what Anta specifically wanted for that basketball shoe to take up the torsion forces and to allow stiffness in one direction and flexibility in another.

***CW*: What other applications and markets do you see as a good fit for Maezio and what makes those attractive?**
LK: Today, we have four key segments that we tackle: Sports and footwear is one, electronics, automotive and consumer goods. All of them need stiffness, light weight and a 'beautiful' surface.

***CW*: What is your assessment of the pandemic's impact on the kind of work that you do?**
LK: Over the last seven, eight months, things first slowed down in China significantly. And then, all of a sudden, it picked up here in China like there was no tomorrow. The innovation potential here and the willingness of China to iterate to bring new products to market is, generally speaking, incredibly high. But in a business where development cycles are a bit longer, then it's a bit of a waiting game, especially in the U.S. and Europe.

ENERGY

GE launches Cypress 6.0-164 onshore wind turbine

GE Renewable Energy (Paris, France) introduced on Nov. 30 the 6.0-164 version of its Cypress onshore wind turbine platform, making it what the company claims is its most powerful onshore wind turbine available.

The 6.0-164 turbine, says GE, will increase annual energy production (AEP) by up to 11% over the 5.3-158 model. Like the other products in the Cypress platform, the 6.0-164 features a proprietary two-piece composite blade that is said to improve logistics and drive down costs. Each 6.0-164 turbine will produce enough electricity to power approximately 5,800 European households. GE says the model will be in the field by 2022.


Source | GE Renewable Energy

"The Cypress platform is already providing our customers the ability to lower the cost of onshore wind and gain added flexibility in siting turbines," says Peter Wells, CEO of GE Onshore Wind Europe, GE Renewable Energy. "This latest product will help them drive additional growth in clean, renewable wind power across Europe and beyond."

The 6.0-164 is the most recent model announced under the Cypress platform, which also includes the 5.5-158, 5.3-158 and 4.8-158 turbines. The Cypress platform, says GE, further advances the proven technology of its 2-megawatt (MW) and 3-MW fleets, which serve an installed base of more than 20 gigawatts (GW).

Further, the new model is designed with services in mind, facilitating up-tower repairs and featuring condition-based predictive services.

The latest unit in the Cypress platform was developed in partnership between GE's Onshore Wind business, GE's Global Research Center and LM Wind Power.

CSP Advanced Materials Center unveils composite battery enclosure and material innovations


Source | Business Wire

Continental Structural Plastics (CSP, Auburn Hills, Mich., U.S.), along with its parent company Teijin Ltd., unveiled in December 2020 an innovative honeycomb Class A panel technology and an advanced, multi-material electric vehicle (EV) battery enclosure that can be molded in any number of CSP's proprietary composite formulations. These component technologies were developed at the company's new Advanced Technologies Center in Auburn Hills, CSP's second R&D facility in the city, and indicate the company's transition into broader R&D capabilities following Teijin's acquisition.

The new Advanced Technologies Center is a 47,500-square-foot facility, of which 24,000 is dedicated to R&D efforts to develop next-generation materials and processes to move CSP and Teijin beyond sheet molding compound (SMC) and into new markets and technologies. Equipment includes a 4,000-ton press with leveling and vacuum, a 750-ton press with vacuum, a 400-ton press with a 10-foot bed, six thermolators, two FANUC Robotics and a coordinate measuring machine (CMM).

In addition to transitioning technologically, the Advanced Technologies Center took on a few projects to fulfill these new R&D efforts. The first of these projects is CSP's new honeycomb manufacturing process that produces ultra-lightweight Class A panels. Considered a "sandwich" composite, these panels use a lightweight, honeycomb core, clad with natural fiber, glass fiber or carbon fiber skins that are wetted with polyurethane (PUR) resin. CSP says this process enables the molding of complex shapes and sharp edges, and results in panels that offer very high stiffness at a very low weight.

CSP is also currently in development and production of more than 34 different electric vehicle (EV) battery box covers in both the U.S. and China. However, to expand the company's offering and provide customers with a superior battery enclosure, CSP and Teijin have developed a full-sized, multi-material battery enclosure featuring a one-piece composite cover and a one-piece composite tray with aluminum and steel reinforcements. By molding the cover and the tray each as one piece, CSP says it has created a system that is easier to seal and can be certified prior to shipment. The company has two patents pending for its box assembly and fastening systems.

The company also developed a mounting frame using a structural foam for energy absorption. This enables a reduced frame thickness and weight, while improving crash performance. Additional benefits of the multi-material battery enclosure include:

- Non-conductive
- Can be molded in complex shapes
- Less complexity in tooling
- High strength
- Dimensional stability
- Molded-in sealing features
- Ability to mold in EMI and RFI shielding
- Corrosion resistance
- Reduced tooling cost

All told, the CSP multi-material battery enclosure is said to be 15% lighter than a steel battery box. Although it is equal in weight to an aluminum enclosure, the CSP enclosure offers better temperature resistance than aluminum, especially if the phenolic resin system is used. Additionally, the one-piece design for the tray has no through holes, so no sealing or sealant are required. This eliminates the chance of leaks, and reduces overall production costs and complexity.

CSP says many of these benefits could not have been achieved without the superior composites chemistry developed by CSP's materials R&D team. Further, the company says this assortment of advanced composites allows customers to select the formulation for the cover and/or base that best meets their specifications. CSP's battery enclosure materials options include:

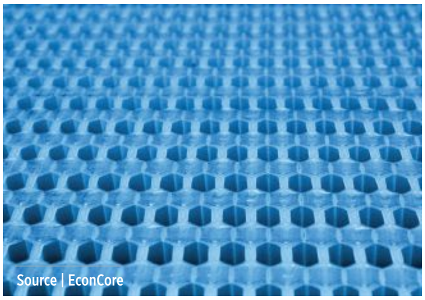
- Traditional high-fill polyester/vinyl ester ATH system that uses conventional SMC chemistries, is easily adapted to existing tools and will give excellent baseline performance in the right design.
- Intumescent system using similar chemistry to traditional SMC, but with better flammability and thermal runaway performance.
- Phenolic system which is said to be ideal for high-temperature applications where parts must meet fire safety, smoke emission, combustion and toxicity requirements. A phenolic system will have excellent flame retardance, heat and chemical resistance and electrical non-conductivity characteristics.

Each of these chemistries can be adapted using different fiber types or formats (e.g. glass/carbon/blended/other, chopped and/or continuous), and any can be formulated to achieve the most stringent VOC requirements.

"The work being done at the Advanced Technology Center, combined with the materials advancements being achieved at our R&D facility at headquarters, is enabling CSP to maintain our leadership position in advanced composites, and establish us as a global player in the multi-materials field," says Steve Rooney, CEO of CSP. "Together, with the carbon fiber and materials expertise that Teijin brings, we are developing lightweight solutions that enable our customers to think outside the box when it comes to vehicle design."

AZL, EconCore, Audi partner to develop composite battery enclosures

Thermoplastic honeycomb specialist EconCore (Leuven, Belgium) announced in November 2020 a partnership involving AZL Aachen (Aachen, Germany), Audi (Ingolstadt, Germany) and others to establish the potential of using composites for battery housings. This eight-month collaborative project will assess the technical challenges, opportunities and benefits of developing battery enclosures for electric vehicles using a variety of materials, including thermoplastics.


Source | EconCore

The project has been established by industry network group AZL, which specializes in composites-based lightweight technologies and seeks to drive innovation through sharing knowledge.

EconCore cites reports from Statista and MarketsandMarkets that project the global battery housing market for electric vehicles will experience a growth rate of more than 13% across the next seven years. The partnership sees much potential for composites within this market, as electric vehicle OEMs aim to increase vehicle operating range through weight reduction, without compromising on strength and quality.

The first phase of this project will be focused on understanding potential opportunities and challenges. For the EconCore team, this means pre-selecting thermoplastic materials, using different composite skin layers and working through different geometrical design variants to optimize the honeycomb material to obtain desirable characteristics and share findings with project partners.

"After successfully establishing the use of the technology in automotive interiors, we feel there is tremendous potential in using composite materials for battery housings, and EconCore is now actively working with Audi and other industrial partners to explore opportunities and to learn how the thermoplastic honeycomb technology can be applied into this area," says Tomasz Czarnecki, chief operating officer of EconCore.

He adds: "There's no doubt there are some interesting opportunities to reduce weight using composite materials. We believe there are even greater potential benefits from using honeycomb sandwich materials, which have incredible strength, while being extremely light compared to aluminum or steel alternatives."

EconCore has experience using honeycomb materials in vehicle interiors, which can be compression molded to produce three dimensional shapes. If the initial phase goes well, the plan is to progress to a prototyping stage.

"It's important we don't get ahead of ourselves. Part of the process is to also understand things like design, material and the likely production costs," Czarnecki says. "These are also critical factors in addition to the potential lightweighting benefits that must be assessed. It must make economic sense, too. However, we remain optimistic. With our journey through automotive interiors so far, we have seen that the thermoplastic honeycomb technology delivers opportunities to save costs on both ends — material and conversion."

AUTOMOTIVE

NCC, Ford partner to lightweight Ford Transit van

A project to lightweight Ford Motor Co.'s (Brentwood, U.K.) Ford *Transit* vans, involving partners Gestamp (Newton Aycliffe, U.K.), the National Composites Centre (NCC, Bristol, U.K.) and the University of Nottingham, was awarded the Innovation in Design Award at the Composites UK Industry Awards 2020.


Source | Ford Motor Co.

The project, part of Ford's Composite Hybrid Automotive Suspension System Innovation Structures (CHASSIS) program, aimed to reduce the weight of three components in the Ford *Transit*: the front suspension crossmember, front lower control arm and rear deadbeam axle. The result was an average weight reduction of 40% across the components at an affordable cost target, representing more than 30 kilograms of weight savings compared to the current steel components.

The CHASSIS consortium aims to develop a multi-material solution to provide affordable weight savings at mass-production volumes. CHASSIS is based on Ford's CLASS project, which was the recipient of the 2018 JEC World Automotive Application Innovation Award.

According to the NCC, the CHASSIS project will have a significant impact on the delivery of composite components to the mainstream automotive industry, resulting in sufficient cost reductions for volume production. When deployed, the hybrid material technology being delivered for the *Transit* program will, the NCC says, reduce emissions by 0.6% with a corresponding improvement in fuel economy.

"We're delighted that this project has been recognized for its innovation — it is another step closer to us achieving a goal for net zero transportation," says Ed Goodman, director of emerging markets at the NCC. "To hear the news on the day the U.K. government launched its Ten Point plan for a Green Industrial Revolution, which will see only electric and hybrid vans on sale in the U.K. from 2030, is apt and demonstrates how important R&D is in this area."

AEROSPACE

NASA, Wisk partnership accelerates UAM capabilities


Source | Wisk

Urban air mobility (UAM) company Wisk (Mountain View, Calif., U.S.) reports that it is teaming with NASA in the first partnership between the two organizations to focus on the safe integration of autonomous aircraft systems into UAM applications at a national level.

The partnership is part of NASA's Advanced Air Mobility National Campaign strategy to develop key guidance for UAM operations, while addressing key challenges, such as certification and standards development, in an effort to accelerate U.S. leadership in emerging automated aviation technology. Specifically, the partnership will initially address critical National Campaign safety scenarios with a focus on autonomous flight and contingency management, including collision avoidance and flight path management.

Through the partnership, NASA and Wisk intend to execute on optimized opportunities to evaluate architectures, perform simulation studies and develop an overall validation framework that can be leveraged for autonomous flight assessments. This will be done in close cooperation with industry standards organizations and may include guidance on airspace structure, flight procedures, minimum performance requirements for participating aircraft and standards that will influence the evolution of autonomous systems.

"Our partnership with NASA will bring together our expertise in autonomy with the unmatched technical capabilities of NASA," says Gary Gysin, CEO of Wisk. "The frameworks and recommendations developed through this collaboration will not only advance autonomous passenger flight but also increase the overall safety of aviation."

Robert Pearce, associate administrator for NASA's Aeronautics Research Mission Directorate, adds, "Wisk brings a tremendous amount of experience in eVTOL [electric vertical takeoff and landing] vehicle development, automation technologies and flight test, and combines it with a safety-first mindset towards advancing autonomous flight. NASA believes our partnership with Wisk will help accelerate the realization of exciting new Advanced Air Mobility [AAM] missions."

Since 2010, Wisk has developed and tested its all-electric, self-flying aircraft, called *Cora*, in an effort to create flight-based solutions that address the growing urban mobility crisis in a way that is effective, accessible and sustainable.

AEROSPACE

Toray, Joby Aviation finalize long-term carbon fiber supply agreement


Source | Joby Aviation

Toray Advanced Composites (Morgan Hill, Calif., U.S.) announced in December 2020 that it has completed a long-term supply agreement with Joby Aviation (Santa Cruz, Calif., U.S.) to supply Joby's as-yet-unnamed piloted helicopter eVTOL for air taxi transport with its carbon fiber composite materials.

According to Toray, because every aspect of Joby's electric aircraft requires range and speed maximazation to achieve its urban transport capabilities, high-strength and lightweight materials are crucial. For this reason, Toray suggests that its high-quality carbon fiber materials are a key component of achieving these goals. Further, Joby selected Toray Advanced Composites materials for their proven history of meeting mechanical and safety requirements in aerospace and high-performance automotive applications.

"Toray's prepreg carbon fiber systems provide unparalleled specific strength and toughness, which have enabled Joby to develop aircraft with unprecedented capabilities," says JoeBen Bevirt, founder and CEO, Joby Aviation. "We are proud to be working with Toray as we certify this aircraft, and look forward to building a long-lasting partnership."

Joby says it will operate an affordable, quiet and clean transportation service, using the revolutionary all-electric, eVTOL aircraft it has spent the last decade developing. With a range of up to 150 miles and a top speed of 200 miles per hour, the vehicle and the service are said to have the potential to make a significant difference to the lives of travelers. Carbon fiber materials are used throughout the vehicle structure, propulsion systems and interior components.

"We are pleased to have finalized this important supply agreement with Joby Aviation, a pioneer in the development of the eVTOL," says Mr. Toshiyuki Kondo, CEO, Toray Advanced Composites. "As children, we dreamed of being able to fly to a destination in a fraction of the time it would take to drive. That is no longer a fantasy. The electric air taxi is becoming a reality and we at Toray are perfectly positioned to meet the industry's needs today and in the future. It's a very exciting time."

Joby Aviation adds that it plans to bring its aircraft into commercial operation as early as 2023.

Bespoke process produces composite brake pedal every minute

Three composite materials are used to create structural composite member that meets demanding mechanical requirements.

By Peggy Malnati / Contributing Writer

■ The final product

The first all-composite brake pedals developed by Boge Rubber & Plastics Group using a bespoke production process meet or exceed the challenging performance specs required of metals at nearly half the weight. Source | Boge Rubber & Plastics Group

»Tier 1 Boge Rubber & Plastics Group (Damme, Germany) manufactures what it says are the lightest, least costly and strongest all-composite brake pedals in the world, and the first in commercial production. As detailed in this month's Focus on Design (p. 44), Boge currently produces a quarter-million brake pedals per year for four vehicle platforms produced by German automakers, and the system could produce up to 1 million pedals annually. While the Focus on Design article assesses the materials and design challenges presented by the brake pedal application, this Work in Progress reviews the manufacturing process develped by Boge to fabricate the pedals.

Three materials increase fiber efficiency

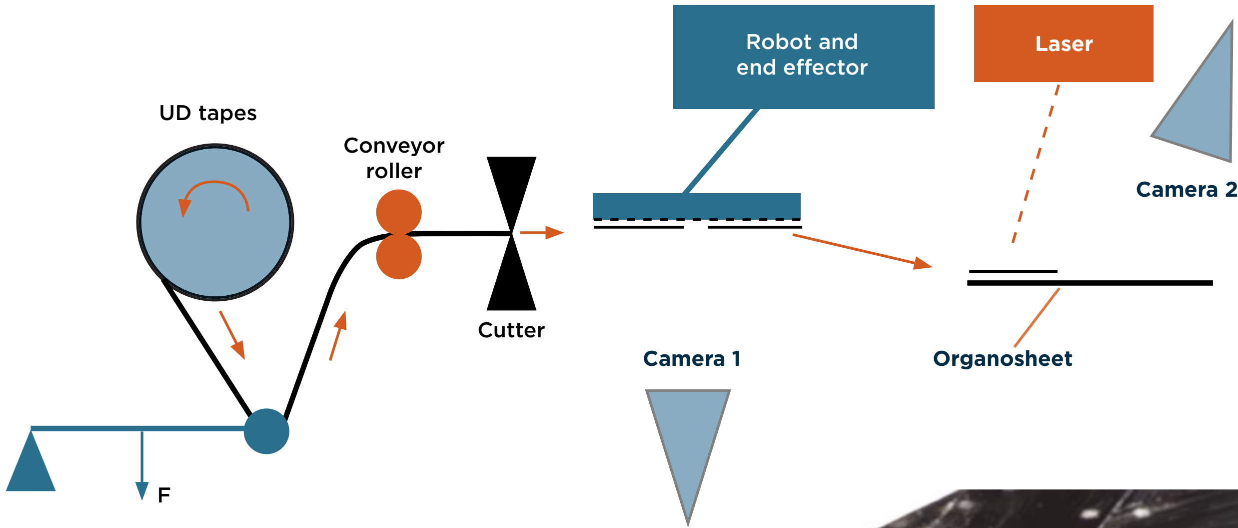
To keep pedals light, thin, cost-effective and capable of meeting challenging OEM specs, Boge uses continuous glass fiber organosheet as the shell structure to carry the part's main loads, which can be as high as 3,000 newtons. Organosheet blanks are supplied precut to size, with two or three layers fully consolidated by supplier Lanxess Deutschland GmbH (Cologne, Germany). To reinforce the main load paths on the organosheet blank, Boge adds strips of unidirectional (UD) glass fiber tapes (supplied by Celanese Corp., Irving, Texas, U.S.) in orientations and layups based on finite-element simulation results. To do this, Boge uses software it has modified and material cards the company has developed with its suppliers based on stress/strain curves measured for each material under temperature and humidity conditions specified by OEM customers. To add functional geometry, Boge uses overmolded chopped glass fiber compounds (from multiple suppliers) to provide structural ribs and attachment features.

All materials feature matrices of precolored black polyamide 6 (PA6), a tough polymer widely used in the automotive industry. Should OEM specs require such, Boge also has the option to use a higher temperature, less hygroscopic PA6/6 matrix in the overmolding compound, since both polymers are similar enough to bond to each other. By using three types of composites with glass reinforcement in three different forms, Boge is able to place fiber where needed to meet performance requirements while avoiding over-engineering. The carry-on effect of this hybrid-composite approach is that it reduces material usage, nominal wall thickness, cycle time and overall part cost.

Process steps and equipment criteria

Partnering with automation/assembly line developer M.A.i. GmbH & Co. KG (Kronach, Germany), Boge has developed a three-step production process that is fast, efficient and produces quality-verified parts at affordable costs. In designing process and equipment, the team had a number of requirements. First, to keep part costs low, the companies needed to keep total effective cycle time at ~1 minute. Achieving this would require automation to ensure materials moved smoothly through the manufacturing cell.

Second, while the organosheet blanks are supplied prestacked,



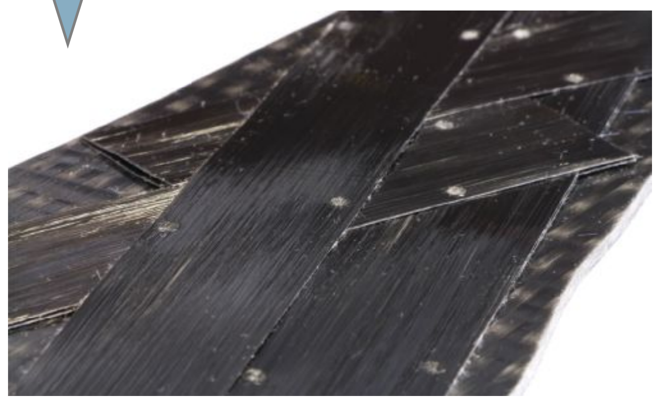
Bespoke production process

Part of Boge's bespoke production process for producing all-composite brake pedals in three different materials. Source | Boge Rubber & Plastics Group

fully consolidated and precut to size (contoured), the requirements of various pedal designs meant the team needed flexibility to cut, orient and place tape strips of different lengths in different locations and directions to reinforce the main load paths of the organosheet shell. Again, to keep costs down, a bespoke tape-laying process was designed to offer a high level of flexibility and control, as well as speed.

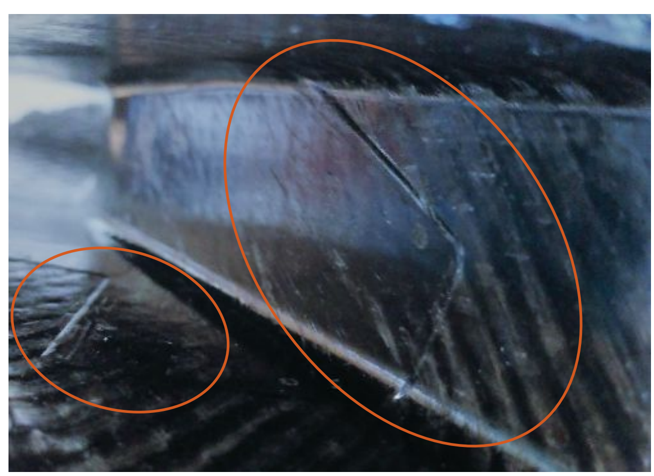
At the start of the process, the manufacturing cell holds two stacks of precut organosheet blanks in cassettes and four creels of UD tapes at one time. First, a robot picks up a contoured blank of organosheet and moves it to the work surface. At the same time, UD tape is fed and cut to the required length. Strips are then placed on a vacuum belt that holds them in place as the conveyor advances. Next, a robot with a revolving pick-and-place end effector plucks one strip at a time from the vacuum belt and a camera checks each strip for quality, dimension and position. When all four pieces have been picked up, the robot moves to the workspace and begins placing one strip at a time on the organosheet blank in the location and position determined by image-based position correction. As each strip is positioned, it is prevented from shifting by multiple spot welds created by a laser. Meanwhile, more tape strips are being cut and placed on the vacuum belt and the process repeats until all tapes required for a given brake pedal design are stacked and tacked in the correct position on the organosheet.

The system that produces this tailored-fiber blank is 100% numerically controlled, with every aspect of the operation fully programmable for maximum flexibility. At each step, cameras or other sensors, which are connected to the system's online quality control (QC) system, detect all edges and positions of tape strips and the organosheet shell and compare geometrical data for »



Up close

Precut and prechecked unidirectional tapes are precisely positioned at strategic locations on the organosheet to reinforce load paths on the part's shell structure. To keep tapes from shifting during subsequent steps, they are tacked (via laser spot welding) to the surface below. Source | Boge Rubber & Plastics Group



UD tape consolidation

Boge's process produces parts with multiple thicknesses, but roughly constant fiber-volume fraction in the shell structure. Shown above, UD tapes (orange circles) can be seen consolidated into the organosheet shell after preheating/consolidation/preforming but before overmolding. Source | Boge Rubber & Plastics Group these materials against known parameters to assure each material is positioned where it needs to be.

To keep production speeds high, the tailored-fiber blank next moves to an infrared oven to heat both materials just prior to draping/preforming/consolidating tapes onto the organosheet. A special antioxidant package in tape and organosheet resin systems prevents thermal damage. Next, the hot blank is quickly moved into the draping/preforming cavity where high pressure is used to form the blank into a U-channel shape while assuring a high-quality surface. The QC system again monitors consolidation and preforming quality via time, temperature and pressure.

Finally, the still warm and draped preform is shuttled into an injection mold where it is overmolded with a short-glass/PA compound to create additional geometry such as a complex rib structure on the underside. After demolding, a quick, automated trim and visual inspection are done. No paint or other surface finishing is needed. Final pedal size is approximately 350 x 90 x 60 millimeters. Before leaving the manufacturing cell, a unique QR code is affixed to each pedal to link it back to the manufacturing and materials data for that pedal in the quality system. After assembly, a functional test of the pedal within its bracket and a final robotic inspection are performed. Assuming the unit passes, another QR code is affixed to the completed brake pedal assembly to provide complete traceability of each pedal and additional components prior to shipment to the OEM.

Because brake pedals are safety-critical parts and must meet demanding OEM performance as well as quality requirements, Boge and its partners have built multiple failsafe mechanisms into the Industry 4.0-compliant QC system to quickly and accurately verify that specifications were met at each step in the process. QC data are stored and the received identification number in the form of a QR code assures 100% traceability of material, shifts and process conditions involved in producing that part.

The all-composite brake pedals Boge is producing are roughly half the weight of pedals in metal. They also improve driving haptics for consumers, are 100% recyclable at end of life and meet or exceed the strength requirement for incumbent steel. CW

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Flexible carbon fiber plates enable high-performance footwear

Carbitex's flexible carbon fiber/thermoplastic composite plates use creative engineering to eliminate design compromises in athletic footwear.

By Hannah Mason / Associate Editor

■ **Enhancing high-performance footwear**

Washington-based startup Carbitex's carbon fiber/thermoplastic composite products are designed to eliminate material compromises in stability vs. flexibility in footwear applications. Pictured here is Carbitex's DFX product. Source, all images | Carbitex

»Carbon fiber midsole plates, shanks and other components have been enhancing the performance and reducing the weight of top-tier athletic shoes for years. However, explains Junus Khan, founder and chairman of Carbitex Inc. (Kennewick, Wash., U.S.), even with composites, shoe developers must typically compromise when it comes to material choice for midsole plates. The choice is between a material rigid enough to support the foot during the required activity, though it may be inflexible and heavy, or a material that is lightweight and flexible, but doesn't provide as much support. Either choice, or a compromise material that sits somewhere in between, makes the shoe — and the wearer — inherently inefficient, something that Carbitex says it has been able to overcome through the development of its product line of flexible carbon fiber/thermoplastic composite materials.

However, Khan notes, he didn't originally set out to transform the footwear industry. A little more than 10 years ago, Khan, whose background is in economics but who learned about carbon fiber composites through working in the automotive industry, took a look at the luggage market and wondered why luggage makers were trying to mimic the aesthetics of carbon fiber using ballistic nylon and other fabrics, instead of using actual carbon fiber. Unable to find a company that made a soft, pliable carbon fiber product suitable for the luggage market, he decided to try his hand at making it himself.

In 2010, Khan began investigating various carbon fiber materials in his garage in his spare time, and by 2011, his first material and process were tested at the U.S. Department of Energy Pacific Northwest National Laboratory. At that point, he says, "I had a viable concept, and a better understanding of the material space," and he decided to turn this concept into a company, with the goal of continuing development and ultimately selling the material. Carbitex Inc. was founded in February 2012.

From luggage to footwear

Khan explains that other companies have developed semi-flexible carbon fiber fabrics by suspending a single ply of fabric in between two thermoplastic films. "However, when you pull that material in tension, the failure mode is those films ripping off the surface of the carbon," he says, meaning that a tendency toward delamination can hinder the amount of actual flexibility available to the laminate.

Carbitex's CX6 product, its original product offering, is also a single ply of carbon fiber fabric laminated between thermoplastic films. But, Khan says, the fabric is first treated with a specially developed binder that, according to a U.S. patent Carbitex filed in 2015, gives the laminated fabric "flexibility similar to fabric not laminated with polymer films, and improved adhesion and tensile strength." He adds, "When you pull our CX6 material in tension, the failure mode is the fibers actually breaking, not the film delaminating. You're really getting that trademark strength of the carbon fiber." The material is also said to have very low stretch properties compared to other composite materials, which Carbitex found a use for in precisely manufactured footwear components with improved power transfer.

Carbitex began selling its first CX6 product within the luggage and handbag industry to companies like Tumi (South Plainfield, N.J., U.S.), as Khan had originally set out to do. Quickly, however, Carbitex began to receive inquiries from a variety of other industries, such as consumer electronics. While the growth was exciting, he says, "At the same time, we started to realize that we were spreading ourselves very thin." About three years ago, the company made the decision to focus on one market that showed the most potential: footwear.

Today, Carbitex supplies its carbon fiber plates across the footwear industry, where they are used in snowboarding, cycling, watersports, running, hiking, fashion products and more. One of the company's most recent and highest-performance footwear applications is a soccer cleat released by Adidas in fall 2020.

AFX and DFX: Transforming footwear

Over the past several years, Carbitex has released two new composite technologies, called AFX and DFX. According to »

Increasing flexibility

Carbitex's CX6 product uses a specially developed binder to increase flexibility of the laminate compared to other composite materials.

Focus on footwear

Though expecting to move into other industries soon, so far Carbitex is putting most of its development focus across the footwear industry. Pictured here is an Adidas Adizero Pro running shoe.

Intentional buckling

The AFX material is designed to bend only in one direction, following the limitations of the human foot.

Khan, unlike "typical composites" whose stiffness is controlled by fiber orientation and ply length, stiffness of a Carbitex carbon fiber sheet is uniform across its length. Where other composites may consist of one type of resin system and fiber, he says, Carbitex's materials are more complex, involving intricate layers of polymer sheets and fabric layers, to achieve the desired flexibility properties. "A very simple version of our AFX material might have two different types of carbon fiber sandwiched between another two or three different types of polymer," he says. "It's an intricate layering system, and you have to understand how those layers have to come together for [the required] properties."

Generally, the manufacturing process starts by layering fabrics, which may be treated with binders or other fabric treatments, and polymer sheets into a panel. A variety of fibers from different suppliers are used, although Khan says most of Carbitex's products include fibers from Toray Composite Materials America (Tacoma, Wash., U.S.), and often spread tow fabrics from Hexcel (Stamford, Conn., U.S.). Polymers also vary by application, but are typically thermoplastic for flexibility and formability, "though sometimes it's not completely thermoplastic, depending on the application," he adds.

These panels are consolidated in heated presses; once removed, individual parts are cut via waterjet and formed. Manufacturing in panels rather than laying up individual parts leads to higher output than traditional layups, Khan says.

Along with balancing rigidity and flexibility, though, there is an added challenge to developing footwear: the human foot can only bend in one direction without overextending or breaking, so shoe materials need to have the versatility to bend in certain directions but not others. Carbitex achieves this, Khan says, through controlled buckling, or bending, of the laminate. "Typically in composites, the word 'buckling' is attributed to failure," Khan says, "but we've come up with ways to enable the fiber to buckle but not break." This invention, he adds, was initially made by accident, as a colleague realized that a certain combination of fiber and polymer layers had resulted in a material that buckled in only one direction. "We realized there had to be some kind of benefit to that," Khan says, "so we started peeling the layers back, to learn how it happened and then understand how we could do it on purpose."

> "Companies no longer have to compromise and choose a specific midfoot stiffness."

The resulting product is called AFX, where the "AF" stands for "Asymmetrically Flexible," indicating that it bends in one direction but is completely rigid in the other. According to a 2018 patent filing, Carbitex's AFX product comprises a woven fabric layer, a prepreg layer and, in between, at least one polymer layer, which are combined into an assembly that is then shaped and cured. "The layered arrangement has a high resistance to bending in a first direction, and low resistance to bending in an opposing second direction," the patent says.

"Our technology enables the level of stiffness and protection in the direction that you want it," Khan adds. A hiking boot incorporating an AFX carbon fiber midsole, for example, includes the support and rigidity needed to protect the foot against bending the wrong way on uneven or vertical terrains, but "when you go to bend your foot to walk on flat ground, [the boot is] just as flexible as, say, a running shoe," he says. AFX is also lighter than the combination of board and rubber materials that are often used to reinforce hiking boots.

Carbitex's third product is called DFX, a derivative of AFX that

■ Dynamic flexibility

In Adidas' X Ghosted soccer cleats and similar applications, the DFX material enables changeable flexibility depending on the movement of the wearer.

stands for "Dynamically Flexible," meaning that the stiffness of the material within the shoe changes as the foot moves. With DFX, "you can have [a shoe] that's going to be super flexible at certain angles, and then become progressively or exponentially stiffer at higher angles," Khan says. "In footwear, this correlates directly to performance." According to its 2020 patent filing, DFX consists of at least three layers assembled and cured into one laminate: a binder-enhanced, flexible woven fabric layer; a more rigid woven fabric layer; and at least one polymer layer.

Khan notes that a running shoe or cleat can be soft and flexible when an athlete is walking onto a track or a field, and then, once the runner takes off and the foot starts bending at higher angles, the shoe will become stiffer to support the movement. "Companies no longer have to compromise and choose a specific midfoot stiffness — we can identify the different functions of a given activity and engineer the stiffness around that."

"Another way of looking at it is that DFX augments the foot's performance, acting like muscles or ligaments that become flexible or stiff depending on which way they're stretched. The AFX material acts more like a joint like your elbow or your ankle — it's designed to bend really well one way," he adds.

Each material iteration so far has been specially designed for a particular performance range and level of manufacturing integration identified as applicable to the industry, with room for customization within that, such as specific stiffness or durability requirements. The company also offers custom samples to potential customers. "We continually gather data about our composites and how they work and why, and have built our own modeling systems to turn around different versions as needed pretty quickly. Usually within a day or two of receiving an inquiry we can have a custom sample made and out the door," Khan adds.

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Beyond footwear

"Right now, our goal is to continue expanding within footwear, and trying to capture that opportunity," Khan says. However, a long-term goal is for the company to grow into other industries, such as aerospace and medical applications.

"One industry that's really top of mind for us, both as a market where our products would have a true benefit and also as one that has some similarities to footwear, is the orthopedic and prosthetic realm, and maybe even the robotic side as well," he says. Dynamic flexibility in prosthetic limbs, he adds, is currently accomplished through heavy and expensive electronics systems and hydraulic actuators. Khan envisions use of Carbitex's products in applications such as knee or back braces, where the material could be engineered to prevent certain motions or hyperextensions, while enabling other movements. He adds, "With a brace, you're typically immobilizing part of someone's body because of just one movement that would be really bad for it. The key would be to make a brace that limits that one direction of movement, but enables the person to then be able to move in other directions."

In alignment with this goal, Carbitex has recently begun development of an application with a company that makes braces geared toward children. The company's materials have also been used to develop a carbon fiber pad for a compression sleeve designed for hikers, and a neck brace that connects to a football player's helmet and shoulder pads to prevent the neck from snapping backward during gameplay.

In pursuing other applications, Carbitex hopes to use its products to eliminate material compromises in other industries, like it continually aspires to do in footwear. Khan adds, "It sounds cooler to say that you're striving for products that make you faster, better and stronger, and we are doing that — but ultimately, we're always pushing for efficiency." CW

ABOUT THE AUTHOR

Hannah Mason joined the *CompositesWorld* team in 2018 after working as an editorial intern for sister magazine *Modern Machine Shop* and earning a Masters of Arts in Professional Writing from the University of Cincinnati.

Composite rebar for future infrastructure

GFRP eliminates risk of corrosion and increases durability fourfold for reinforced concrete that meets future demands as traffic, urbanization and extreme weather increase.

By Ginger Gardiner / Senior Editor

»Worldwide, concrete structures are under attack like never before. Not only has traffic increased on roads, bridges and overpasses, but climate change has increased extreme weather events, including violent storms and torrential rains that result in flash floods and other destructive events. Under such stress, concrete can crack. This allows rapid deterioration in aggressive environments through exposure to elements such as saltwater, which is corrosive to steel rebar.

"Cracks create paths for the agents of the aggressive environments to reach the reinforcing and/or prestressing steel and begin the corrosive oxidation process," explains the Florida Dept. of Transportation (FDOT, Tallahassee, Fla., U.S.) structures innovation website. "An innovative approach to combat this major issue is to replace traditional steel bar and strand reinforcement with fiber-reinforced polymer (FRP)." FDOT has been a leader in FRP rebar use and testing, as well as the development of design and use standards, like those issued by the American Concrete Institute (ACI, Farmington Hills, Mich., U.S.). Although composite rebar is primarily made with glass fiber (GFRP or GRP), products have also been developed using basalt (BFRP) or carbon fiber (CFRP).

"With a long and costly history of corrosion worldwide, steel is no longer viewed as a cost-effective option in aggressive environments," says Nick Crofts, CEO of GFRP rebar manufacturer Mateenbar (Dubai, UAE and Concord, N.C., U.S.), lead supplier for the largest GFRP rebar project in the world. This project is the 23-kilometer-long and up to 80-meter-wide flood mitigation channel in Jizan, Saudi Arabia. Although GFRP rebar has been around for 30-40 years, says Crofts, key projects like the Jizan Flood Channel are now propelling it into mainstream infrastructure. This growth is already justifying Mateenbar's new factories in Saudi Arabia and the U.S.

Pioneering GFRP rebar technology

Mateenbar GFRP rebar was developed by Pultron Composites (Gisborne, New Zealand), a pioneer and specialist in pultrusion technology and product innovation. Mateenbar addresses the unique challenges of the rebar market, which not only demands high volume and low prices, but also requires the product to be specified by project architects and/or engineers. Thus, Mateenbar's first factory in 2008 was built close to potential customers and project engineering firms in Dubai, United Arab Emirates, a region known for large infrastructure projects and pioneering use of composites in construction. Pultron remains a strategic partner to Mateenbar and a key supplier of bespoke technology and product development.

Mateenbar's factory uses Pultron's advanced technology to produce very consistent pultruded rebar at high throughput without volatile organic compound (VOC) emissions. "We inject resin and cure *inside* the engineered steel pultrusion die," says Crofts.

"This rebar is an engineered product with dimensional performance better than ±1%," he adds. "There is no excuse to see resin on the floor or dust in the air. The fiber used is corrosion-resistant ECR glass from Owens Corning (Toledo, Ohio, U.S.) and the resin is our own variant of an epoxy back-boned vinyl ester. It maximizes toughness, strength and durability, and is far superior to a polyester backbone with epoxy terminations."

The pultruded round rods are then machined to create a spiral profile that enables load-bearing adhesion inside the concrete. "That

is also a closed operation," Crofts points out, "using machining booths equipped with Donaldson (Bloomington, Minn., U.S.) air filtration systems. We then apply a resin film on the outside to improve handling." Mateenbar's rebar is produced in lengths of up to 80 feet, cut to length as required. "It is typical to see 40-foot lengths for most infrastructure and construction projects," says Crofts.

"Our average straight rebar is 0.75-inch in diameter, with a tensile modulus of 8,700 ksi (60 GPa) made from 11,600-ksi (80-GPa) glass fiber; thus, the fiber content is very high — more than 80% by weight. There is no way to bend this, so our bent GFRP rebar is made using a different process and resin, with proprietary technology."

World's largest GFRP rebar project

Jizan (also spelled Jazan) is the capital of the Jizan Region, which lies in the southwest corner of Saudi Arabia, north of the border with Yemen. Disastrous flash flooding occurs during periodic heavy rains due to runoff from nearby mountains. The 23-kilometer-long reinforced concrete stormwater drainage channel was built to protect a large industrial zone that includes an oil refinery for Saudi Aramco (Dhahran, Saudi Arabia).

Largest GFRP rebar project

Roughly 11,000 kilometers of GFRP rebar reinforce this concrete flood mitigation channel in Jizan, Saudi Arabia, and enable its 100-year service life.

Source for all images | Mateenbar

Until the COVID-19 pandemic, Saudi Aramco was the world's largest company in terms of revenue. It handles all of the Kingdom's oil and derivative products business and also accounts for 10% of all construction in Saudi Arabia. "Saudi Aramco realized that a huge percentage of its annual budget was spent replacing concrete structures," says Crofts. "The high salinity in the region's sand and high delta in temperature from day to night causes faster cracking in the concrete. Saudi Aramco began looking for alternative technologies, and, as members of ACI, they took their strategy from the FRP rebar standards developed, further adapting and refining them as Saudi Aramco standards. The company then mandated use of GFRP rebar in certain high-corrosion environments."

Saudi Aramco asked for tenders for the Jizan flood channel project and then selected three GFRP rebar suppliers. Mateenbar »

1 Glass fiber is fed into the pultrusion die and injected with resin in a closed-molding process.

2 The pultrusion process creates glass fiber/vinyl ester composite rods in length of up to 80 feet.

3 A spiral is machined into the rods to assist with adhesion in the concrete.

4 Straight and bent GFRP rebar is shipped to the construction site.

5 Rebar is placed per design drawings, supported at the right height by sections of round pipe and held together with stainless steel ties.

6 Concrete is poured on top of the rebar, then tamped and compressed to remove air bubbles.

7 The finished reinforced concrete channel in Jizan will direct flood water away from roads and industrial production facilities.

Photo Credit: Al Yamama Group

was awarded 50% of the contract. "We waited for several months while the project geared up," Crofts recalls, "and then, suddenly, all of the materials were needed immediately. The Dubai factory went to being flat out within the space of a week and produced almost 6,000 kilometers of GFRP rebar over seven months."

Once delivered, the rebar was installed by the project's contractor, Al Yamama Group (Dammam, Saudi Arabia). "We thought we would need to provide a lot of assistance during installation, but it wasn't necessary," says Crofts. "They found it much faster to install than steel rebar." With a weight 25% that of steel rebar, GRFP rebar enables handling of longer lengths with fewer people and is easier to move and position. "There are also fewer positioning pipes required," he adds. "These round sections of pipe are used to support the rebar at the right height position within the concrete."

After the rebar is placed, tied together with stainless steel wires and inspected, it is ready for concrete to be poured on top. The rebar installation team moved so quickly, notes Crofts, they were actually a kilometer down the 40- to 80-meter-wide channel before they realized the concrete pouring operations couldn't keep up. "So, they stopped and let the concrete catch up," he adds. "This is important because if heavy rains come, the flooding fills the channel with sand. This happened on a couple of occasions, causing delays, but also highlights the importance of this drainage channel."

After pouring the concrete on top of the rebar, the installation team tamps and compresses it to remove air bubbles, and then it cures over the following days and weeks. "There is no difference between GFRP and steel rebar for these steps," says Crofts. "We finished supplying rebar in January 2020, and the channel has just been completed [November 2020]."

Design, cost and GFRP future

Crofts points out that GFRP rebar is not a direct replacement for steel. "GFRP rebar has different properties to that of steel rebar. These differences must be accommodated in the design. So, whereas concrete reinforced with steel would typically be designed to ACI 318, this would not be suitable for GFRP rebar, which relies on the ACI 440 design guide instead. As an example, GFRP rebar has a higher tensile strength than steel, but a lower tensile modulus. It is also elastic to the point of failure." Crofts notes that in a steel design, the quantity of rebar would typically be determined by the tensile strength. However, for GFRP, the modulus is typically the factor that determines the quantity of rebar required. Meeting this requirement typically results in a structure that will exceed the ultimate strength requirements. It also ensures a desirable failure mode in the GFRP rebar-reinforced structure.

Another consideration is the production of bends and shapes. Crofts notes the ratio of bent to straight rebar in projects is, on average, roughly 30%. With steel rebar, this fabrication is often completed on site. "Mateenbar bent bars are produced in our controlled-environment factory and delivered directly to site without intermediate fabrication steps," he explains. "This can

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be a challenge from a supply point of view as needs change from one week to the next. We have found that flexibility and having a factory located in the same region are very important."

"The cost of GFRP rebar is three to four times higher than steel if calculated in dollars per pound," says Crofts, "because our product is one-fourth the density. The appropriate measure is *dollars per foot* because rebar is actually specified and bought as a fraction of the concrete volume. When you measure its cost by volume, GFRP rebar is cost-competitive with steel."

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"Jizan was the first mega-project not to allow steel," says Crofts. "They had a team to design the required structures with a service life of more than 100 years. Several GFRP rebar producers are looking to locate in Saudi Arabia now as demand grows." Mateenbar is also building a new factory there, and in Concord, N.C., U.S., to serve North America, which is the second-largest market after the Middle East. Both plants are modern, 100,000-square facilities that use Pultron's advanced pultrusion system. For both, equipment was delivered in October 2020 and production is expected to begin by early 2021.

As demand for GFRP rebar ramps up in the Middle East, the market in North America continues to mature. "Currently, the largest GFRP rebar applications in North America are sea walls and bridges along the coast or where roads are heavily salted," says Croft. "However, DOTs and asset owners are now looking to improve cost over the lifetime of structures [see Learn More], which includes reducing the need for maintenance and building infrastructure that is both long-lasting and sustainable. Consulting engineers and end users are seeing the value of GFRP rebar technology and GFRP rebar producers are cooperating on quality and performance standards. There are also leading users, such as FDOT, who are promoting the technology and assisting other DOTs, which has helped to spread knowledge."

Crofts notes that FDOT recently hosted a webinar on GFRP-reinforced concrete design with 200 attendees. In another webinar, Dr. Antonio Nanni, one of the key researchers at Miami University working with FDOT stated, "FRP rebar is ready for prime time." That has been proven, says Crofts. "The job now is for more companies to specify it and contractors to use it." CW

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» RECYCLED MATERIALS
ReSound R recycled content portfolios target circular economy

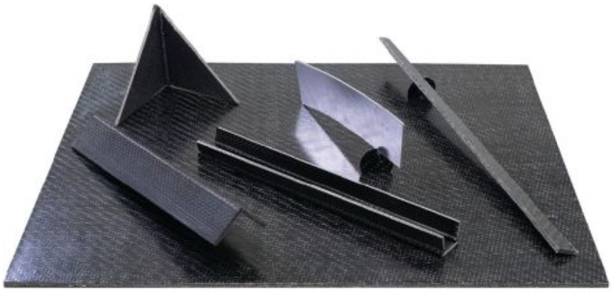
To enable its customers to achieve sustainability goals and add options to its circular economy commitment, **Avient Corp.** (previously PolyOne and Clariant Masterbatches, Avon Lake, Ohio, U.S.) has launched several new post-consumer recycled (PCR) and post-industrial recycled (PIR) portfolios under the reSound R brand name. This includes reSound R VX thermoplastic elastomers (TPEs), reSound R ND polyamides and reSound R PC polycarbonates.

Available in North America, injection-moldable reSound R VX TPEs are said to use 25% PCR and up to 40% PIR content. Both grades can be overmolded onto polypropylene (PP). The PCR grade is formulated with recycled ocean plastics from Oceanworks (Burnaby, British Columbia, Canada), an accelerator program participant within the non-profit Alliance to End Plastic Waste. This portfolio targets consumer applications.

Avient is also expanding its polyamide portfolio to include reSound R ND with post-consumer content. These nylon formulations are said to contain 100% PCR resin, and are available in both PA6 and PA66 grades with various levels of glass fiber and mineral reinforcements. These products are targeted at applications in the consumer, automotive and powersports markets.

The third portfolio, reSound R PC, offers a range of polycarbonates with glass reinforcement levels from 10-30% and PCR- or PIR-recycled content ranging from 25-75%. Avient adds that several grades in this portfolio are on par with virgin PC in terms of tensile elongation, tensile strength, notched Izod impact, flexural modulus and flexural strength. While the portfolio is only available in Asia, global availability is under evaluation, depending on regional sourcing capabilities.

avient.com


Source | Manna Laminates

» PRECONSOLIDATED LAMINATE
Organosheet laminate aims for automotive crash applications

Manna Laminates (Misgav, Israel) reports that, after four years of development, it is introducing its Formtex family of semi-raw, thick organosheet laminate materials, which are said to meet the most stringent specifications for automotive crash applications.

Formtex is made using advanced woven fabric or layered unidirectional (UD) tape reinforced with continuous fiber thermoplastics (CFT). According to the company, the laminates can be customized per part or industry requirement, making them ideal for quasi-isotropic-loaded hybrid parts. The result is said to be an innovative, affordable material that offers outstanding quality and performance capabilities.

Moreover, says Manna Laminates, Formtex provides a significant advantage for automotive crash-testing applications and even electric vehicle (EV) battery casings because of its high energy absorption, high impact resistance and the thickness of the laminate itself, which provides multi-axial reinforcement. It can also accommodate the need for location-specific strength, flame retardancy and electrical and thermal conductivity.

Kobi Goldenberg, managing director of Manna, notes that, while Formtex is mostly used for parts with large surface areas, it can also be used as an insert for local reinforcement in overmolding processes. One example is the company's newly awarded Front End Module (FEM) carrier project for a European car platform. The three preheated strips of organosheet were placed on the cavity side of the injection mold and backfilled with 30% LFT-PP, eliminating the need for several heavy stamped steel brackets on the sides of the front-end module carrier, while still meeting front crash requirements and engine hood-latch load constraints.

Using what the company says is an innovative impregnation and consolidation process, Manna reports that it can manufacture laminates up to 10 mm thick in a single step with shorter thermal history and superior mechanical and delamination resistance properties.

Formtex is available in a range of fiber/resin combinations and product formats. Fiber materials include E-glass and carbon fiber; resin options include PP, PA6, HDPE, LDPE, PC and more. It can be supplied as a rectangular-cut laminate or cut to shape.

manna-g.com

» ADDITIVE MANUFACTURING

Water-soluble support filament reduces downstream processing cost, time

Infinite Material Solutions LLC (Prescott, Wis., U.S.), a material design company focused on additive manufacturing, presents its water-soluble, 3D printing support material AquaSys 180. Built for exceptional temperature stability, the material is compatible with high-temperature thermoplastics such as polyetheretherketone (PEEK) and polyetherimide (PEI) and can be printed at chamber temperatures up to 180°C. Further, the support material significantly reduces the cost and time of downstream processing, and is said to enable complete design freedom.

Source | Infinite Material Solutions

According to the company, AquaSys 180 provides an apparent advantage to companies that use fused filament fabrication (FFF) to print parts made from high-temperature thermoplastics. Until now, printing parts with this process required that each part be printed with support structures made from materials that either needed to be removed manually, or dissolved with harmful solvents. AquaSys 180, however, enables users to dissolve support structures with warm water, leaving behind a finished part with minimal residue.

infinitematerialsolutions.com

» NON-DESTRUCTIVE INSPECTION

Customizable, high-precision CT system offers versatile test part inspection

VisiConsult X-ray Systems and Solutions GmbH (Berlin, Germany) presents a standardized high-precision computed tomography (CT) system. The modular device is designed to precisely inspect a wide variety of test parts via integrated monitoring devices including cooling systems, temperature and humidity controls. Further, the manipulator is customizable in a variety of suitable materials, including granite (with a low thermal expansion) and steel.

Source | Visiconsult X-ray Systems and Solutions

A handheld controller is used to fine-tune the axes while the user is standing next to it. Heavy loads of up to 60 kg and a diameter of up to 300 mm can be loaded into the system using an overhead crane and then scanned with high precision. A number of options are also available, such as filter wheel, shutter, target cooling and detector aperture.

Additional customizable features are offered to customers for an adaptable product, including the mounting of two separate X-ray sources for a more flexible system, among others.

visiconsult.de

» LIGHTNING STRIKE PROTECTION

VeeloVEIL material improves metallized nonwoven conductivity

Veelo Technologies (Cincinnati, Ohio, U.S.) has recently improved the performance of its VeeloVEIL, a metallized nonwoven advanced material, which is now available with conductivity of 3 mOHM/sq, 55 g/m^2, with less than 5% electrical uniformity in a 36-inch-wide continuous product form. The lower resistivity is a departure from the Veelo report, which states that VeeloVEIL was engineered to deliver 5-10 milliohms of electrical resistivity at an areal weight of 40-50 g/m^2. Veelo says the new offering sets a new standard in the high-growth aerospace and defense lightning strike protection market.

Source | Veelo Technologies

According to Veelo Technologies, at 3 mOHM/sq, VeeloVEIL offers twice the specific conductivity of expanded copper foil at 195 g/m^2, and 7-150 times better performance than other available metallized nonwovens. Additionally, VeeloVEIL is said to provide superior EMI shielding effectiveness, and is reported by Veelo to be one of only a few products to meet the aerospace and defense industry's most stringent Zone 1A Lightning Strike Protection requirement.

According to Larry Christy, director of research and development at Veelo, VeeloVEIL is a light, highly conductive and electrically uniform material designed to protect composite air vehicles from electromagnetic effects as well as lighting strikes. The expansion of Veelo's capacity to a 36-inch continuous form also enables VeeloVEIL to be used in a wider variety of applications. VeeloVEIL is available with tailored resistivities from 3-40 mOHM/sq and basis weights from 20-55 grams/m^2. It is available as a dry reinforcement, film adhesive or surfacing film.

veelotech.com

» CONTINUOUS FIBER STRUCTURAL REINFORCEMENTS

Thermoplastic tension members enable flex strength improvement

Integrated Composite Products (ICP, Winona, Minn., U.S.) has developed selective polypropylene (PP) thermoplastic reinforcements, also known as tension members (TM), to help improve the performance of plastic parts. The reinforcements are said to offer mechanical engineers a lightweight option that offers the ability to significantly improve strength, stiffness and impact properties, at a reduced cost. According to ICP, designers will no longer have to settle for increasing weight and/or the dimensions of the part.


Source | ICP

The TMs are essentially continuous fiber-reinforced rods (shown in image) that are inserted in the mold and strategically placed at the bottom of a molded rib before the polypropylene plastic is injected. When a molded part is stressed, notes ICP, it normally fails at the bottom of the rib. By placing these "rods" directly at the bottom of the rib, the force is said to be distributed across the entire rib, dramatically increasing the load capacity and overall stiffness of the molded part.

For example, in the case of injection molded, 5-inch-wide x 18-inch long x 1-inch deep panels processed in 40% long fiber glass-filled PP, ICP's thermoplastic tension members provide flex strength improvements of 72% and flex modulus improvements of 21%, without increasing part weight. In compression-molded, 8-inch wide x 18-inch long x 1-inch deep panels using the same 40% long fiber glass-filled PP, the property improvements are said to be even greater, with flex strength improvements of 142% and flex modulus improvements of 50%, again without impacting part weight. Further, the use of PP TMs in conjunction with glass-filled PP ensures the entire part is recyclable.

Tension Members are manufactured and sold based on the number of glass filaments within the TM and the overall length of the TM. For example, an 8,000-filament product has an overall diameter of 0.090 inch and sells for around $.034 (i.e. 3.4 cents) per foot at high volume. A 12,000-filament product is 0.160 inch in diameter and sells for approx. $.061 (i.e. 6.1 cents) per foot at high volumes. ICP can vary the number of filaments in the TM to meet application needs and rib size. Production is done in the company's Winona, Minn. site; product is readily available, and applications are being sampled and developed.

icpcenter.com

Source | CFP Composites

» MACHINABLE COMPOSITE LAMINATE

Low-cost, carbon fiber laminate processes like metal

CFP Composites Ltd. (Solihull, U.K.) has launched its low-cost, 5-mm-thick carbon fiber laminate, BM-5. According to the company, one global industrial Tier 1 engineering company described the material as being "just like black metal," as the laminate board can be screwed, tapped, fastened, bonded and painted just like a metal, with no delamination. It also has a comparable cost to metal, removing operator and financial barriers to adopt carbon fiber.

Made using a proprietary blend of chopped carbon fiber mixed with a polyamide binder, CFP says BM-5 is simple to use. Users buy the ready-to-cut/machine sheets, and cut out the required shape for completion. Prepreg, layup and/or oven/autoclave cure is not required.

Furthermore, to cut or machine BM-5, only standard metallic cutting tools are necessary. The material is said to generate no carbon dust, only safe and easily disposable chippings, eliminating need for specialized cutting rooms or equipment.

The lightweight, carbon fiber laminate has a wide range of application potential, particularly if the application has a flat geometry. Decks, platforms, cladding, bulkheads, reinforcements, enclosures, casings and even certain components are a few examples.

CFP also carried out a cost analysis comparing 275 mm x 125 mm BM-5 and aluminum boards on a finished part basis. Between materials (£10.00) and machine (£45.00) for the aluminum board, the total was £55.00 in price. Compared to BM-5 — materials (£17.00) and machine (£45.00) — the total equaled £62.00, indicating comparable costs between the two.

According to Simon Price, managing director of CFP, the most important thing to take away from BM-5 is that it removes the operating barriers to using carbon fiber materials in industrial applications, with a cost that works for end users, compared to metals. BM-5 is distributed globally via CFP partners, and there is no minimum order quantity. The company says shipping is typically 7 days.

cfpcomposites.com

Source | Vastex Industrial

» CURING TECHNOLOGY

Compact infrared conveyor oven ensures edge-to-edge temperature uniformity

Vastex Industrial (Bethlehem, Pa., U.S.) has introduced its new D-100 model infrared conveyor oven for laboratory testing and low-volume production applications. At 46 in. (117 cm) long x 24 in. (61 cm) wide x 24 in. (61 cm) tall, the compact unit fits in tight spots and can be placed on tabletops or wheeled utility carts with tops as small as 24 in. (61 cm).

Offered in 120V or 240V models, the D-100 oven is equipped with a 16-in. (40-cm) square, 1,625-watt infrared heater that achieves temperatures up to 750°F (400°C). Heater shields reportedly maximize edge-to-edge temperature uniformity, while variable controls for both heat intensity and conveyor speed allow fine-tuning of the heating process.

The heating chamber has a fixed in-feed width of 19.5 in. (49.6 cm), and an in-feed height that can be raised and lowered from 2-7 in. (5 to 17.7 cm). The heater can also be raised, lowered and pivoted using lock knobs on the sides of the heating chamber, according to the shape of the items, for uniform heating. Heater shields are included as standard to maximize edge-to-edge temperature consistency.

Further, the oven is equipped as standard with an 18 in.-wide (45.8 cm) Teflon-coated fiberglass conveyor belt driven by a 50-lb motor, and aligned by a continuously variable tracking device patented by the Vastex. Optional Kevlar and stainless steel mesh belts are offered for high-heat and/or sanitary applications.

Larger conveyor/tunnel models are available with belt widths up to 54 in. (137 cm), chamber lengths up to 162 in. (412 cm) and infrared heaters to 68,400 watts. A 3-year warranty against defects and a 15-year warranty on infrared heaters are standard.

Also offered are cabinet/batch ovens in three sizes with forced, filtered air, adjustable racks and stainless steel finned strip heaters up to 3,100 watts.

vastexindustrial.com

Source | Dynamic Modifiers

» FST POLYMERS

TP flame-retardant materials target low-smoke, non-toxic capabilities

PAL...VersaCHAR, a non-halogenated, low-smoke, lightweight, flame-retardant thermoplastic polyolefin compound developed by **Dynamic Modifiers LLC** (Atlanta, Ga., U.S.), is said to address several concerns surrounding more traditional flame-retardant materials. Ideal for a wide range of markets — including aerospace, consumer, mass transit, marine, defense, oil and gas, construction and more — the technology is said to possess several advantageous and physical and performance qualities.

Compared to traditional thermoplastics, PAL...VersaCHAR reportedly is not bioaccumulative, meaning that it generates a very low smoke density. According to Dynamic Modifiers, the compound has passed ASTM E84 (Class A/1), which includes less than 2.3% of allowable smoke generation limits, and is able to match the stringent requirements of UL 94 V-0 flammability standard performances. Further, it does not contain or generate toxic off-gassing chemicals when exposed to flames, reducing the probability of highly toxic combustion gas concentrations, which is a large concern for aerospace and public transport applications.

PAL...VersaCHAR is said to offer a low flame spread without flaming drips, and has been tested up to 1,950°C (the highest temperature tested to date). The material can be extruded or calendered as a film, sheet or coated fabric, molded to shape, or overmolded and bonded to most material substrates including metal for corrosion resistance. Properties of the compound include extreme chemical resistance and customizable UV, color, or glass fibers for added stiffness, toughness and tenacity.

PAL...VersaCHAR is fully recyclable, sustainable and also yields advantages to gain LEED points in the Green Building Market and Healthy Hospital Initiative. This is achieved via the compound's ability to nominally modify hydrophobic or hydrophilic properties, as well as its high level of chemical, solvent and water resistance/absorbency. Further, the compound is non-polar, enabling a natural resistance to microbial growth. No volatile organic compounds, halogens or heavy metals are present.

dynamicmodifiers.com

Source | Testia

» NON-DESTRUCTIVE TESTING DATA MANAGEMENT

Multi-method acquisitions system delivers flexible NDT inspection method capabilities

Testia (Toulouse, France), an Airbus company that specializes in aircraft structure inspections and services, has released its current acquisition systems portfolio, comprising the multi-method UE1 Box and phased array U32 Box. According to the company, these products are available for those who need to meet multiple technical specifications and accomplish different inspection goals from a single device.

The Box concept is designed to deliver hardware and software on embeddable units. This architecture allows operators to define best suitable non-destructive testing (NDT) inspection methods for their operations, whether it is a desk job, a remote task or a large machine.

The UE1 Box device enables the performance of ultrasonic testing (UT) and eddy current testing (ET) including bore holes with rotary probes and/or resonance data acquisition all in one. It is said to be fully suitable to test any type of material for defect detection, material characterization, thickness assessment, etc.

The U32 Box device is dedicated to phased array ultrasonic data acquisition including conventional UT. With its 32 elements, Testia says it is fully suitable for ultrasonic inspection automation of aerospace parts as well as for other applications.

Further, in an effort to deliver smart and scalable solutions, Testia offers its SDK packages, which provide a set of functions that allow dynamic control of Testia's Box via Testia's software. Users now have the capability to give instructions to the box and manipulate its functions flexibly with full exploitation of the equipment's features. Functions are categorized and organized by type (Initiators, Getters and Setters) to enable easier adoption. The SDK's tree architecture permits quick access to all available functions in the library; detailed documentation, examples and support are said to make for uncomplicated software creation capabilities.

Testia notes that it also launched its flexible SmartScan earlier this year, available in various sizes, from scanning areas of 120 x 80 cm. SmartScan enables multi-method acquisitions by embedding the UE1 Box or the U32 Box. The SmartScan 3-axis system is said to fulfill the highest requirements for versatility, efficiency and accuracy. Used in combination with Testia's SDK, and powered by its analysis software NDTkit, the company says users will be able to quickly set up a fully customized and accurate inspection acquisition system.

testia.com

» PROCESS SIMULATION

Injection mold evaluation software offers earlier component design optimization

Altair Engineering (Troy, Mich., U.S.) launches Altair Inspire Mold, an end-to-end solution for simulating injection molding.

Inspire Mold is said to offer engineers fast, highly capable tools with what Altair claims is unrivaled solver performance and unprecedented opportunities to make better design decisions earlier, reduce costs, speed time-to-market and optimize the quality and manufacturability of finished parts. Altair compares this alternative to conventionally laborious processing and design iterations when evaluating injection molded plastic parts, as well as the building and reworking of prototype molds.

With Inspire Mold, Altair says manufacturability of new components can now be evaluated at the outset of the development process, and the risk of defects such as warping, sink marks and short shots are mitigated before any costly investments are made in mold fabrication. Design iterations are completed faster, and fewer are needed before an optimal solution is identified. Further, scrap, tooling and rework costs are said to be slashed, and there are no requirements for specialized, GPU-computing hardware. Other key features of Inspire Mold include:

- Optimized user experience: Product designers and engineers are able to easily conduct virtual testing, validation, correction and optimization of molding designs via an intuitive, five-step workflow.

Source | Altair Engineering

- Fast, next-generation 3D technology: Experimental approximations of traditional 2.5D solvers are eliminated. Support for advanced physics empowers advanced and novice users with deeper insights and understanding.
- Access to materials data: Data for 60 materials is embedded in Inspire Mold and the Altair Material Data Center (MDC) will soon be integrated, allowing MDC license holders direct, immediate access to reliable, high-quality material data.
- Comprehensive end-to-end solution: Technology stretches from initial design through to material mapping of reinforced engineering polymers, analyzing and optimizing the structural and fatigue performance of complex parts.

Inspire Mold joins Altair's existing Inspire manufacturing simulation offerings including casting, forming, mold-filling, extrusion and additive manufacturing. **altair.com**

» LAMINATION RESIN SYSTEM

Epoxy laminating system produces clear, bright finish for surfboard products

ATL Composites (Molendinar, Australia) has launched KINETIX R111, a clear, bright laminating system for production surfboard lamination.

A solvent-free, liquid epoxy resin optimized with a translucent blue tint that produces a clear, bright finish, KINETIX R111 is said to cure to a bloom-free finish that is UV stable and has excellent resistance to yellowing. With two hardener speed offerings, fabricators also have a choice of flip speeds for faster production. The H130 Fast, for example, can be flipped within three hours and sanded within five hours at 25°C, which is approximately half the turnaround time of the H125 Standard hardener. According to Jake Holloway, COO at Shapers, which distributes KINETIX R111, the system represents a new benchmark for production boards, allowing them to maintain a new-board look for a longer period of their lifespan. Further, the epoxy system is said to be user friendly and enhances product performance. **atlcomposites.com**

Italian student design team uses composites to improve automotive performance

Politecnico di Milano's Formula SAE team worked with Exel Composites to transition to lighter, better-performing composite vehicle components.


Source | Exel Composites

›To help develop automotive engineers of the future, the Formula Society of Automotive Engineers (Formula SAE) is a global student competition that pits a variety of university teams against each other to develop small, Formula-style race cars. These teams are increasingly finding composites to be the ideal solution for pushing their vehicles' performance to the next level.

For example, for its 2019 competition vehicle, the student-led racing department of the university Politecnico di Milano (Milan, Italy), called Dynamis PRC, was looking for a new material to improve the performance of its car's steering column and suspensions. In 2018, the team's car placed in the top 10 of the competitions it entered, but Dynamis wanted to find a way to score even higher the next year.

Andrea Vezzoli, technical director at Dynamis, explains that the team had specific goals: "There were two main objectives we wanted to achieve for that year's model, named the *DP11*. The first was reduce the weight of the car and the second was to improve the suspension because we felt that in the previous year, this is what had held us back."

Singling out the steering column as the main area for weight reduction, Dynamis began searching for new materials. Making weight improvements was critical because every other team would also be finessing their cars.

When researching new materials, Dynamis connected with Politecnico di Milano alumnus Francesco Ierullo, who is currently head of sales for South and West Europe and IMEA at composites fabricator Exel Composites (Vantaa, Finland), who agreed to help the team.

"[Exel Composites is] always looking for ways to get composites into the hands of students, because they are the engineers of the future and the more experience they have with composites now, the better equipped they will be when they work in the field," Ierullo says. "More and more fields of industry are using composites, but direct student exposure to the material remains low. Whatever we can do to help is always crucially important to us."

After reviewing the focus areas with the racing team, Exel Composites suggested several options of carbon fiber tubes for the vehicle's steering column.

The team ended up selecting several lengths and sizes of Exel's carbon fiber/epoxy tubes, ranging in diameter from 105 to 299 millimeters, for applications on the driver interface, vehicle suspension and aerodynamic structures. Exel manufactures the tubes via a pullwinding process.

"We were impressed by the performance of the material," adds Ernesto Ricciardi, head of suspension and drivetrain department at Dynamis. The carbon fiber tubes ended up reducing weight on the steering column by 800 grams, which helped shave two seconds off the vehicle's lap time, while also increasing the rigidity of the vehicle's suspension. In addition, the car's steering column was required to resist three times the peak load, which for the original design was 100 newton meters. Switching from metal to a stronger carbon fiber part enabled the team to push the peak load to 140 newton meters.


Source | Exel Composites

With the new carbon fiber structures installed, Dynamis took the vehicle to four competitions in 2019. At Formula SAE competitions, teams compete in a variety of events that measure qualities of each car. Stopping time, acceleration and agility are evaluated, and teams are awarded points for each focus area. The team that scores the most points wins the competition.

The team won overall at its first and third competitions that year, in the Netherlands and Italy. The fourth competition, held in Germany, was the toughest, Vezzoli says. With some of the world's largest car manufacturers located in Germany, he says, "many of the German teams are directly linked with their local car manufacturers, so we knew the car would have to perform well to help us hit our targets." Despite the challenge, Dynamis placed third, making the season one of its most successful to date.

The 2020 Formula SAE events did not occur as planned due to the pandemic, but Dynamis says it is looking ahead toward its next goal: electric vehicles.

For the next vehicle iteration, the team plans to use more of Exel's composite products, incorporating glass fiber composites into the vehicle's aerodynamic wings for additional lightweighting. CW

Composites Events

Editor's note: **Events listed here are current as of Dec. 15, 2020. Visit short.compositesworld.com/events for up-to-date information.**

Jan. 21-23, 2021 — Mumbai, India — POSTPONED
International Conference & Exhibition on Reinforced Plastics (ICERP)
icerpshow.com

Jan. 25-28, 2021 — Birmingham, U.K. — POSTPONED to 2022
MACH
machexhibition.com

March 8-12, 2021 — Salt Lake City, Utah, U.S.
D30 Joint Meeting with ASTM D30 Composite Materials and CMH-17
astm.org/COMMITTEE/D30

March 10-12, 2021 — Barcelona, Spain
BIT's 6th Annual World Congress of Smart Materials
bitcongress.com/topwcsm2021

March 30-April 1, 2021 — Moscow, Russia
Composite-Expo
composite-expo.com

April 12-14, 2021 — Rosemont, Ill., U.S.
North American Pultrusion Conference
web.cvent.com/event/822b0342-d26d-4212-afef-466ba0d2203a

April 14-15, 2021 — Silverstone, U.K.
MotorsportAM
motorsportam.com

April 21-22, 2021—Brussels, Belgium
Clean Sky Spring event
cleansky.eu/news/clean-sky-spring-event-brussels-21-22-april-2020

April 28-29, 2021 — Manchester, U.K.
ConstructionAM
constructionam.com

May 24-27, 2021 — Long Beach, Calif., U.S.
SAMPE 2021
nasampe.org/events/EventDetails.aspx?id=1244902&group=

May 31, 2021 — Paris, France — NEW DATE
SE Summit 21
sampe-europe.org/conferences/se-summit-21-paris

June 1-3, 2021 — Paris, France
JEC World 2021
jec-world.events

June 29-July 1, 2021 — Mexico City, Mexico
UTECH Las Américas
utechlasamericas.com

July 6-7, 2021 — Southampton, U.K.
MarineAM
marineam.com

Aug. 1-6, 2021 — Belfast, Northern Ireland
International Conference on Composites Materials (ICCM 23)
iccm23.org/about-the-conference/

Aug. 10-12, 2021 — São Paulo, Brazil
Feiplar Composites and Feipur — International Fair and Congress of Composites, Polyurethane and Thermoplastic Composites
feiplar.com.br

Aug. 23-25, 2021 — Raleigh, N.C., U.S.
Techtextil North America
techtextil-north-america.us.messefrankfurt.com

Aug. 23-26, 2021 — Colorado Springs, Colo., U.S.
Space Symposium 365
spacesymposium365.org

Sept. 7-9, 2021 — Southampton, U.K.
Fiber Polymer Composites in Construction
fpcc-conference.com

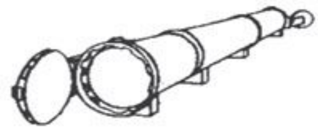
Sept. 8-10, 2021 — Detroit, Mich., U.S.
SPE ACCE 2021
speautomotive.com

Sept. 14-15, 2021 — Leicester, U.K.
SpaceAM
spaceamcon.com

Sept. 21, 2021 — Detroit, Mich., U.S.
SPE Automotive Awards Competition and Gala
speautomotive.com/innovation-awards-gala

MANUFACTURING SUPPLIERS

AUTOCLAVES
New or Remanufactured



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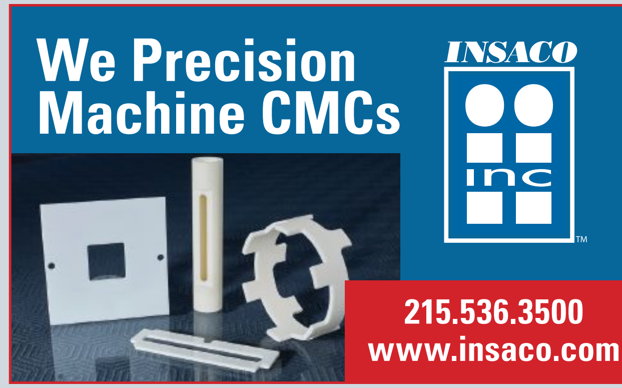
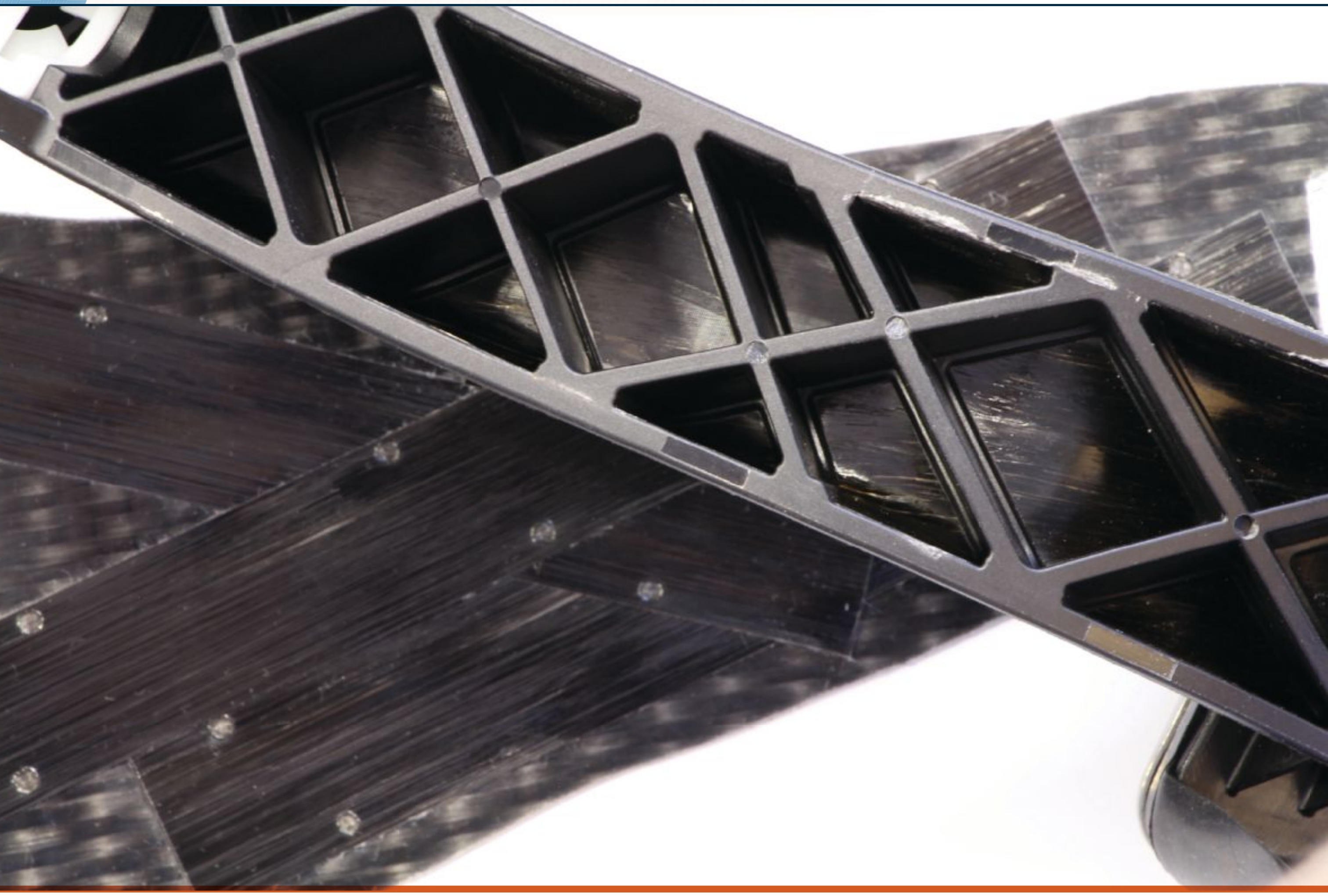


ADVERTISING INDEX



Thermoplastic composite structure replaces metals on safety-critical brake pedals

First all-composite brake pedals developed by Boge Rubber & Plastics Group are lighter, stiffer, stronger and offer improved driving haptics.

By **Peggy Malnati** / Contributing Writer

» The automotive industry converted accelerator pedals from metals to injection molded short-glass thermoplastics in the 1990s. However, brake pedals — being safety-critical components with challenging stiffness, strength and torsional loading requirements — took much longer to convert. Tier 1 automotive supplier Boge Rubber & Plastics Group (Damme, Germany) says it is the first supplier to meet demanding OEM performance and cost targets for brake pedals in thermoplastic composites. Unique design, three different materials and a bespoke production process enable the company to produce pedals that are stronger, stiffer, lower weight and lower cost.

Stronger, lighter, stiffer

Boge Rubber & Plastics Group uses three different types of composite — organosheet (bottom), UD thermoplastic tapes (laser-tacked onto organosheet, middle), and short-glass overmolding compound (top ribbed structure) — in fiberglass-reinforced PA6 or PA6/6 to achieve a very efficient, thin and light brake pedal structure that can be molded in roughly a minute.

Source | Boge Rubber & Plastics Group

Finding a niche that counts

Boge is a developer and producer of products for vibration damping and powertrain/

DESIGN RESULTS | **All thermoplastic-composite brake pedal**

- Continuous-glass/PA6 organosheet forms pedal's main structure and carries majority of loads.
- Unidirectional-glass/PA6 tapes strategically applied to organosheet to reinforce main load paths inside U-channel.
- Short-glass/PA6 overmolding compounds produce ribbing and other functional structures.

Susan Kraus / Illustration

chassis mounting as well as lightweight plastic modules and pedal boxes (including combinations of brake, clutch and accelerator pedals) for the auto industry. It has produced automotive components in continuous-fiber organosheet with short-glass overmolding compounds since 2008. It added unidirectional (UD) thermoplastic tapes to the mix in 2018. Through continuous process innovation, cycle time and costs were reduced and business increased.

"In 2015, my boss came to me and said, 'These changes you've made are nice, Daniel, but it would be good if you could find a bigger market with production volumes that really count,'" recalls Dr.-Ing. Daniel Häffelin, senior manager/head of lightweight team at the Boge Global Innovation Center. A team of Boge engineers accepted the challenge and brainstormed how to increase fiber efficiency to reduce costs and gain more business.

"Organosheet is a great product, but you have to use it in the right way, only where needed," Häffelin explains. "We'd already made our production process very lean, so we wouldn't gain much by trying to lower cycle times further. We reasoned that the best way to reduce cost was to reduce the amount of endless fiber we used by using that fiber more efficiently."

Simply making pedals smaller or thinner also wouldn't work because there are practical constraints on brake pedal size and shape, not to mention challenging performance specs owing to its safety-critical nature. What made most sense was finding ways to better control fiber orientation to optimize local properties in areas of the part that saw the highest peak loads, providing opportunities to reduce wall thickness in less critical areas.

"We sought a way to locally 'steer' fibers so we could place them just where we needed them to maintain stiffness and strength," adds Dr. Torsten Bremer, Boge Rubber & Plastics Group chief executive officer. "We knew, in principle, this was possible because we'd already considered pick-and-place machines used in sporting goods and medical, but they were too expensive. That's when we decided we needed a new process." »

Thermoplastic brake pedal

The first all-thermoplastic composite brake pedals (complete assembly shown) are in production on four vehicle platforms produced for German automakers. Developed by Boge Rubber & Plastics Group, the pedals not only meet or exceed the challenging performance specs required of metals, but they do so at roughly half the weight, while providing improved driving haptics for consumers and at performance and cost parity to aluminum.

Source | Boge Rubber & Plastics Group

"We were already working with a German OEM to find ways to make all-composite brake pedals that met their performance and cost requirements," recalls Burkhard Tiemann, Boge Plastics & Rubber Group executive vice president, product line leader – Plastics. "We said to our customer, 'We will develop a new process using UD tapes and organosheet.' They said to us, 'If you can reduce mass and cost further, we will do it.' That was our starting point. We made a big promise in 2015 that we could deliver an all-composite brake pedal that was cheaper, lighter and could be produced in high quantities. It took three years to work out the details and deliver our first products."

Fiber steering

Composite brake pedals must meet the same performance specs as pedals in incumbent steel or aluminum. That includes special failure mode requirements with loads as high as 3,000 newtons and steel-like deflection at maximum load. Given these requirements and the restricted package space available, the pedal's main shell structure, which carries the maximum loads, requires continuous fiber reinforcement. Hence, the team decided to use organosheet to form the pedal backbone. UD tapes would then be used to locally increase stiffness/strength and reinforce interior walls during peak stresses in the area of the part that would subsequently be bent into a U-channel during preforming. And in areas where functional geometry like ribs was needed, chopped-glass overmolding compound was specified. The team felt this hybrid approach would increase fiber efficiency while reducing material usage, average wall thickness and cycle time.

The team began intensive simulation work to optimize fiber locations during production. The foundation for Boge's work was based on a 2011-2014 publicly funded German research program called SoWeMa (Software, Tools, and Machine Development for a Fully Automatic and Closed Lightweight Manufacturing Chain).

"The SoWeMa research covered many of the questions we would ask a year later for our own venture," explains Häffelin. "Because design is part of Boge's core know-how, we started with the fundamentals of the SoWeMa program and built our own FE [finite-element] simulation capabilities for anisotropic layup structures."

> The current manufacturing cell can produce up to 1 million parts/year and roughly one pedal/minute.

One area of focus was combined topology optimization for the tape layup and the rib structure. "We created an iteration cycle to optimize placement of tapes and adapt the rib structure accordingly, since both are linked together over the stiffness and strength of the part," continues, K. Siebe, FEA-engineer, CRRC Innovation Center. "Since the material combination of UD tapes, organosheet and short-fiber materials is unique and their application is bound to a specific window of humidity and temperature, we built our own material cards to more accurately characterize how these materials would behave during physical testing."

Boge specified the layer structure and fiber architecture for each material based on simulation results and a given pedal design. Lanxess Deutschland GmbH (Cologne, Germany) supplies organosheet in fiber volume fractions (FVFs) of 45-50%. UD thermoplastic tapes with FVFs of 55-60% were supplied by Celanese Corp. (Irving, Texas, U.S.). Short-glass injection compounds for this application, at 40-60% fiberweight fraction

(FWF), were supplied by multiple sources. All materials are black and feature either a polyamide 6 or 6/6 (PA6, PA6/6) matrix. To meet customer specs, PA6 is the default resin for all three composite types. However, depending on humidity and temperature levels during manufacturing, as well as space constraints and pedal geometry, Boge also can use PA6/6 for the overmolding resin, since the two polymers are similar enough to bond well.

The final product

The as-molded brake pedal (measuring approximately 350 x 90 x 60 millimeters) without additional surface treatments.

Source | Boge Rubber & Plastics Group

Three-step production

Parallel to design, the team worked on a three-step production process. In the first step, a tailored-fiber blank is created by using precut and preconsolidated organosheet as a stable base on which to strategically tack strips of UD tape aligned to load paths to reinforce the part's shell structure. In the second step, the blank is moved and sequentially heated, consolidated and shaped/draped. In the third step, it is overmolded with short-glass compound to create the ribbed structure.

To achieve fast cycle times, robotic handling was a given for this system. A key process feature that the team wanted to include was the flexibility to place tapes of any length, in any orientation, and in any position on one side of the organosheet shell, and to laser tack those tapes to the shell to avoid shifting in subsequent steps.

Another decision the team made was to not preconsolidate the tailored blank immediately after layup, but just prior to draping/preforming and overmolding. The team reasoned the material would have to be reheated during draping/preforming anyway and to be cost-effective, they had to keep total cycle time close to one minute. Hence, Boge heats and consolidates the blank just before draping/preforming using a rapid temperature increase combined with high pressure to create a strong mechanical bond between tape and organosheet. Heating stops and part temperature begins to drop as the still-hot consolidated blank moves into the draping cavity before it is moved again and overmolded with ribs and other functional features in a second cavity. Strong mechanical bonds, with verified polymer chain penetration, are achieved between all three materials. No post-mold finishing is required.

To meet quality requirements for these safety-critical parts, the team also developed a fast, accurate and Industry 4.0-compliant system that uses vision, force, time, pressure and temperature sensors that check material at each step in the manufacturing process. The system then stores that data and ties it back to each pedal's unique identification number. This ensures 100% traceability of all materials, shifts and process settings involved.

Accomplishments to date

Boge's bespoke, fully automated and quality-controlled process made the step from prototype to high-volume serial production in 2018. Producing a new pedal roughly every minute, the current manufacturing cell can manufacture up to 1 million parts per year. The all-composite pedals use 33% less organosheet than earlier designs and nominal wall thickness dropped from 3 to 2 millimeters. The pedals also are 50-55% lighter, yet meet or exceed strength requirements for steel. The lighter pedals are said to improve driving haptics for consumers and the entire system is 100% recyclable at end of life. With the current process, composite pedals are at cost-parity to aluminum and slightly higher cost than steel. Other automotive as well as sporting good applications are in development.

What does the future hold as automakers shift resources to fleet electrification? "As drive-by-wire [electro-mechanical actuation systems] and powertrain electrification become more common, gas pedals could go away, but brake pedals will remain," Häffelin muses. "However, we'll likely see greater electronics integration, including sensors, in brake pedals. That will increase part complexity substantially, making composites even *more* competitive than metals."

Material use, process steps and equipment criteria for the Boge brake pedal are explained in more detail on p. 20. CW

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Wind blade fabrication

Traditional wind blade fabrication is done in two female molds that are attached by a hinge. Dry glass fiber fabrics, balsa and foam core and spar caps are laid up in each side and then infused under a vacuum bag. A shear web is placed inside the stationary mold half, followed by closure of one side of the mold/blade half onto the stationary side. Holding these two halves together is a thick line of bonding paste placed along the edge of the blade. The green bonding paste shown here is Hexion's (Columbus, Ohio, U.S.) RIM BP535, used by Aeris Energy in Caucaia, Brazil, to fabricate wind blades for domestic and foreign markets.

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