CW

CompositesWorld

Pushing to new levels: CFRP COMPONENTS IN ELECTRIC VEHICLES

NOVEMBER 2018

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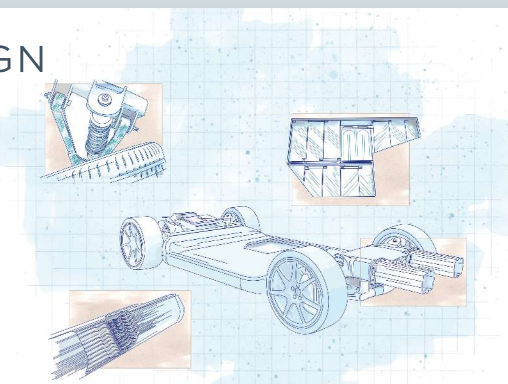
ON THE COVER

The *FW-EVX* electric vehicle platform features these CFRP wishbones, which are made using unidirectional and recycled carbon fiber (rCF) in an HP-RTM process called RACETRAK. See p. 44

Source / Williams Advanced Engineering

FOCUS ON DESIGN



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MEMBERSHIPS:

CW CompositesWorld

@CompositesWrld

PUBLISHER Ryan Delahanty
rdelahanty@gardnerweb.com

EDITOR-IN-CHIEF Jeff Sloan
jeff@compositesworld.com

SENIOR EDITOR Sara Black
sara@compositesworld.com

SENIOR EDITOR Ginger Gardiner
ggardiner@compositesworld.com

DIGITAL EDITOR Scott Francis
sfrancis@compositesworld.com

ASSISTANT EDITOR Hannah Mason
hmason@compositesworld.com

DIRECTOR, STRATEGIC INITIATIVES AND EVENTS Scott Stephenson
sstephenson@compositesworld.com

ADVERTISING PRODUCTION MANAGER Becky Taggert
btaggert@gardnerweb.com

GRAPHIC DESIGNER Susan Kraus
skraus@gardnerweb.com

MARKETING MANAGER Chris Saulnier
csaulnier@gardnerweb.com

CW CONTRIBUTING WRITERS

Dale Brosius dale@compositesworld.com
Donna Dawson donna@compositesworld.com
Michael LeGault mlegault@compositesworld.com
Peggy Malnati peggy@compositesworld.com
Karen Mason kmason@compositesworld.com

CW SALES GROUP

MIDWESTERN US & INTERNATIONAL Dale Jackman / REGIONAL MANAGER
djackman@gardnerweb.com

EASTERN US SALES OFFICE Barbara Businger / REGIONAL MANAGER
barb@compositesworld.com

MOUNTAIN, SOUTHWEST & WESTERN US SALES OFFICE Michael Schwartz / REGIONAL MANAGER
mschwartz@gardnerweb.com

EUROPEAN SALES OFFICE Eddie Kania / EUROPEAN SALES MGR.
ekania@btopenworld.com

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HEADQUARTERS
6915 Valley Ave., Cincinnati, OH 45244-3029
Phone 513-527-8800 Fax 513-527-8801
gardnerweb.com
subscribe@compositesworld.com

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» Many years ago, when I was in college and studying journalism, one of the first classes I took was on basic journalistic reporting. This is the task of collecting information about an event, person or place and then presenting that information in a clear, succinct, easy-to-read format for the audience. In 1987, when I took this class, the format was primarily print media, either newspaper or magazine — the concepts of digital media, social media and the Internet did not yet exist. Our reporting class focused on telling stories about the types of events we were likely to encounter as journalists: Public meetings, political speeches, crime scenes, etc.

There is no shortage of innovation for us to document.

One of my professors, eager to demonstrate the difficulty of using written language to clearly convey information, had us perform a simple exercise. We were given 10 minutes to write step-by-step instructions on how to tie a lace on a shoe. We were then instructed to trade our instructions with another student in the class, untie our own shoes and then follow the instructions we were given — to the letter — to re-tie our shoes. The question was simple: Could we write instructions well enough that a person could use them to tie shoe laces. The short answer is "no," although some of us came pretty close. (If you doubt the difficulty of this assignment, I suggest you try it with your own friends and family, but don't blame me for whatever arguments ensue).

This shoe lace-tying exercise has been brought to my mind often over the last several years as I edit the stories we publish in *CompositesWorld*. I say this not to cast aspersions on *CW*'s writers and contributors — they are as well-versed in shoe-tying as they are in composites design, engineering and fabrication. I say this because *CW* operates in a composites industry that has proven admirably adept at generating complex, fast-evolving materials and processes that often are difficult to explain with the written word.

Take, for example, senior editor Ginger Gardiner's story this month on filament winding (p. 24). As she was doing research for this story, Ginger called me one morning about a new technology she'd just unearthed. It was, she said, developed by Daimler and dubbed FibreTEC3D. Here's what Ginger said, as I remember it: "It's not really filament winding, but it uses filament winding concepts. There's no mandrel and no core, but it does use a towpreg-like material, which is wound around a series of vertical aluminum or steel pins by a multi-axis robot. It's room-temperature cured, so no autoclave or oven."

Got that?

Neither did I, until I backed Ginger up several sentences and sorted out what she was telling me. Fortunately, you can see, and read about, this system for yourself on p. 24, and you can understand immediately how inspired and creative it is.

Technology like what Ginger found is par for the course, and finding the words to explain it is a big part of what we do. For almost every story we publish, we look for some basic raw data covering a range of topics: Application requirements, design challenges, resin type, fiber type, fiber format, tooling type, manufacturing process, manufacturing parameters, finishing process, inspection protocol and assembly requirements. Then, we take what we get and put it all together to tell a story. It's during the editing process that we work hardest to verify we are telling a story that makes sense and has value and utility for you — that we are, to complete the metaphor, helping you understand how that shoe is tied.

Rare, of course, is the story that sheds full, unbridled light on an application or process, but we like to think that we come close more often than not. Fortunately, we get a lot of practice, for there is no shortage of innovation and change in composites manufacturing for us to document and chronicle. And such a dynamic environment is not only great fun to be a part of, but it also drives the evolution of composites.

JEFF SLOAN — Editor-In-Chief

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Global offshore wind — the new frontier for composites

» Land-based wind power generation has been around for several decades, providing a strong and growing market for the composites industry. Turbine blades are the major application segment in the wind power market, with glass fiber being the largest material segment. In this context, it is worthwhile to look at the globally growing offshore wind market, as this sector offers even more opportunities for composites than onshore wind.

Let's first look at some basic market facts. With land-based wind power generation costs at an all-time low, what makes the — by comparison — more expensive offshore wind so attractive? The answer varies by location. Europe's established wind power markets such as Scandinavia, Germany, Spain and the UK have already used most of the best onshore wind resource areas. Therefore, offshore wind plays a major role in meeting the EU renewable energy target of 32% by 2030.

In Asia, Japan is leading the way with floating offshore wind demonstration projects, while Taiwan has awarded a total of 5.5 GW of offshore wind capacity to be developed by 2025, using existing bottom-fixed foundation technology. South Korea plans 500 MW of offshore wind for the near term and a total capacity of 12 GW longer term. China now has 2.7 GW of installed offshore wind capacity, ranking it third globally after the UK and Germany. A large portion of China's population, and its economic activity, are located along the coast, and this means that offshore wind is a renewable energy source close to major load centers.

The same applies to the United States and is one major driver behind the more than 10-year push for offshore wind, especially by Northeastern states. Various studies in 2010, such as by AWS Truepower, show that offshore wind along the US East Coast has a strong diurnal coincidence with load compared to onshore wind as generation peaks in the late afternoon and early evening. In addition, the coincidence of offshore wind and load is better defined in the summer months when loads peak. This also explains the interest by US grid operators in offshore wind. In December 2016, the first US offshore wind project was commissioned when the 30-MW Block Island offshore wind farm, consisting of five Alstom Haliade 150 6-MW turbines, started sending power into the grid.

Beyond Block Island, there is a project pipeline of more than 14 GW planned along the US East Coast, driven by Renewable Portfolio Standards (RPS) of the various states and, in some cases, offshore wind-specific requests for proposals (RFPs) in

■ **Floating offshore wind presents new opportunities**

Floating offshore wind turbines, like this Hitachi 2-MW downwind turbine mounted on a floating spar in Kyushu, Japan, present new opportunities for composite suppliers.

Source | Annette Bossler

Massachusetts, Connecticut, Rhode Island and New York. Massachusetts recently awarded a Power Purchase Agreement (PPA) for 800 MW of offshore wind to Vineyard Wind at a PPA price starting at US$84.23/MWh including RECs (renewable energy credits). New York and Massachusetts have asked the US government to identify additional offshore wind lease areas in American federal waters and make them available for lease auctions. Unsolicited lease requests have also been filed for areas off California and Hawaii. Even though the rest of the world is now catching up to Europe's offshore wind lead, European companies are key drivers behind the international offshore wind growth, from a funding as well as a supply chain perspective. In the US, 50% of the offshore wind areas are leased by European developers or their US subsidiaries; the situation is similar in Taiwan.

The offshore wind project lineup in Europe, and beyond, opens up new business opportunities for composites companies. Obviously, turbine blades are the biggest application segment for composites. For example, the blade for GE's Haliade X 12-MW turbine is anticipated to be 107m/351 ft long. Assuming that a typical offshore wind farm comprises 50-100 turbines, then we are looking at 150-300 blades per farm. The existing US offshore wind project pipeline alone requires the equivalent of 4,200 blades or more if turbines of 10 MW or larger are used for all projects.

In addition to turbine blades, the offshore wind sector has demand for other components, such as fiber and synthetic mooring systems as well as support vessels and boats. The 14-GW-plus offshore wind project pipeline in the US creates a sizable demand for crew transfer vessels (CTVs) and other support ships, as European vessels cannot be deployed in the US without complicated waivers. European engineering and design firms, as well as manufacturers, have started to look for US partners to build their designs, or are willing to develop a US version of proven European offshore wind support vessel designs. US boatbuilders, including manufacturers of high-end yachts, should consider this market as a real opportunity.

The ultimate frontier for offshore wind is opened up by floating offshore wind turbines. Northern New England, the entire US West Coast, large parts of Hawaii, Japan, the Mediterranean, areas off Portugal, Spain, Scotland and Norway, to name a few, require offshore wind turbines to be mounted on floating substructures because water depths exceed 80-100m.

More projects, more composite components

With more and more offshore wind projects around the world, the demand grows for other related components such as those for crew transfer vessels, like this one used to service the Fukushima Forward floating offshore wind project in Japan.

Source | Annette Bossler

Bottom-fixed foundations are simply not feasible in these areas. Floating wind has moved beyond niche status and initial pilot and demonstration projects in Norway, Portugal, Scotland and Japan.

Floating offshore wind substructures are defined by their type of stabilization. A buoyancy-stabilized floating wind turbine platform consists of a barge base with catenary mooring lines. Examples of this include Principle Power's semisubmersible substructure, Ideol's floater and Japanese semisubmersibles from Mitsui and Mitsubishi, deployed off the Fukushima coast. Statoil's Hywind floating wind turbine uses a ballast-stabilized spar buoy with catenary mooring and drag-embedded anchors. The third type is the tension leg platform (TLP), well known from the oil and gas industry. The platform is stabilized by the forces from tensioned mooring lines and buoyancy in the platform.

What all three technologies have in common is the need for mooring systems: the other major opportunity for composites and advanced material suppliers. The most common approach is to use large chains for mooring these types of substructures. However, there is currently only a handful of companies worldwide that can manufacture such large chains. Floating substructure technology providers have therefore identified the availability of mooring chains as a major supply chain bottleneck. As a result, some of the next demonstrator units will experiment with synthetic fiber mooring lines, in addition to chains, to compare and verify the impact from tension, corrosion, snap loads and wear.

Developers and suppliers of synthetic fiber lines, and comparable technologies, have a long-term market opportunity if they engage with floating wind technology developers now. While it will be another 5-7 years until we see a large-scale floating wind farm of 50-plus turbines, the technology is likely to go mainstream. Floating substructures offer better economies of scale, as only one substructure design is required for a wind farm project; wind farms that use bottom-fixed foundations require multiple foundation designs to accommodate the seafloor variations within a project zone. These variations are handled by adjusting the mooring line lengths of floating wind turbines. CW

ABOUT THE AUTHOR

Annette Bossler is owner and managing director of Main(e) International Consulting LLC, a firm specializing in international marketing and business development, based in Maine, US. She is a market expert on deepwater offshore wind and the author of numerous market reports on floating offshore wind substructures in Europe, the US and Japan.

Carbon fiber pickup box: A GM redux?

The 18th Society of Plastics Engineers Automotive Composites Conference and Exhibition (SPE ACCE) was held in Novi, MI, US, in early September. This year's event was a testament to the continued high level of interest in composites for automotive applications, drawing a record 1,100 registered attendees and nearly 100 technical papers over the three days. More than 75 of the industry's leading companies had exhibits, and the show floor was populated with many innovative vehicle applications.

Among these included advances in structural thermoplastic overmolding, combining continuous tapes or fabric prepregs with short fiber-reinforced compounds to provide edge details and complex features. Also on display was a hybrid thermoplastic (long glass inner panel with low-CTE unreinforced outer panel) tailgate for the 2019 Jeep *Cherokee*, carbon fiber SMC wheels for urban mobility vehicles and a phenolic-based sheet molding compound (SMC) for a fire-resistant battery enclosure demonstrator. Ford and Warwick Manufacturing Group in the UK showed a front suspension component combining steel, carbon fiber/epoxy prepreg and carbon fiber/vinyl ester SMC molded in a single process.

> The *CarbonPro* box is GM's first foray into using carbon fiber outside high-performance vehicles.

One innovation that attracted considerable attention was the *CarbonPro* composite pickup box, slated for production starting in mid-2019 for the GMC 1500 Sierra *Denali* full-size truck. The display was augmented by a morning keynote speech from Mark Voss, engineering group manager of body structures, advanced composites and pickup boxes, at General Motors. I have known Mark since 2001, when he was new to composites at GM and I was serving as the project manager for the Tier 1 supplier of the 2004 Corvette *Le Mans* Commemorative Edition carbon fiber hood, GM's first Class A carbon fiber panel on a production vehicle. This component led to deployment of carbon fiber on subsequent generations of the Corvette platform. Mark and I co-authored a paper for the 2004 SPE ACCE on the design and manufacturing process for the hood.

Initially unveiled earlier in 2018, the *CarbonPro* box is GM's first foray into using carbon fiber outside Corvette or high-performance versions of the Cadillac line. Up to this point, all previous carbon fiber components have been made from thermoset epoxy prepregs. The truck box changes that paradigm by being thermoplastic-intensive, employing a 35% chopped carbon fiber-filled, UV-resistant polyamide 6 resin for the box floor, sides and end panels. GM has worked closely with material supplier Teijin since 2011 to develop Teijin's *Sereebo* manufacturing technology used to make the structure, resulting in a box that is 28 kg lighter than the equivalent all-steel version. GM claims that testing shows it to be more durable than steel or aluminum, or any fiberglass composite box on the market. Molding of the thermoplastic composite mat is principally via compression, similar to SMC. The box is truly multi-material; in addition to the thermoplastic box interior, other supporting components have been produced from recycled in-plant offal (thermoplastic), thermoset SMC and steel. The outer panels of the box remain in steel and are painted the body color. Molding of the box components and assembly will occur at Teijin subsidiary Continental Structural Plastics' facility in Huntington, IN, US, then shipped to GM's nearby Fort Wayne, IN, assembly plant.

Wait. Why does this story have a familiar ring? Didn't GM release a truck with a composite pickup box years ago? Indeed, it did. Called the *Pro-Tec* box and molded in the same Huntington factory as the new *CarbonPro* version, it was offered as a customer option on certain versions of the Chevrolet *Silverado* and GMC *Sierra* pickups starting in 2001. It was one of the largest parts produced using chopped fiberglass preforms and *polyurethane* resin, employing the structural reaction injection molding (SRIM) process. I visited the Huntington factory and wrote a feature story about the box in the April 2002 edition of *Composites Technology*. In production for only two years, only an estimated 10,000 boxes were produced, less than 10% of the anticipated volume. While a technical success, the box was considered a commercial failure, attributed partly to it only being available in a short-bed version, and partly to a lack of promotion by GM to incentivize dealers to sell the $850 upgrade instead of a steel box with a thermoformed bedliner.

Is *CarbonPro* destined for the same fate? I hope not, and so should the composites industry. Slated for initial production of 15,000 per year and aimed at a specific high-end target market, GM is making sure to walk before it runs. Even at relatively low volumes, the application will consume sizable quantities of carbon fiber. Improvements in materials and manufacturing costs could see growth of this and other applications. 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 US-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.

Composites Index expands into rarely seen territory

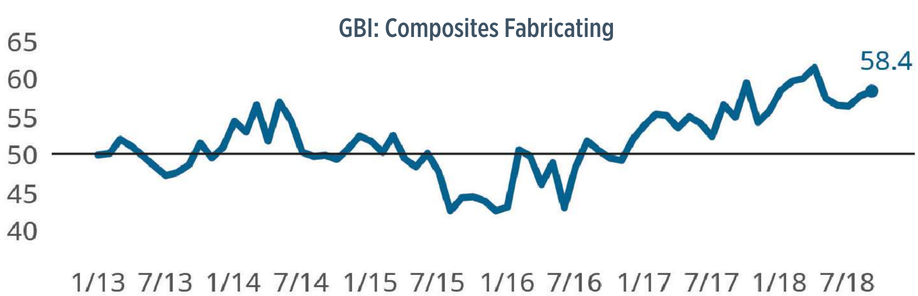
September 2018 — 58.4

» The GBI: Composites Fabricating Index extended its latest expansion run into rarely reached territory with a reading of 58.4 in September. The latest reading marks the third time in the Index's history during which the index has been on an upward trajectory that took it above a reading of 57. The latest reading is 6.2% higher than it was during the same month one year ago. Gardner Intelligence's review of the underlying data for the month indicates that the Index was pulled higher by supplier deliveries, backlog, production and new orders. The Index — calculated as an average — was pulled lower by employment and exports. Among all components, backlogs expanded faster than all other components except for supplier deliveries.

After new orders expansion peaked in March 2018, supplier deliveries and production were regularly the two fastest-expanding components of the Composites Index. At the same time, new orders expansion fell, indicating only that the monthly rate of growth of new orders was slowing. Since July's new order reading, however, new orders growth has rebounded. This has occurred despite the fact that exports have contracted since June 2018. The net effect appears to suggest that while export demand has slowed in the composites space during the second quarter of 2018 and early in the third, total demand for composites manufacturing is doing very well. New orders since mid-2015 have continued to cyclically improve. CW

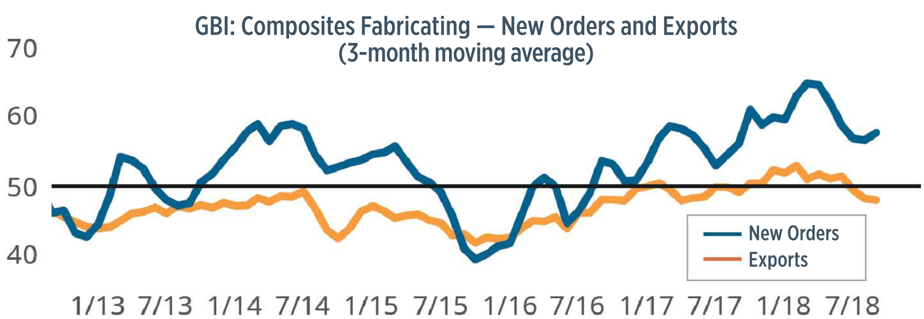
ABOUT THE AUTHOR

Michael Guckes is the chief economist for Gardner Intelligence, a division of Gardner Business Media (Cincinnati, OH US). He has performed economic analysis, modeling and forecasting work for nearly 20 years in a wide range of industries. Guckes received his BA in political science and economics from Kenyon College and his MBA from Ohio State University. **mguckes@gardnerweb.com**



Industry growth continues into second month

The September Composites Fabricating reading extends the quickening growth rate for the industry for a second month. Rarely in the Composites Index's history has it pushed above a reading of 57.0.



New orders improve despite export weakness

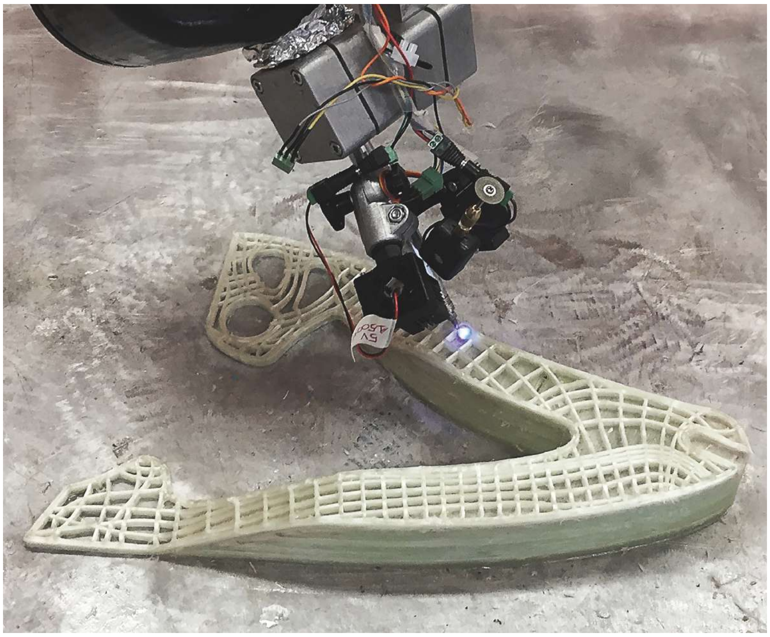
New orders readings have been improving along their long-run cyclical path since mid-2015. The latest readings indicate new order growth despite weakness in exports.

Strides in continuous fiber manufacturing, new insights into the size of the global aerospace industry, new ways to use pultrusion in the rail sector and more.

Continuous fiber manufacturing blurs the line between 3D printing and AFP

Continuous fiber manufacturing (CFM) is the 3D printing/continuous fiber deposition process patented by moi composites (Milan, Italy). The company was established in February 2018 by materials engineer and professor Marinella Levi, design engineer Gabriele Natale and architect Michele Tonizzo. It was spun off from the +LAB, a collaborative 3D printing hub that Levi founded at the Politecnico di Milano.

CFM was patented in 2015 and demonstrated in 2016 through the Atropos project, which involved printing a continuous glass fiber/epoxy propeller blade using a Kuka industrial robot. The blade featured an internal truss and an exterior shell, demonstrating both a multiaxial laminate (e.g., 0°/+45°/-45°) and fiber placement along a nonlinear axis. Moi composites has developed a second-generation system using a Comau robot with a 1.0-by-0.5-by-0.8m height build envelope. "We have also used larger robots with rotary tables and larger build volumes, demonstrating that our technology is easily scalable," says co-founder Tonizzo. "We currently can print with UV-cure in epoxy, acrylic and vinyl ester," he says, "but we are not tied to UV curing." Glass fibers up to 2400 tex and basalt fibers have reportedly printed well and moi composites is now working with carbon fiber, though not with UV cure resins. The company can also print with electrically conductive fibers and is producing parts for biomedical, marine, oil and gas and aerospace applications, mainly using glass fiber. It is also developing a third-generation, all-in-one print head with a system to apply pressure to the fibers, sensors, cutting mechanisms and a milling tool. Tonizzo says this will close the gap between 3D printing and automated fiber placement (AFP). "3D printing does not achieve the performance of AFP, but CFM offers more flexibility. We can already print with fibers 0.25-mm thick and have the ability to create curves and place continuous fibers in the ideal position," he adds.



Continuous glass fiber and UV-cured vinyl ester resin are deposited along nonlinear curves in 3D space to form the back fork of a BMX bike frame using the CFM process. Source | moi composites

Hybrid materials processing has been explored by moi composites; one result of this exploration is the Superior-brand lightweight, low-deflection lower limb prosthesis. The prosthesis is made with a printed continuous glass fiber internal core that is then sheathed with a hand-laid, vacuum bag-only cured carbon fiber/epoxy skin. "The whole design reduces deflection and increases customization while significantly cutting cost and production time," says Tonizzo.

Part of this optimization is produced through the digital design and workflow, which uses Autodesk software with moi composites' algorithms for stress and path optimization. This is what produces the optimized fiber path for the structural loads and fiber deposition process.

CFM is open to a variety of materials and design innovations explored by +LAB, including 3D-printed infill patterns with a tunable elastic response, and printing with novel matrices like geopolymers, which behave like concrete. As moi composites continues advancing its CFM technology, will it sell print heads and machines? "Yes, but in the future," says Tonizzo. "For now, we are producing parts and bringing the technology to the client's facility, using our know-how, print head and software to realize part solutions on demand. We are also seeking investors to further scale CFM machines and processes for commercial market opportunities."

Read more in the online blog | short.compositesworld.com/cfm_moi.

AEROSPACE

A new look at the aerospace market

A comprehensive, bottoms-up study was recently undertaken, as reported in *Aviation Week & Space Technology* magazine (*AW&ST*, Sept. 3-16, 2018), to provide the aerospace industry a clearer look at its overall size. The Teal Group (Fairfax, VA, US) and AeroDynamic Advisory (Ann Arbor, MI, US) collaborated on the study, which defined "aerospace" as all activities pertaining to the development, production, maintenance and support of aircraft and spacecraft. AeroDynamic Advisory's Kevin Michaels, who has contributed to *CW* in the past, reports in the *AW&ST* column that the global aerospace market is currently worth $838 billion, a larger figure than most previous estimates.

Michaels breaks that figure down by activity and country. Aircraft manufacturing (including Tier 1s and sub-tiers) makes up 54% of that total. Maintenance, repair and overhaul (MRO) makes up a surprising 27% of aerospace activity. Satellites and space (7%) and UAVs (5%) make up the rest (the remaining 7% was tagged as "other"). Not surprisingly, the US tops the country list, comprising 49% of the total market activity ($408 billion), followed by France ($69 billion), and China ($61 billion). According to Michaels, most of China's aerospace activity is focused on aircraft and spacecraft for its own consumption: "The lack of aerospace exports differentiates China from other top players, but it will likely surpass France for second place in the next decade." Michaels concludes that strong air travel growth means that there's room for growth over the next few years, and "there should be plenty of room at the table for everyone."

BIZ BRIEF

The University of Exeter (UK) and **Victrex** (Thornton Cleveleys, UK) have announced a strategic partnership to introduce next-generation polyaryletherketone (PAEK) polymers and composites while improving the performance of the underlying additive manufacturing (AM) processes. The collaboration is driven by Victrex R&D and the University's Center for Additive Layer Manufacturing (CALM). As part of the partnership, Victrex recently announced newly developed advanced PAEK products designed for AM: A high-strength material for laser sintering, a filament with better Z-strength than existing PAEK materials and better printability for filament fusion.

MASS TRANSIT

New study examines benefits of composites in the rail sector

Applications for pultruded composites in the rail sector are set to grow, according to a new report from the European Pultrusion Technology Assn. (EPTA, Frankfurt, Germany). Lightweight, durable composite materials offer energy-efficient solutions with lower environmental impact and reduced life cycle costs in rolling stock and rail infrastructure, according to "Opportunities for Pultruded Composites in the Rail Market."

Growing populations, accelerating urbanization, resource scarcity and other drivers are spurring investment in the rolling stock and infrastructure that will be required to create more sustainable and energy-efficient railway systems, says the report. Composites can offer cost-effective alternatives to traditional construction materials like metal or concrete, without compromising safety, and offer benefits including faster train acceleration, increased payload, lower maintenance and customizable solutions.

"As international policies continue to push to mitigate CO_2 emissions from global transport activity, demand for lightweight materials such as composites will increase," explains Dr. Elmar Witten, secretary of EPTA. "Increased demand for lightweight, high-performance, fire-retardant materials for train interiors will favor pultruded components, and proven performance in interior applications over time will strengthen the case for adoption of composites in structural applications. The rail sector's growing focus on life cycle costs is a further factor improving the competitive position of composites against other materials."

Pultruded profiles can find applications in external and internal parts, enabling multi-functional design. For example, full-span roof panels are possible, from window to window, with integrated air conditioning ducts and heating channels. Partitions, luggage shelves and storage units, tables, window trims, catering and toilet modules, and door components are also applications for pultruded profiles. Unlike metals, glass fiber composites do not need to be electrically earthed, making them ideal for cable trays, third rail covers, rail joints and trackside cabinets, and ballast retention systems. Further infrastructure applications include railroad ties and embankment shoring systems, tunnel lining panels, access platforms, and fencing and barriers. The full briefing can be downloaded from the EPTA Web site.

AEROSPACE

Luminati Aerospace uses vortex formation in quest for perpetual stratospheric flight


Source | Luminati Aerospace

Luminati Aerospace (Calverton, NY, US) announced in August that it has conducted an in-flight experiment that suggests that the key to perpetual stratospheric solar flight may be automated vortex-seeking formation flight.

In a vortex formation, vortices produced by the lead aircraft generate lift for trailing aircraft flying in formation, thereby conserving energy in the trailing planes. By rotating the lead aircraft, the entire formation can achieve an overall reduction in the amount of energy used. This is important because in craft powered by solar energy, nighttime operation of the aircraft is purely battery-powered. Efficient use of battery power, therefore, is paramount.

Luminati says that data generated by an experiment with two solar-electric aircraft and multiple data logging devices closely matched the results of high-fidelity, autopilot hardware-in-the-loop, computer simulations.

Luminati claims its flights and simulations indicate four aircraft in a diamond formation can fly perpetually at up to 50° latitude. Ultimately, the company hopes to use perpetual flight to provide Internet access to the 4 billion people in the world who are currently without access.

Luminati's *Substrata* solar-electric aircraft is made from Hexcel (Stamford, CT, US) yarns that were spread using proprietary spreading technology and then processed into multiaxial nonwoven fabric on highly customized Liba Max 5 and 3 knitting machines. The company next plans to build larger aircraft with the ability to carry heavy commercial communications and ISR (intelligence, surveillance and reconnaissance) payloads.

AMRC to add ultrasonic-assisted machine tool


Source | DMG MORI

The world's largest ultrasonic-assisted machine tool is coming to the University of Sheffield Advanced Manufacturing Research Centre (AMRC, Sheffield, UK). The £1.8m DMU 340 G linear machine tool arrives at the AMRC at the end of the year and will be the first of its size to be fitted with an ultrasonic-capable spindle for use in 5-axis machining applications.

The specification for the machine — which has a 59m^2 footprint — has been tailored and developed by DMG MORI (Bielefeld, Germany) with the input of Dr. Kevin Kerrigan, the lead for the Composites Machining Group at the AMRC Composites Centre.

The DMU 340 G reportedly is capable of providing significant improvements in composites machining, ranging from high-end luxury vehicle monocells to next-generation aero-engine fan blades. It is also capable of titanium drilling and finishing operations, and working with advanced materials such as glass fiber-reinforced aluminum — a glass fiber in a resin laminate interspersed with sheets of aluminum and an array of high-temperature composite materials.


Source | DMG MORI

Other features of the machine are said to include linear motors for high accuracy and rapid motion, dust extraction technology, high pressure cutting fluid delivery systems, on-machine inspection technology, and industry 4.0 capabilities including wireless in-process monitoring and control technologies, enhanced connectivity and plug-in technologies to interface with the AMRC's data analytics suite.

According to AMRC, the advantage of the machine's ultrasonic capabilities is that the high-frequency movements — 40,000 micro-movements per second — bring a higher degree of control of chip formation and heat within the system. The result, claims the AMRC, is less damage, less waste and a better finish, making the technology well-suited to machining hard, abrasive, brittle material like carbon fiber composites, alloys and ceramic matrix composites (CMCs).

According to Kerrigan, "The ultrasonic-assisted machining process is basically the same as a standard rotatory cutting tool operation, but with an added highly tuneable, micro-scale, axial motion of the cutting tool, providing a secondary motion during cutting. The additional movement has the ability to control the amount of energy supplied into the cutting interface, affecting the amount of thermal energy and fracture energy associated with the process."

The machine is digital-ready, featuring an intelligent, customizable controller that allows the machine to integrate process monitoring techniques, providing data that can measure performance and improve tool life. The DMU 340 G will be installed in late December.

BIZ BRIEF

AMSilk (Planegg, Germany), the world's first industrial supplier of synthetic silk biopolymers, recently announced it has entered into a joint cooperation agreement with **Airbus** (Toulouse, France) to develop a new composite material for use in the aerospace industry.

Airbus, which has been one of the aerospace industry's leaders in experimenting with carbon fiber composite materials, intends to explore how AMSilk's Biosteel fiber might allow the company to think differently and more creatively about how commercial aircraft are designed and manufactured.

The companies plan to create a new composite material using AMSilk's Biosteel fiber technology, which is made from a biopolymer based on natural spider silk and enables lightweight construction with multiple shock resistance and flexibility. AMSilk and Airbus aim to launch a prototype material in 2019.

CW / MONTH IN REVIEW

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New research project aims to boost electric vehicle performance
Research will develop cost-effective, scalable carbon fiber composite solutions, with goal of boosting the performance of electric vehicles.
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Fraunhofer opens new project center for lightweight construction
The new center in Poland aims to promote the development and production of hybrid lightweight components.
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A highly manufacturable, high-performance hang glider

A small Swiss company has developed a fast and easily deployed manufacturing method for producing a competition-worthy rigid hang glider.

By Sara Black / Senior Editor

Two generations of all-composite hang gliders

The progenitor of the *xxtherm2*, the *xxtherm1*, is shown here, at a launch site in the Swiss Alps. Both it and the *xxtherm2*, under development, are all-composite rigid wing hang gliders that fall under Class 2, Subclass O-2 rules for competition hang gliders. Source | Wehren Emcom *xxtherm2*

» *"We returned ... with the conviction that sailing flight was not the exclusive prerogative of birds." — Otto Lilienthal, 1874.*

Those words, written by a hang gliding pioneer, speak of a rich history of design development, one that continues today to attract enthusiasts drawn to soaring like a bird — without the noise of an engine. Switzerland is particularly well known for offering ideal hang gliding conditions — that is, tall mountains with steep slopes that serve as launch sites for pilots strapped into their gliders, as Helmut Wehren can attest. Wehren heads up a project group, dubbed "Wehren Emcom *xxtherm2*," aimed at manufacturing the high-performance rigid hang glider of the same name in Jegenstorf, Switzerland: "The project was initially just for fun, among a group of friends." He notes, "But we realized our initial ideas and first aircraft didn't consider manufacturability, so six years ago we started on a second aircraft design, the *xxtherm2*."

The Fédération Aéronautique Internationale (FAI, Lausanne, Switzerland) defines three classes of competition hang gliders: flexible wing hang gliders, where the pilot is suspended, typically in a sling or bag, and controls a delta-shaped wing with simple weight shifts; rigid wing hang gliders that require spoilers and ailerons for flight control; and Class 2, Subclass O-2 rigid wing hang gliders with flight controls and a fairing or small cockpit. Pilots in all three types have set impressive soaring and distance records over the years. The all-carbon composite *xxtherm2*, intended for such long-distance competitions, falls into the third category.

Building a better hang glider

Says Wehren: "In 2006 we had only the intention to build a foot-launchable glider for our own flying, without any plan to produce it. The *xxtherm1* was designed the classic way: first some crazy ideas, then more detailed concepts, studies and design calculations. And at the end, we asked the most important question: *How is this supposed to be manufactured?*"

In 2012, the group started again with a clean sheet, using design tools that included a lot of paper and pencil, in addition to ViaCAD software by punch!CAD (Cedar Rapids, IA, US) for 2D and 3D modeling and drafting. Aerodynamic analysis and design of airfoils and wings operating at low Reynolds number was carried out using open-source web software XFLR5. Also important were spreadsheets used for calculation of structures, loads, composite characteristics, weight and balance, bill of materials, etc.

Clearly, composites were the only material option for the small craft. They would deliver the lightest possible weight, which would enable foot launching while delivering tailorable flight characteristics and very high glide (lift:drag) ratio. The *xxtherm2's* glide ratio is greater than 35, thanks to wing refinements and the use of a laminar airfoil, compared to the original *xxtherm1* iteration.

The design also had to balance the demands of aerodynamics with portability, given that one must be able to disassemble and pack a hang glider in a container for car transport to competitions. The group wanted the aircraft parts to fit within a 4.8m/16-ft-long container, which could be placed on a small trailer and weigh, together with the container, less than 75 kg.

The wings, each 4.8m long, are built in three parts, to enable breakdown and transport, yet deliver performance while facilitating foot-launch. Wehren points out that an aircraft's planform should be designed with the center of gravity and the aerodynamic center of the aircraft in the same location: "In a light, foot-launch aircraft like the *xxtherm2*, the main wing spar would cross the fuselage at the place where the pilot sits. So, I moved the wing forward in front of the pilot. And to compensate, the outer wings are swept back to move the aerodynamic center back to the pilot. This way, the aircraft is balanced when the pilot is lifting it and also balanced in flight, with no aerodynamic trim control needed during foot launch."

To determine where the wing segments detach/assemble, Wehren explains that it depended on the bending moment in the spar: "The greatest bending moment in a spar is in the center of the wingspan. By designing the outer wings' detach point more than 2m away from the fuselage, the bending moment is reduced to roughly 40% of the maximum, making the coupling of the wings much easier and lighter in weight." He adds that the spar of the inner wing has a pocket at the end, into which the stub spar of the outer wing is inserted. A spring-loaded bolt secures the outer wing, while the inner main wing is fixed on the fuselage with bolts in bushings.

The *xxtherm2* craft's wings, tail and flaps are made with carbon fiber, a 160-g/m^2 (4.7-oz/yd^2) spread carbon twill (Style 67442), over Nomex honeycomb core, Type CS 3.2-29, both from the supplier for all the project's materials: distributor Swiss-Composite (Fraubrunnen, Switzerland). Wehren notes that the honeycomb sandwich had to be overdesigned, beyond the stiffness needed for air loads: "There exist some challenges for the aircraft panels caused by spectators and other curious people, who look with the fingers

Breaking down for easy transport

The glider is broken down for transport in a relatively small trailer, shown here hitched to a tow vehicle. Source | Wehren Emcom *xxtherm2*

instead of the eyes. This leads to some higher strength demand for sandwich panels, in the realm of 5 kg per thumb," he quips.

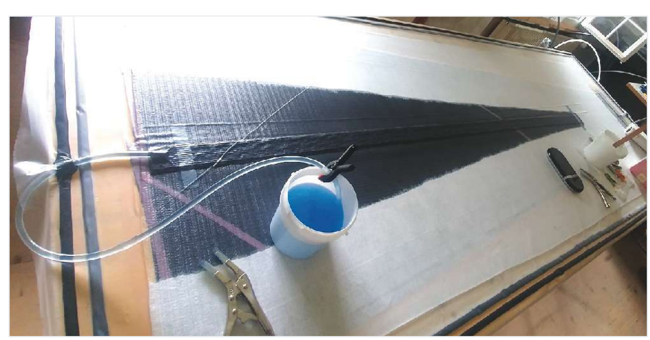
The craft's cockpit was designed as a hybrid shell of carbon fiber and ultra high molecular weight polyethylene (UHMWPE) (using Dyneema UHMWPE fiber from DSM Dyneema, Geleen, The Netherlands), with a stiff carbon frame and thermoformed side skins, cored with a polyvinyl chloride (PVC) foam (Airex C 70.75, from Airex AG, Sins, Switzerland).

The tail is a conical monolithic carbon fiber tube, constructed using the same materials used for the wings and flaps, and with internal composite stiffeners and frames and protective outer ply of 105 g/m^2 glass fiber twill in a resin infusion process.

A focus on manufacturability

To fabricate the *xxtherm2's* parts, Wehren, his son Hannes and the rest of the group developed a low-cost, efficient manufacturing process technology they call BFM, for bifunctional flexible molds.

All parts of the airframe are produced with this technology, via resin infusion, using Hexion (Columbus, OH, US) L-285 epoxy resin. Instead of typical solid female molds or male mandrels, the process uses thin composite laminate sheets that function in a dual capacity: Flexible molds that become part of the component. Says Wehren, "It »



Using bifunctional flexible mold technology

The prototype *xxtherm2's* fuselage tube being infused on a flat table, without a typical mold, using the process technology called bifunctional flexible molds (BFM). Once cured, the panel will become the mold supporting additional composite plies needed to complete the laminate. Source | Wehren Emcom *xxtherm2*

Layup and curing of fuselage tube

Once all layers are layed up, the fuselage tube is simply rolled to its final configuration, with edges joined wet-on-wet, and cured.

Source | Wehren Emcom *xxtherm2*

BFM process for wings and flaps

BFM is also used for wings and flaps. In this example, a glass fiber ply acts as the flexible mold, with additional carbon plies added. BFM allows the wing skins to be produced as seamless shells from trailing edge to trailing edge, without a splice at the airfoil nose. The trailing edges are joined, wet in wet, and cocured. Shown are the templates and forms used to create the proper part shape. Source | Wehren Emcom *xxtherm2*

can be described as a construction equipment being itself part of an assembly." The composite laminates or sheets can be carbon, glass or aramid, in prepreg form or dry reinforcements.

The process takes advantage of the specific in-plane stiffness of a bent fiber-reinforced composite sheet. It can produce components in solid laminate or cored sandwich form. The end result can be anything from simple panels, straight or tapered tubes and cylinders to aircraft wings, ailerons, flaps, rudders and fuselage tubes. The process is capable of much beyond aerospace, says Wehren. Automotive bodywork or coachwork, railway coachwork, boat decks, masts, rudders, poles, beams, furniture, trays and the inner reinforcing structures of any component can be fabricated. Parts can be built in negative (female) or positive (male) form.

Wehren describes how it works. A thin carbon sheet forms the mold for an aircraft wing panel and then becomes the outer layer of the wing after cure of the additional laminate plies: "There are only two resin infusions on a flat surface, the first one to produce the flexible mold sheet, the second one to complete the part laminate." The thin composite laminate that will double as the mold is made on a flat or otherwise formed surface and cured until hard. This gives the molder a flexible but, if bent, stiff composite sheet. "The flat working surface defines the structure and quality of the laminate lower, or outer, side."

One or more plies of reinforcing fibers (glass, carbon, aramid, etc.), or one or more layers combined with foam or honeycomb cores or other materials, are added on top of this sheet and impregnated with resin. This still flexible but lengthwise-stiff ensemble, the lower side being the cured flexible shell and the upper side consisting of the additional wet layers, is then placed over appropriately positioned templates, frames or ribs, giving the assembly its specific designated shape, at which point the flexible lower shell takes final part shape (after having served as the mold for the wet layers on the upper side). At cure, the mold thus becomes a member of the part (e.g., the wing surface) and, together with all the added layers, forms the complete wing panel. For example, the bi-functional flexible mold process allows the molder to produce wingskins as *seamless* shells from trailing edge to trailing edge, without a splice at the airfoil nose. The trailing edges are joined, wet in wet, and co-cured. This process can be used at room temperature or at elevated temperature. "It's an ideal method for resin infusion processes. A panel is produced with two single infusions on a flat plate and there is no need for work in a 3D mold," Wehren sums up.

Concludes Wehren: "The *xxtherm2* was designed inversely, beginning with simplicity, manufacturability, reliability, safety, quality. This led to structures, ways of construction, choice of materials, jigs and tools, ways of working, balance of external labor and personal contribution, and a balance of material vs. labor costs. And we allowed ourselves enough time to walk the road without detours." The actual *xxtherm2* is in a prototype stage, and first test flights will commence before the end of 2018. CW

LEARN MORE

Read this article online | short.compositesworld.com/hangglider

See an *xxtherm* prototype's launch and flight videos on Helmet Wehren's YouTube channel | www.youtube.com/user/militki/videos

ABOUT THE AUTHOR

Sara Black is a *CW* senior editor and has served on the *CW* staff for 19 years.
sara@compositesworld.com

Filament winding, reinvented

Robots and digital technology deliver speed plus larger, more complex parts, while *generative* 3D winding obviates mandrels and waste for automotive applications.

By Ginger Gardiner / Senior Writer

» Filament winding, one of the oldest composite manufacturing processes, was used to produce solid rocket motor cases after World War II. By the early '60s and '70s, commercial winding machines were also being used to fabricate fiber-reinforced pipes, pressure vessels and streetlight poles.

Traditional filament winding impregnates fibers in a resin bath just prior to application on a rotating mandrel (tool) while keeping them in tension. Though wet winding is still popular, processes have also been developed to use prepreg tapes, towpreg or dry fibers, the latter serving as preforms for liquid molding processes. By varying the angle of fiber or tape placement, filament winding can produce tailored laminates to efficiently meet a range of loads. Typically, no further compaction is needed thanks to the tension maintained on the fibers/tapes.

Well-suited to automation, filament winding is fast, cost-effective and creates lightweight, high-performance structures. It is now used to produce a range of composite structures including golf club and drive shafts, yacht masts, oars/paddles, bicycle rims and forks, small aircraft fuselages, spacecraft structures, car wheels and pressure vessels, the latter ranging from firefighter oxygen bottles and liquid propane gas (LPG) tanks to cryogenic fuel tanks for spacecraft measuring 5-10m in diameter and 10-15m long. Wind turbine manufacturer ENERCON (Aurich, Germany) is using automated filament winding systems installed in 2016 by Roth Composite Machinery (Steffenberg, Germany) to produce the shorter, inner sections for the segmented blades used in the E-115, E-126 and E-141 turbines.

"FibreTEC 3D"

This robotic gripper for automotive assembly weighs 50% of a standard aluminum version. It is made with the FibreTEC3D process, a zero-waste system that winds carbon fiber tow impregnated with epoxy around aluminum pins. Source | Daimler AG

Over the last few years, increased use of robotics and the latest digital technologies have dramatically increased filament winding production speeds *and* product complexity. Examples include Cygnet Texkimp's (Northwich, UK) high-speed, 3D winding machine, designed to produce complex layup parts that vary in both cross-section and shape. Similarly, filament winding specialist MF Tech (Argentan, France) is developing "very complex wound carbon fiber structures with ribs, beams and machined features for automotive applications," says co-founder Emmanuel Flouvat. The company also is combining filament winding (FW) with automated fiber placement (AFP) and other processes, as is turnkey system supplier MIKROSAM (Prilep, Macedonia), which introduced its own hybrid AFP/FW work cell in 2017.

Winding also is being hybridized with 3D printing. Composites engineering firm CIKONI (Stuttgart, Germany) uses a robotic process to wet-wind carbon fiber/epoxy onto 3D printed plastic, composite or metal cores. Generative 3D winding — with a robot but without a core — is being developed by Daimler (Stuttgart, Germany).

Where is filament winding headed? *CW* walks through these developments to find out.

Multi-filament winding

The quest to reduce cycle time has become a major driver of filament winding innovation. Murata Machinery Ltd. (Kyoto, Japan) has achieved this by moving away from conventional single-tow/tape winding, where the fiber feed unit must move along the rotating mandrel multiple times to wind all of the fibers for just one layer. Instead, it has developed a *multiple* fiber system — what it calls multi-filament winding (MFW) — that simultaneously applies 48-180 tows/fiber inputs.

Murata presented its technology in 2015 at the 20th International Conference on Composite Materials (ICCM20, Copenhagen, Denmark) and installed the MFW-48-1200 system at the Institut für Textiltechnik der RWTH Aachen (ITA, Aachen, Germany) in 2017. The system comprises four main components: a creel, a ring-like adaptive nozzle, a rotating mandrel or liner unit and an annular hoop unit (Fig. 1). The MFW-48 creel contains 48 bobbins of fiber. The circular adaptive nozzle (also called an *iris*) feeds and applies the 48 fiber inputs from the creel onto a rotating mandrel or liner that moves horizontally in and out of the nozzle. The result is similar to braiding in that the fibers/tows cross over each other, but without inducing crimp. The winding angle is determined by the relative speed between the rotational and horizontal movement of the liner/mandrel and its diameter. Four additional fiber feeds may be applied at 90° via the hoop unit. Murata and ITA claim a complete layer can be applied in one pass, resulting in a cycle time 50 times faster than standard winding machines, with a 90% increase in torsional stiffness compared to braided laminates. Having reportedly developed the first machine of this type in Europe, ITA and Murata are now working to characterize the MFA process and begin prototyping applications such as hydrogen storage cylinders for automotive applications.

Robotic 3D winding: speed *and* complexity

Robots have been asserting influence on filament winding for some time. When MF Tech was launched in 2004, *all* of its systems were based on robots. This included the conventional filament winding arrangement where the rotating mandrel is kept in a fixed position and the fiber feed unit moves linearly. MF Tech simply mounted the fiber feed onto a robotic arm, gaining up to eight axes of motion. However, MF Tech also developed an »

FIG. 1 Multi-filament winding touted as 50 times faster

Murata Machinery's MFW-48-1200 simultaneously winds 48-180 fibers from its creel onto a rotating mandrel in the liner unit, which moves horizontally in and out of the adaptive nozzle.

Source | Murata Machinery and Institut für Textiltechnik (ITA) der RWTH Aachen

FIG. 2 Robot-enabled flexibility

An early adopter of robotic filament winding, MF Tech has developed an unconventional system where the rotating mandrel is manipulated past a stationary fiber feed (creel and orange and black tower at right). Source | MF Tech/CEA

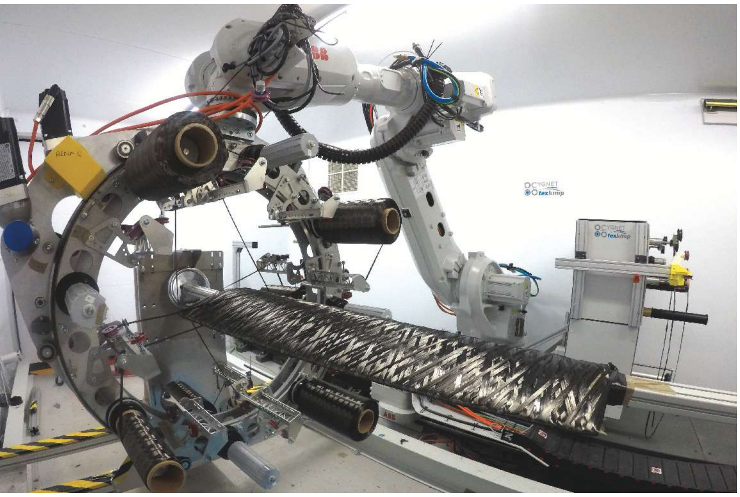


FIG. 3 **Robotic 3D winding: speed and complexity**

Comprising two counter-rotating fiber application rings moved by a robot arm along the part being wound, Cygnet's 3D winder was designed for scalable, speedy production of complex shapes, able to wind 24K or 48K carbon fiber at a rate of 1 kg/min. Source | Cygnet Texkimp

unconventional arrangement where the rotating mandrel is carried by a robot, which moves it past a stationary fiber feeding unit (Fig. 2, p. 25). This system could pick up a liner, wind a pressure vessel onto it and then place the wound tank into a curing oven.

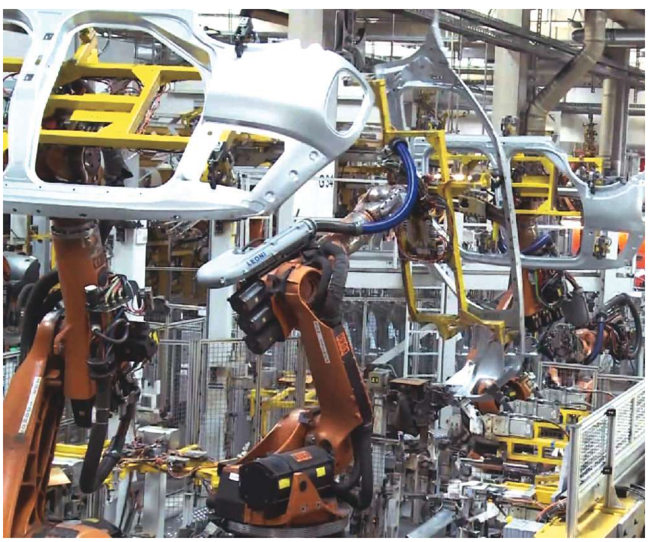
More recently, filament winding systems have been developed where *both* the mandrel and fiber feed may be moved and rotated by robots. These robots cooperate to increase the range and accessibility of fiber winding, enabling larger structures as well as more complex fiber layups and shapes.

Speed and complexity were goals for Cygnet Texkimp's development of its robotic, high-speed 3D winding machine. The system combines rotation and fiber feed into a single mechanism that is robotically moved along the liner, mandrel or core, winding as it goes. Based on a 9-axis robotic winder conceived by University of Manchester (UK) professor Prasad Potluri, the Cygnet 3D winder uses two counter-rotating fiber application rings mounted together on the end of a robotic arm. As the arm maneuvers the rings so that a complex-shaped mandrel is passed through their center, fiber is fed from eight bobbins on each ring — that number is scalable — and is wound onto the mandrel (Fig. 3).

"The inspiration for this was the F-35 [fighter jet] inlet duct," explains Cygnet Texkimp managing director Luke Vardy. That roughly 3m-long, complex part transitioned from a large, round cross-section to a smaller, square shape while tracing through a moderate, elbow-like curve. "This machine can match that complexity, offering more degrees of freedom than a stationary winder," he adds. "The mandrel can be whatever shape you want."

Cygnet's 3D winder is also designed for speed, winding 24K or 48K dry carbon fiber at more than 1 kg/min, "and creating a multiaxial laminate," says Vardy. "We can vary the angle of the fiber, winding 30° on one ply, -30° on another ply and then we can apply 0° by adding another ring." (Note: That ring would function like the hoop unit in Murata's MFW system.) Vardy says the winder is scalable, suitable for winding a car wheel or yacht mast, "yet we can make it big enough to wind a bridge arch, whole wind turbine blade or aircraft fuselage. It's simply a matter a putting the robot on a rail and sizing the rings appropriately."

Cygnet has also developed a traditional robotic filament winder from this technology, replacing the 3D winding head with a driven creel mounted to the robot, which controls fiber feed and tension to a high level of accuracy. Vardy explains that whether the creel contains four or 50 positions, each can be tensioned independently. "We can manage the machine speed to deliver higher resolution where you need smaller-scale features or complex geometries."



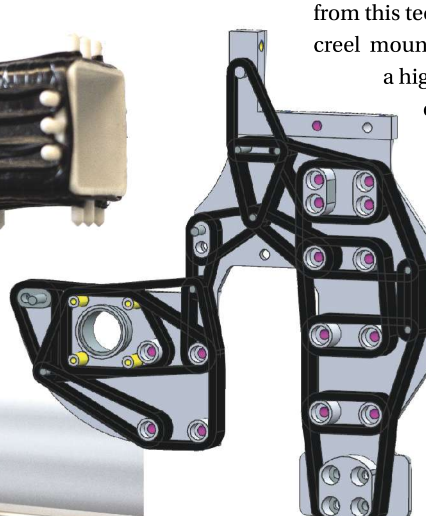


FIG. 4 **New type of joining**

Aluminum-framed robotic grippers used in auto assembly (yellow structures in example at Magna, top photo) can be lighter with components made by 3D winding carbon fiber and epoxy to join snap-together, 3D printed plastic modules or around pins printed on a plastic mandrel (bottom left). CAD analysis converts the tension loaded areas into fiber paths for winding around plastic or metal (shown in black, bottom right). Source |Magna International and Cikoni

He also describes a resin application system that differs considerably from a conventional resin bath. "We bring in two-part epoxy from heated tanks through heated lines and mix in a Y nozzle at the winding head, less than a foot from the part," says Vardy. "We are almost making towpreg on the fly. The tension control is actually spreading the fiber, so this is very close to ATL, but we don't apply pressure for consolidation."

The current R&D unit features a 3m-diameter, 3m-long mandrel and combines functions like trimming and machining. Vardy says it will next be used to run *thermoplastic* tape, adding, "we can run slit prepreg tape on this filament winder *and* on the 3D winder." Cygnet will produce the tape in-house, as it already supplies high-speed prepreg slitters to the industry.

3D printed cores for 3D winding

CIKONI has an interest in hybridized filament winding, which came through its founders. Farbod Nezami had modified FW to build grippers and truss parts for assembly robots at Daimler, while Diego Schierle was using it to build tailored, high-performance pressure vessels for cars at the German Aerospace Center's (DLR) Institute for Vehicle Concepts (Stuttgart). Although CIKONI provides design and engineering services across the spectrum of composite materials and processes, it has already sold two customized winding cells for development work at German automotive suppliers and is close to finalizing a contract for its first automotive production machine.

Nezami says 3D winding has proven to be a particularly good solution for the manufacture of robot grippers because they are specialized, yet need to be lightweight. "Because each gripper is different, only one or two of each kind is made, which makes tooling cost-prohibitive," he explains. "We can 3D print a polymer T-mandrel with pins, and then 3D wind carbon fiber wet out with room-temperature cure epoxy resin around these pins [Fig. 4, p. 26]." The core and pins can remain in the part, or be melted/washed out. If the part has high compression loads, the core can be 3D printed metal, which Nezami says, "enables a very interesting hybrid design. We use finite element analysis [FEA] to identify areas of tension and compression, which guides which materials and hybridization strategy we choose."

Generative 3D winding

The aforementioned development work on grippers at Daimler has led to a new, potentially revolutionary, coreless 3D winding technology for the manufacture of production robot parts *and* automotive parts. Referred to as FibreTEC3D, the Daimler technology involves two cooperative robots, one that holds and manipulates an aluminum tooling plate with pins protruding from the surface, and one that wet winds carbon fiber around the pins (Fig. 5, p. 28). Daimler assembly process engineer Niklas Minsch calls these pins deviation points because they deviate the fiber path, which forms the composite structure. »

"The idea is that this manufacturing method and the parts it produces are *generative*," says Minsch. In *generative design*, a part's geometry is not predefined, but is instead computer-generated by applying advanced algorithms to data derived from the application's requirements and constraints — size envelope, loads, strength, stiffness, impact, deflection, cost, etc. (see Learn More). In short, the requirements of the application dictate the design. Applied to manufacturing, this approach enables the economical production of highly optimized, small-series products. Typically, the more complex a part is, the more generative design and manufacturing pay off.

"The initial idea was to make assembly robot grippers lighter, enabling us to downsize the robots, which saves money, and also extends their reach," Minsch explains. "Our car development department saw what we were doing and wanted to use the same technology to make a body part." These parts start with a topology-optimized design, he says, "so that we are putting the right material in the right places, which minimizes the amount of material needed and means carbon fiber is in tension."

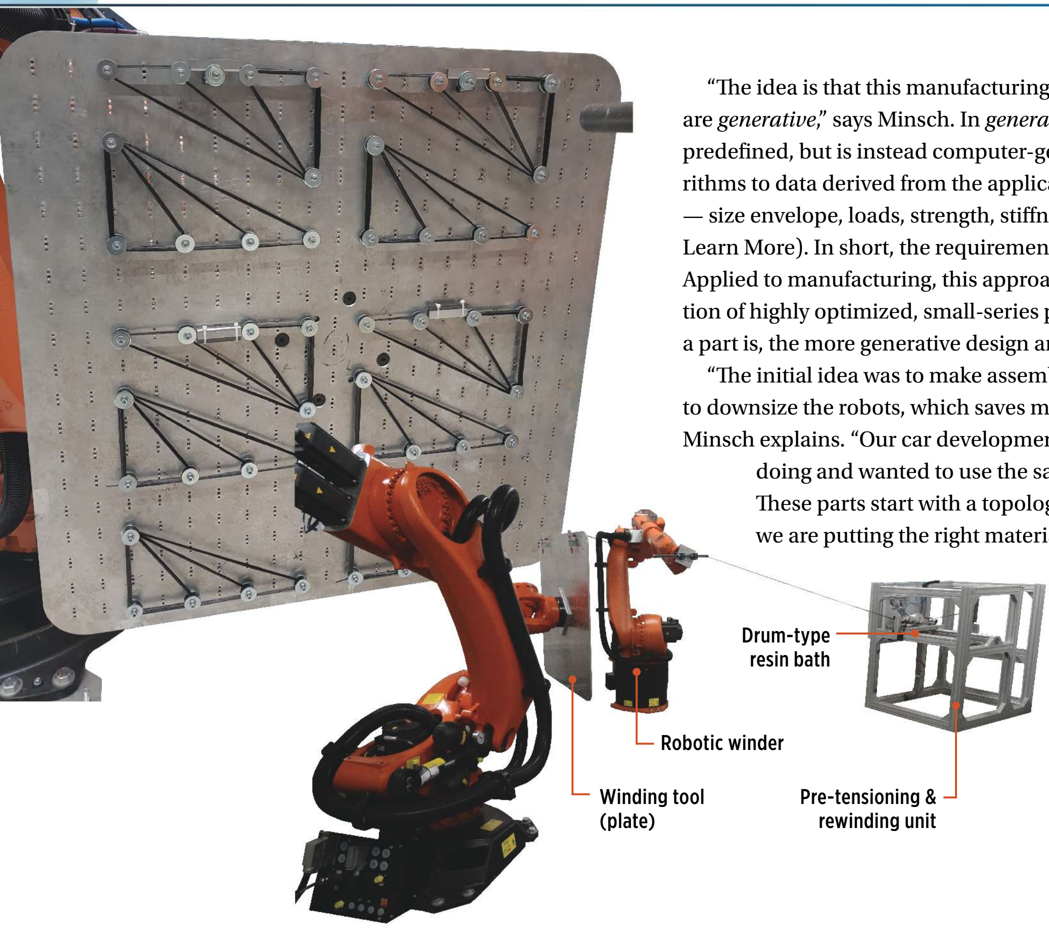


FIG. 5 Generative 3D winding

Developed to cut weight in assembly robot grippers by 50%, Daimler's robotic and generative 3D wet winding process eliminates molds, waste and carbon fiber as the cost drivers (aluminum winding pins now assume that role). Source | Daimler

The part's digital design directs placement of the pins and generation of the robotic winder code — the combination, in turn, actualizes the part. The entire design process is managed by software developed in cooperation with the Institute of Textile Machinery and High Performance Materials (ITM) at the TU Dresden (Dresden, Germany). "The deviation points (pins) can be made higher or lower to create the 3D depth versus a planar structure," Minsch observes. "Longer deviation points will induce more bending moment, so there is some tradeoff. The structures we are making are more like 2.5D."

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Minsch explains that because there is no cutting and no waste, the aluminum becomes the cost driver, not the carbon fiber. "We're using 24K tow, which is typical for automotive," he adds. The resin is a room-temperature cure laminating epoxy because there are no high-temperature requirements for the first production part. "We are also able to integrate metal inserts easily for wear points," says Minsch. "This was necessary when we started with grippers because they need a lot of attachment points — which is also why we don't use composite pultrusions. With our approach, we can match the strength and stiffness of a standard aluminum gripper but at 50% of the weight."

If towpreg is typically faster to filament wind, why is wet winding preferred in the FibreTEC3D process? "We tried towpreg," says Minsch, "but it was too sticky and damaged the roving. This doesn't happen with wet winding because the roving is slippery." He notes towpreg also requires compression, post-winding, to compact the separation between plies. "The tension in wet winding compacts the fiber as it is wound," says Minsch. "We're using pretension as well, which is important for final part properties." He concedes that additional compression could increase composite properties by 10-15%, "but it increases cost severely because you then need tooling, vacuum and pressure. This isn't a rocket motor casing. Our approach provides sufficient properties and meets the cost target."

That, ultimately, is the driver for and potential disruptive power of the latest filament winding developments: putting fiber where it needs to be with precision, speed and practically zero waste. CW

ABOUT THE AUTHOR

CW senior editor Ginger Gardiner has an engineering/materials background and more than 20 years of experience in the composites industry.
ginger@compositesworld.com

The long view for composites in long-haul trucks

Composite components on heavy trucks and trailers continue to grow, both in volume and in kind, but they won't be carrying structural loads until the mid-2020s.

By Karen Mason / Contributing Writer

» Is the long haul trucking industry poised for a transformation to large-scale use of composite materials? If so, could it look anything like last decade's leap in commercial aircraft composites use — for example, from 9% composites by weight on the Boeing 777, to 50% on the Boeing 787? According to trucking industry insiders who spoke with *CW*, a surge in composites applications is a realistic possibility, though somewhat less dramatic than that experienced in the aerospace market, and not until the mid-2020s at the soonest. If and when a jump in composites use does occur, it will share a common feature with commercial aircraft: a substantial increase in composites by weight will be the likely result of composites moving into structural applications.

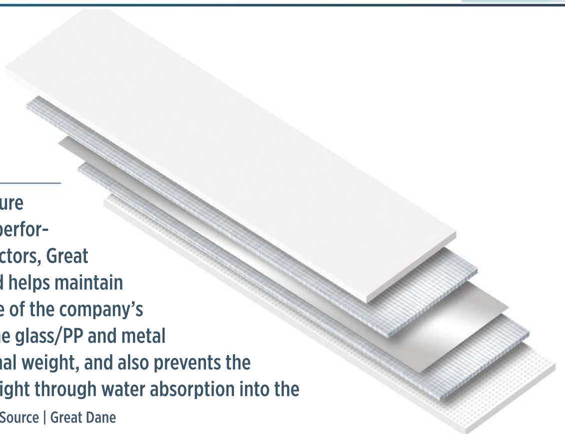
Importantly, the need for a paradigm shift — a clean-sheet, "purpose-built" design approach — is emphasized as a prerequisite to any such transformation. "Almost everyone's current vehicle is metallic with composite 'covers,'" says Todd Altman, senior director of strategic markets for TPI Composites Inc. (Scottsdale, AZ, US). To gain significant new mass savings and performance advantages, he believes, OEMs are best served by designing from the ground up. "Don't take all the legacy components," he says, "and try simply to replace metal with composite. Part consolidation will improve the value of new composite designs. You can integrate the roof, and you don't need a fairing on top. The integrated unit becomes structural."

Rethinking truck and trailer technology is thus taking place on a fundamental, systemic level, including the powertrain, drive shafts, axles, suspensions and wheels, as well as the elements more commonly associated with composites — truck cab, trailer floor and walls, and in the future, the frame and chassis.

In the meantime, heavy truck and trailer OEMs continue to gain production experience with composite materials, their properties and their long-term performance, through components that have already made the transition. In fact, for many truck and trailer components, composites are the stock-in-trade, and have often been so for decades. Market forecasts for these components are optimistic. A work-in-progress report from Future Market Insights (London, UK), for example, predicts a

The old with the new

Oak has long been the preferred flooring material for dry vans, and Havco's Fusion floor reinforces oak with a composite laminate to provide greater strength and more durability at a lighter weight than a pure oak floor. Source | Havco Wood Products



Protecting insulation performance

By sealing out moisture intrusion and other performance-degrading factors, Great Dane's ThermoGuard helps maintain thermal performance of the company's refrigerated vans. The glass/PP and metal laminate adds minimal weight, and also prevents the van from gaining weight through water absorption into the insulating material. Source | Great Dane

near-term upswing in the market for heavy-truck components made from advanced materials including composites, with a long-term (10-year) expected annual growth rate of 6-8% globally.

Component milestones

The current stalwart application for composite component manufacturers serving the heavy-truck and trailer sector is reflected in recent news. Core Molding Technologies Inc. (CMT, Columbus, OH, US), for example, surrounded the 2014 production of its 2 millionth truck hood with great fanfare, also reporting at the time that the company was serving 32 hood programs for seven truck brands, and was producing about 150,000 truck hoods annually. CMT's glass-reinforced polymer hoods are manufactured through a variety of processes, from fiberglass spray-up molding to high-volume compression molding of sheet molding compound (SMC). In another example, at this writing, the commercial vehicles landing page for Molded Fiber Glass Cos. (Ashtabula, OH, US) touts the company's heavy-truck trailblazing activity, dating back to the 1960s, as well as its current annual production of 40,000 composite roof caps.

While market maturity presents many of these component manufacturers with dependable business, it also creates challenges. A case in point is the Fusion Floor by Havco Wood Products LLC (Scott City, MO, US), a hybrid product in which a glass/epoxy panel, produced on a double-belt press, is subsequently bonded to laminated oak flooring. Under development since 1993, this product made its way into production in 2000; but it was not until about 2007 that sales accelerated. Fusion Floor inventor Gopal Padmanabhan, VP of product development, presented the patented technology at a JEC Composites Forum that same year, and by then Havco had collected data from a 10-year field test of the flooring. "The results showed that the 10-year-old composite floor board is stronger than a new 1.31- or 1.38-inch standard oak floor board," the forum proceedings report.

As John Carr, Havco VP of sales and marketing, notes, "Usually when fleets go to Fusion — even with its price premium — they never go back." This is especially true of fleets transporting goods that "weigh out before they cube out." That is, they reach maximum gross vehicle weight of 80,000 lb before the volume of the trailer is filled. Goods such as beverages or paper (for which a single roll may weigh upwards of 8,000 lb) place extreme demands on the trailer floor, especially during loading and unloading.

Havco says it has sold more than 300,000 of these composite/wood floors. Such floors captured an increasing market share of dry-freight vans between 2007 and 2017, plateauing at 16%. One of the challenges Havco faces is that its North American patents ran out in 2016 and 2017, which has led to increased competition. With other companies trying their hand at wood/composite flooring, a variety of approaches — and quality — has emerged. "There's confusion in the market about what the specification of the composite sheet should be," Padmanabhan notes.

Havco has continued to advance the technology, maintaining its market share. Since introducing the product, the company has worked with vendors to increase glass content in the epoxy composite laminate from 70% to 75%. Havco also has worked with hot-melt adhesives makers and laminating equipment manufacturers to increase processing speed without sacrificing performance. "We used to bond the composite and wood together at 25 ft/min; now the rate is 40 to 45 ft/min," Padmanabhan says. Floors can be shipped within 4 hours of bonding and obtain full cure within three days; previously, 24 hours and seven days, respectively, were required.

A broadening field of applications

Additional composites applications in trailers, as well as in aerodynamic auxiliary components such as skirts and fairings, are emerging and/or growing. "The trends are definitely on the positive side," says Chris Lee, VP of engineering at long-haul trailer manufacturer Great Dane (Savannah, GA, US). One reason, he says, is cost. "The price of polymer-based composites has come down through optimization of resin to fiber ratio, manufacturing processes and strength-to-weight ratio." »

Providing lightweight durability

Great Dane's PunctureGuard lines the walls of some of its trailers, preventing damage while adding minimally to the trailer's empty weight. Source | Great Dane

Composites and aerodynamics

Composites have been employed in trailer skirts, tails and other aerodynamic components for some time, but advanced configurations like Wabash's recently introduced Ventix DRX improve aerodynamic performance and fuel efficiency.

Source | Wabash National

Among long-haul trailer manufacturers, Great Dane has one of the more well-established histories with composites. The company offers Wingolite composite/wood hybrid floor from Prolam (Cap-Saint-Ignace, QC, CN) as optional equipment on its Champion dry vans. PunctureGuard, the company's glass/polypropylene (PP) composite laminate, was introduced in the early 2000s. Used to protect interior trailer surfaces in applications such as side wall lining and scuff band, PunctureGuard continues to be a popular, premium option on Champion vans, and is standard equipment serving as lining in the company's Everest refrigerated van (or "reefer"). The popularity of PunctureGuard prompted Great Dane in 2011 to launch a sister company, Impact Guard LLC (Leetsdale, PA, US), to sell similarly designed and manufactured composite panels into other trailer applications, as well as new markets, such as building and construction.

Great Dane's Everest reefer line may also be fitted with ThermoGuard insulation material, which the company introduced to the market about a decade ago. ThermoGuard laminate includes a metal barrier layer surrounded by layers of glass/polypropylene (PP) composite, which is produced by heated belt forming of unidirectional glass and PP film. The laminate seals the van's insulation foam to reduce its degradation rate, to keep it from degassing and to prevent water intrusion. (Water absorption into a reefer's insulated walls can also add hundreds of pounds to the trailer's empty weight, in addition to degrading insulation performance.) Vans fitted with ThermoGuard lose less than

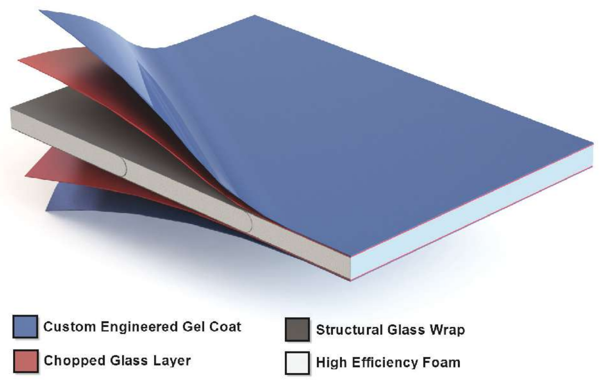
Boosting thermal performance

Wabash launched its *Cold Chain* reefer line, which employs the company's molded structural composite (MSC) technology, in 2016 with a smaller truck body unit. The full 53-ft trailer is moving into product launch at this writing. Source | Wabash National

5% insulation performance over the first two years, compared to 15-20% for the typical conventional liner. After 5 years, ThermoGuard's thermal degradation reportedly remains less than 15%, vs up to 30% for conventional materials.

Other trailer OEMs are introducing composite technology in their reefer lines. Wabash National Corp. (Lafayette, IN, US) launched its Cold Chain truck body series with advanced molded structural composite (MSC) technology in 2016. MSC, which makes up the trailer's walls, floor and roof, consists of a high-efficiency foam core encapsulated in a fiber-reinforced polymer shell and protective gel coat. It is reported to boost thermal performance over conventional wall material by up to 28%, double puncture resistance and reduce weight by up to 20%. (Note that, though Wabash refers to its well-known DuraPlate product as a composite, it is a metal/neat resin sandwich structure with no fiber reinforcement. Trailer makers also use the term "composite" to describe a construction of van walls, without necessarily meaning that fiber-reinforced polymers are used.)

The 2016 *Cold Chain* truck body is a smaller (14-26-ft) refrigerated unit that mounts directly on the chassis. About 100 of these »



■ **Efficiency through composites**

Wabash MSC technology encapsulates insulating material with glass composite and gel coat layers, protecting the insulation from degradation while keeping weight low. Source | Wabash National

units are on the road, reports Wabash VP of product engineering Robert Lane, and sales continue to ramp up. A full-length 53-ft Cold Chain trailer, which is currently moving into product launch phase, incorporates MSC walls and roof as well as next-generation CoCure hybrid metal/composite technology, developed by Structural Composites (W. Melbourne, FL, US). This technology, which is used for the trailer's flooring, combines metal (aluminum or steel) with fiber-reinforced polymer which allows the cold air to circulate. Structural Composites' CoCure resins and adhesives effectively serve both as the matrix resin in the component's composite layer, and as a tenacious bonding agent with metals.

Outside of van components, Wabash and Great Dane, as well as other truck and trailer OEMs, Tier 1 and aftermarket suppliers, are offering numerous aerodynamic devices that aid fuel efficiency. A mix of materials is used to make nose, roof and rear fairings, as well as side skirts. Great Dane's Lee notes that 80-90% of skirts are made from composite materials. As trailer add-ons, these devices boost a vehicle's empty weight, so the high strength-to-weight ratio of composites is important to optimizing the contribution these devices make to freight efficiency.

While Wabash's most popular side skirt is constructed from its DuraPlate material, the company also offers the Aeroskirt CX, constructed from a glass-reinforced polymer. Further, the company's most recent product, the segmented (up to five panels per side) Ventix DRS (Drag Reduction System), is also made from composites. The skirt segments of Ventix DRX eliminate drag that standard skirts create by trapping air under the trailer. The segmented configuration reportedly increases fuel savings 50% more than standard trailer side skirts.

Some of the newest developments in aerodynamic composite components, as well as other composites applications, are an outcome of the US Department of Energy's (DOE) SuperTruck I program. The DOE's interest in long-haul heavy-duty trucks stems from the opportunity this sector presents to improve freight-hauling efficiency and reduce greenhouse gases: Commercial trucks comprise only 4% of on-road vehicles, but use 20% of fuel consumed in the US.

Though programs like SuperTruck I serve as technology demonstrators, technology readiness was only a secondary focus of this initiative. In fact, TPI Composites decided not to pursue an opportunity to participate on a SuperTruck I specifically because the principal investigator's approach using non-structural carbon composite exterior panels appeared to be "a one-off show vehicle with no path to production," Altman recalls. The company is concerned whether new technologies can be "productized." The criterion, Altman says, is whether "the value the technology provides buys its way onto a production vehicle platform."

Composites applications in trailers are emerging and/or growing.

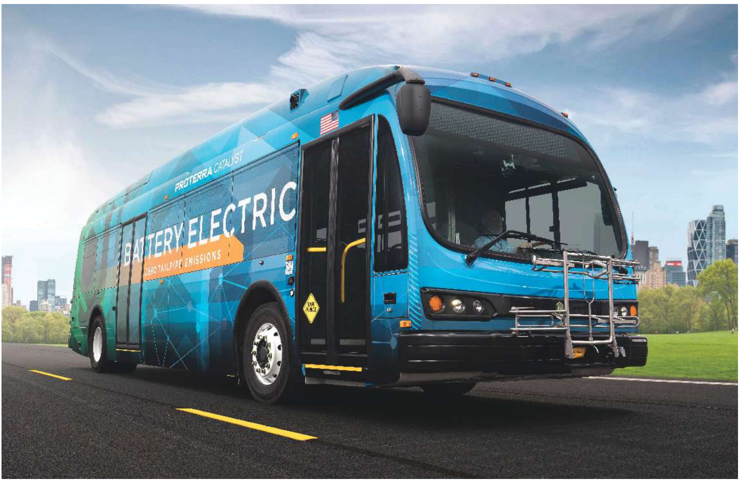
Will composites go under cover?

While steady market growth for non- and semi-structural composites applications on trucks and trailers is expected, the larger question is whether, and when, composites will expand into structural applications. The DOE's SuperTruck II initiative, which began in 2016, gives participants an opportunity to explore structural composites that could move beyond demonstrator status and into production.

Navistar chief engineer of advanced technologies Dean Oppermann reports that, during SuperTruck I, Navistar (Lisle, IL, US) deliberately maintained the same steel structure of its cab to avoid the major developmental work that would have been required to incorporate carbon fiber composites – dealing with new materials, new forming technologies and new joining challenges. In SuperTruck II, however, Navistar and TPI are aiming for a "structure and shell that's completely composite," Oppermann continues. "To make it more production-feasible, we will focus carbon reinforcement only in places where we need the strength. We're designing it as a system."

Of Daimler's SuperTruck II plans, reports Justin Yee, the company's manager of vehicle concepts in advanced engineering, as well as principal investigator for its SuperTruck II work, "At this time, we are not developing new composite technologies." Great Dane, on the other hand, is "studying the possibility of new composite sandwich panel technology on some structure members," Lee reports.

The joint SuperTruck II effort of TPI Composites and Navistar is using a purpose-built design approach. TPI's Altman says one route of entry into production vehicles may be created by the fact that, with composites, "We can tool up for a fraction of the cost of »



■ **Monocoque bodies in trucking's future?**

Truck manufacturers may soon leverage lessons learned in bus design, moving away from metal frames with composite "covers" to structural composite bodies. Source | Proterra and TPI Composites

metallic tooling." Stamps for large metal truck components can cost millions of US dollars, while composite tools are much less costly. This low capital investment would help build the business case, especially for lower-volume truck models, he notes. Oppermann concurs: "On a line haul truck, lightweighting alone is not going to sell composites," he says. The design must benefit from other factors, including a lower tooling investment, or the ability to incorporate more complex features such as aerodynamic profiles. He notes, for example, that Navistar may incorporate more aerodynamic packages in long-haul sleeper cabs, a lower volume application for which the company could leverage lower tooling costs, and therefore lower manufacturing costs. On the other hand, such aero packages would be cost-prohibitive in high-volume applications that are less aerodynamically sensitive.

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A futuristic gateway

Compared to conventionally fueled tractor-trailers, the potential for a leap in composites use may be greater with alternatively fueled vehicles – electric vehicles (EV) in particular. The opportunity to use a purpose-built design approach for EVs, their greater weight sensitivity, and the lower initial volumes of these vehicles, should help to cost-justify composite-specific design, tooling and manufacture. Oppermann mentions autonomous vehicles as another future opportunity.

TPI's Altman cites the Proterra (Burlingame, CA, US) *Catalyst* E2 (see Learn More) composite bus as a model for the path forward into greater composites application. "The purpose-driven *Catalyst* design affords the best efficiency rating ever for a 40-foot transit bus, at up to 28 mpg equivalent," states Rick Huibregste, senior VP of vehicle engineering at Proterra. "Proterra buses are the only mass transit vehicles built from the ground up as electric vehicles. With a unique aerodynamic body made from a combination of advanced composite materials, we are able to reduce mass for maximum efficiency." The bus is capable of achieving a nominal range of up to 426 miles on a single charge, meeting the needs of transit agencies across North America. TPI and Proterra collaborated in the design and development of the monocoque bus body, and the companies entered a strategic long-term agreement for TPI to supply the production bodies. With Proterra's purpose built composite platform, Proterra now has more than 90 customers. "Similar to Proterra success, purpose built composite trucks will provide industry-leading efficiency and will raise the performance bar to a new level," Altman believes.

Economic and technological advances are needed for significant increases in composites, especially for structural components. A business case must be made to the end user, especially to fleet owners, NACFE's Andrew Halonen, president of Mayflower Consulting LLC (Calument, MI, US), notes. "The fleet managers know every last number," he says. "They have a complete cost understanding of their vehicles." While fuel efficiency during fleet operation is an important factor, so too is resale value. Halonen reports that, today, the optimal time for fleets to resell a truck is 3-5 years. This short window places downward pressure on the return on investment needed for the cost premiums of fuel-efficiency measures. "If I'm going to keep this vehicle for 3 years, why would I care that a composite truck body lasts 10 times longer?" Halonen points out.

To build an acceptable business case for more composites, Great Dane's Lee cites necessary market changes to include reduced cost of carbon fiber composites and glass fiber composites with higher strength-to-weight ratios for trailer frame and wall applications, as well as higher strength composite sheets and panels. He also suggests a need for more manufacturing-friendly sandwich panel constructions with higher strength-to-weight ratio and more dent- and crush-resistant core materials — all at more economical price points. Repair methods are also a significant concern to truck and trailer makers. Though techniques are well-developed in aerospace composite applications, the tractor-trailer market needs faster and less labor-intensive repair methods to make repairs cost-effective.

Ultimately, Navistar's Oppermann says, a major transition in the long-haul truck market to composite materials, will have to wait until the next generation of trucks is created, which for the long-haul industry is in the 2023-2024 timeframe. "To make the business case, we have to do it at the system level. The entire cab has to be designed that way," meaning a purpose-built design from the ground up. In heavy trucks, says Oppermann, "that happens only [once] every 15 years." CW

ABOUT THE AUTHOR

CW contributing writer Karen Mason focused academically on materials science and has been researching and writing about composites technology for more than 25 years.
kmason@compositesworld.com

Racing catamaran still performing

Gougeon Brothers Inc. created a composite racing catamaran in 1990 that is still setting speed records decades later.

› *Incognito*, a 28-year-old catamaran, is still setting speed records and besting much newer craft. It was fabricated by Gougeon Brothers Inc. (Bay City, MI, US) in 1990, and is owned by Russell Brown of Port Townsend, WA, US, who was the first solo finisher in the 2018 grueling R2AK (Race to Alaska). The secret to the G-32's longevity and success is largely the detailed development, design and construction process that Meade and Jan Gougeon carried out back in 1990.

"When we reopened our wind blade manufacturing plant in 1990, we decided to produce a trailerable 32-ft-long catamaran called the G-32," says Meade Gougeon. The design enabled the entire structure to be built in only two large parts, upper and lower, that were joined at the centerline in one large bonding operation. This meant a minimal investment in molds, making low-volume production financially feasible. The single biggest design challenge, say the two brothers, was to build the G-32 light enough for towing by a mid-sized car, with boat and trailer weighing less than 2,200 lb/998 kg. Unnecessary weight was designed out and the lightest materials possible were used, within the cost constraint of $10/lb for the molded shells.

Source | Gougeon Bros. / PRO-SET


Source | Gougeon Bros. / PRO-SET

The two had built many one-off carbon fiber racing boats but wanted to save costs on the G-32 by using vacuum infusion in female molds, and less expensive materials. In their view, vacuum bag infusion was a must to save laminate weight, along with a long-out-time PRO-SET epoxy resin, formulated in Gougeon's own labs; the long open time allowed the entire cored laminate to be laid up and compacted in one vacuum step, without intermediate debulking. They also developed a tie-coat substance that allowed use of a polyester-based gel coat for minimal print-through.

A matrix of 30 material combinations, including cores, were evaluated, by means of test panels. The material combination ultimately chosen had adequate stiffness, ultimate strength and fatigue to support the structural needs of the G-32, and met cost, weight and ease of manufacturing targets; it consisted of multiaxial fiberglass skins from Brunswick Technologies Inc. (later acquired by Owens Corning, Toledo, OH, US) over a Klegecell PVC foam core from DIAB (Laholm, Sweden).

In late 1992, the brothers decided to sell the wind energy division, which eliminated the main reason for the boat project, and only 14 G-32s were produced. Meade and Jan Gougeon believe that their fabrication process dramatically reduced the cost of manufacturing epoxy-based boats: "...the 14 G-32s have performed as expected, with no structural failures of any kind. A bonus is that their light weight, combined with long slim hulls, has made for exceedingly fast boats that have won many races," concludes Meade Gougeon. CW

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4th Int'l Composites Congress (ICC)
composites-germany.org/index.php/en/dates/4th-icc

Nov. 6-8, 2018 —
Stuttgart, Germany
Composites Europe/Lightweight Technologies Forum
composites-europe.com

Nov. 6-8, 2018 —
São Paulo, Brazil
Feiplar Composites + Feipur 2018
feiplar.com

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JEC Asia
jeccomposites.com/events/jec-asia-2018

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German Wood-Plastic Composites Conference
10times.com/wood-plastic-composites

Nov. 14-15, 2018 —
Santa Clara, CA, US
3D Printing USA
idtechex.com/3D-printing-usa/show/en/

Nov. 21-22, 2018 —
Marknesse, The Netherlands
International Symposium on Composites Manufacturing ISCM 2018
nlr.org/events

Nov. 21-22, 2018 —
Dusseldorf, Germany
2018 European Thermoplastic Compounding Summit
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ICERP 2019
icerpshow.com

Jan. 30-Feb. 1, 2019 —
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TCT Japan 2019
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Feb. 19-20, 2019 —
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spethermosets.org

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March 6-8, 2019 — Rome, Italy
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April 10-11, 2019 — Amsterdam, The Netherlands
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composite-expo.com

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g. Copies Not Distributed	700	700
h. Total (Sum of 15f, 15g)	29,939	31,088
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I certify that the statements made by me above are correct and complete.

Richard G. Kline, Jr., President

New Products

» IN-MOLD MATERIAL SYSTEMS

Updates in in-mold electronic materials

DuPont Electronics & Imaging (Wilmington, DE, US) has announced that it is launching its second generation of in-mold electronic (IME) materials with key advancements in its electrically conductive adhesive, protection encapsulant and crossover dielectric.

IME technology enables functions such as touch controls and lighting to be directly embedded inside of plastic parts by printing circuits onto plastic sheets, which are then thermoformed and injection molded. This is said to allow product engineers to reduce weight and cost while increasing design aesthetics and functionality in everything from car dashboards to home appliances, using fewer parts and manufacturing steps.

DuPont's IME second-generation advancements include a new electrically conductive adhesive that is more flexible than epoxy-based systems, a protection encapsulant for use as tie-coat and top seal, and crossover dielectric that reduces the number of layers required. **dupont.com**

» RESIN SYSTEMS

UV-curable resins for thermoset composites

Allnex (Alpharetta, GA, US) has announced its range of UV-curable resins, falling under the EBECRYL brand, engineered for the manufacture of thermoset GFRP composites having regular geometries.

The EBECRYL resins will cure upon exposure to UV light, allowing composites manufacturers to cure with UV lamps instead of a thermal curing oven. While this makes UV curing impractical for carbon fiber composites and irregularly shaped laminates, the company says that several benefits can be captured when the use of UV technology is feasible.

The styrene-free resins are said to reduce energy consumption by up to 90%, supporting green initiatives. The one-component systems reportedly have no pot life limitations and produce almost no waste. A high throughput per line and shortened cycle times are said to be possible thanks to fast curing times. **allnex.com**

» THERMOPLASTIC COMPOSITES

Wear-resistant thermoplastic composite

Greene Tweed (Kulpsville, PA, US) has introduced WR 650, a wear-resistant thermoplastic composite with a three-dimensional carbon fiber architecture that reportedly offers enhanced performance over other PFA-based materials. According to Greene Tweed, WR 650 offers a 2.5 times higher PV limit in dry run conditions and a coefficient of thermal expansion four times lower in the axial direction.

WR 650 reportedly offers enhanced dry run capability, good chemical resistance and an operating temperature up to 260°C/500°F. Its higher fiber content is said to provide a harder material over a wide range of operating temperatures. **gtweed.com**

» 5-AXIS MACHINING

5-axis CNC machine for ultra-hard materials

Synova (Duillier, Switzerland) has announced the launch of a new CNC machine with full 5-axis capability to process complex three-dimensional geometries. Applications targeted include the machining of industrial diamond employed in toolmaking as well as various composite materials used in aviation. The LCS 305 laser system is said to offer accuracy, quality and speed with highly dynamic axes, water-cooled linear and torque motors, a mineral casting machine bed and a fully automatic offset calibration system.

According to Synova, the flexible Laser MicroJet (LMJ) system enables 3D cutting and shaping of large and multi-tooth diamond tools resulting in smooth cutting surfaces and sharp edges for ultra-hard materials such as PCD, SCD, natural diamond or tungsten carbide. The machine's two highly dynamic torque motor-driven rotary axes also allow chamfering for K-land edges and single or multiple clearance angles. Tools reportedly can be exchanged quickly and with accuracy thanks to the HSK 63 tool holder. The LCS 305 laser system with water jet-guided laser technology is said to be capable of precision-machining parts made of ceramic-matrix composites (CMCs) while protecting the material from heat-related effects. Low-weight and heat-resistant CMCs are being used for hot-section aeroengine components to increase engine and aircraft efficiency. The LMJ "wet laser" technology cools workpieces while washing away debris. The water jet maintains the laser's focus, creating a cylindrical laser beam that reportedly results in parallel walls and tight kerf widths. **synova.ch**

» FIRE PROTECTION SYSTEMS

Fabrics designed for fire protection in composites applications

SAERTEX (Saerbeck, Germany) recently announced two new products in the area of fire protection for composites, SAERTEX LEO Coated Fabric and SAERcore LEO.

SAERTEX LEO Coated Fabric meets the most stringent fire protection requirements for rail transportation, the marine sector and the construction industry. It complies with the strictest fire safety standards and railway applications HL3 according to EN 45545-2 (-3). It is suited for manufacturing simple or curved structural parts and is processed using the vacuum infusion technique.

The product SAERcore LEO, also meets the HL3 fire protection requirements in accordance with the EN 45545-2 standard. It is suited for parts with complex shapes that are also subjected to low mechanical stresses. SAERcore LEO can be used within resin transfer molding (RTM) and light RTM. **saertex.com**

» CARBON FIBER FILAMENT

Carbon fiber filament for 3D printing composite prototypes, parts

Royal DSM (Geleen, The Netherlands) recently launched its new carbon fiber-filled grade PA6/66 filament Novamid ID1030 CF10 for 3D printing. Despite the low carbon fiber loading of 10%, it reportedly produces functional prototyping and industrial parts with properties close to what is usually achievable only by injection molding, while matching the fast printing of unreinforced plastics.

Novamid ID1030 CF10 3D is designed for printing structural parts that are said to be strong, stiff and tough with high tensile strength and modulus, high dimensional stability and free of warpage. These mechanical properties and smooth appearance reportedly make the carbon fiber filament well-suited for a range of applications that require robust performance at elevated temperatures. Possible applications include parts for automotive, sports gear, manufacturing jigs and fixtures and medical braces and prosthetics.

The material can be printed on standard desktop fused filament fabrication (FFF) machines with a hardened nozzle. Tests have shown that users can run their printers at the same speeds as with unreinforced plastics, while achieving improved strength and toughness. The material has been tested on several open FFF platforms, including on GermanRepRap and the Ultimaker S5. **dsm.com**

» FOAM CORE MATERIALS

Polyethersulfone particle foam

BASF (Ludwigshafen, Germany) recently announced it has developed prototypes of what it says is the world's first particle foam based on polyethersulfone (PESU). The foam is characterized by high-temperature resistance, inherent flame retardancy and light weight coupled with good stiffness and strength.

According to BASF, Ultrason E is an amorphous thermoplastic with a high glass transition temperature of 225°C and remains dimensionally stable up to this temperature. Foams made of Ultrason E are approved for use in aircraft. The material, with its high limiting oxygen index of 38 (according to ASTM D 2863), meets the requirements for commercial aircraft with regard to combustibility, low heat release and low smoke density without the addition of flame retardants. The expandable PESU granulate is pre-foamed into beads with densities of 40-120 g/L and can be processed into molded parts with complex 3D geometries.

Despite its low density, the PESU particle foam is said to enable stiff and strong components with good dimensional stability at high temperatures. According to BASF, it is well-suited for complex-shaped components in cars, airplanes and trains, which must be able to withstand high operating temperatures and meet stringent flame-retardant requirements. **basf.us/composites**

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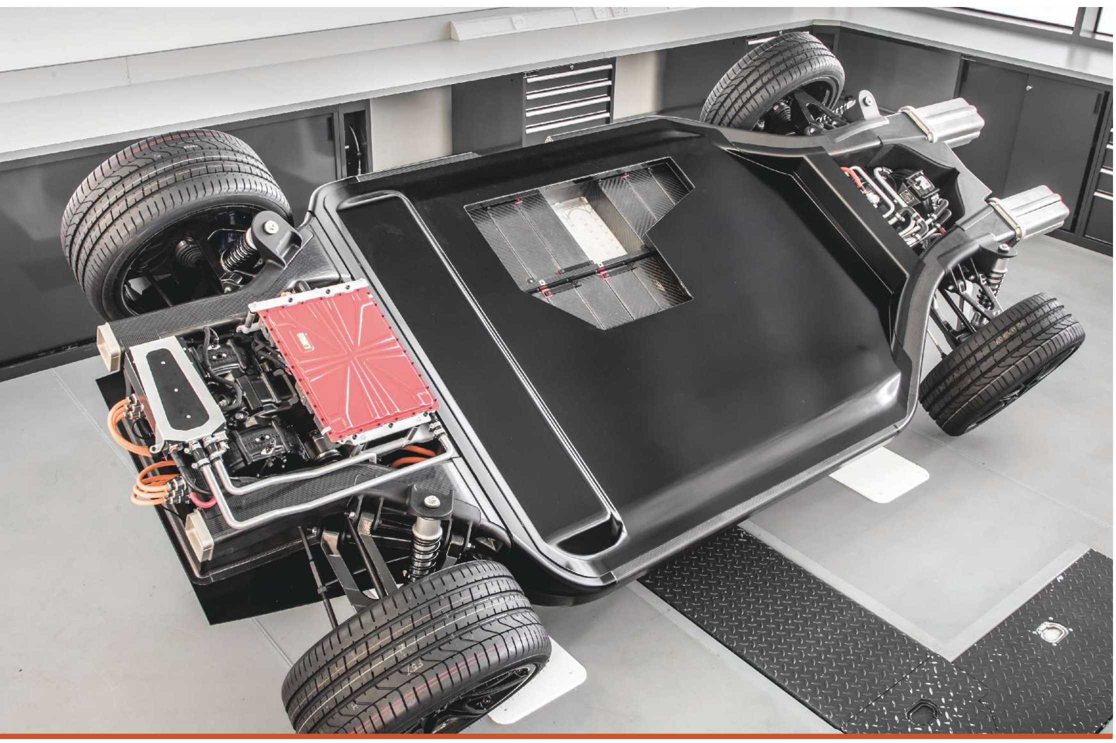
SHOWCASE

Pushing EVs forward

Multifunctional chassis design and novel composites processes enable lighter, longer-range, safer electric vehicles.

By Ginger Gardiner / Senior Editor



Scalable EV platform

Williams Advanced Engineering developed the *FW-EVX* as a lightweight, compact platform for automakers seeking next-generation technology. Its modular battery design supports multiple model types and wheelbases, while its construction processes can be scaled up for high-volume applications.

Source | Williams Advanced Engineering

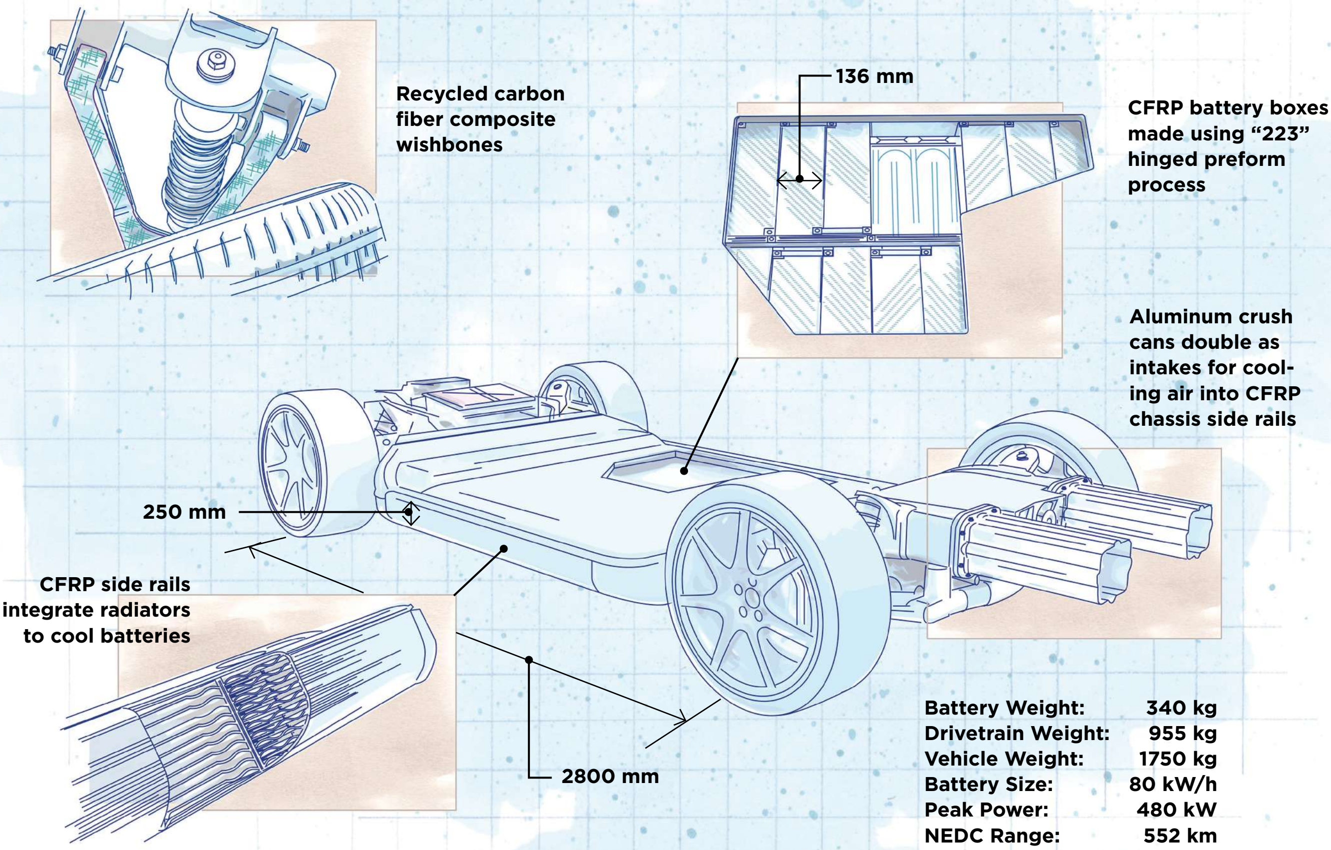
» Ongoing concerns about the harmful effects of internal combustion engine pollution, combined with advancements in battery technology — costs have dropped 50% in the past three years — are accelerating growth in electric vehicles (EVs). According to the International Energy Agency (IEA, Paris, France), the world EV fleet grew 54% to 3.1 million in 2017 and will hit 125 million by 2030. Bloomberg New Energy Finance predicts that EVs will comprise 55% of all new car sales and 33% of the global fleet by 2040.

With almost every automaker planning expanded EV portfolios (Ford recently announced 40 EVs for its global lineup by 2022), Williams Advanced Engineering (Grove, Oxfordshire, UK) unveiled its *FW-EVX* platform in 2017. Aimed at manufacturers seeking either a next-generation EV platform or simply specific areas of technology improvement, the *FW-EVX* purely battery EV (BEV) is scalable by adding or subtracting battery modules to its nominal 2800-mm wheelbase. BEVs are growing faster than plug-in hybrids (PHEVs), currently commanding 66% of the global EV market and 16 of Ford's planned models.

The *FW-EVX* pushes a standard format — central, under-floor battery pack with e-motors for front and/or rear axles — to a new level of performance by making the carbon fiber composite-intensive chassis multifunctional, integrating battery cooling and crash protection into the lightweight structure. This high level of integration creates a virtuous circle of reduced weight and aerodynamic drag, increased battery capacity and extended range, explains Williams Advanced Engineering technical director Paul McNamara.

Performance and pedigree

The drivetrain — chassis with 38 battery modules, twin electric motors in rear and one in front, transmission, differential,



DESIGN RESULTS | **Williams Advanced Engineering *FW-EVX***

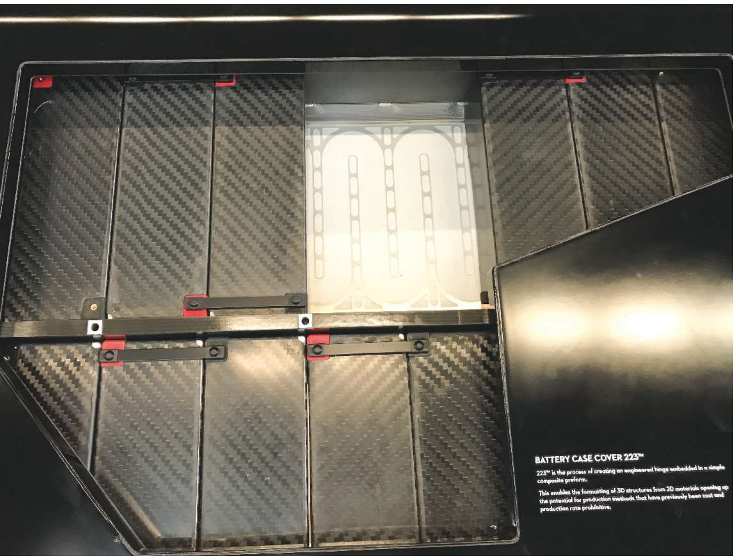
- At 955 kg, with projected vehicle weight (including bodywork) of 1,750 kg, the platform is 400-700 kg lighter than Tesla X and S Models.
- Integrated, lightweight design offers ≥552-km range and 480-kW peak power vs. 150 kW for closest competitors.
- CFRP suspension wishbones are 40% lighter yet cost-neutral vs. forged aluminum, using 80% recycled carbon fiber and RACETRAK HP-RTM process with 90-second molding cycle.

Illustration / **Karl Reque**

electronics, wheels, tires and four wishbone suspensions — weighs 955 kg/2,105 lb. With lightweight bodywork added, Williams projects a BMW *M4*-sized vehicle would total 1,750 kg/3,858 lb. This platform, with an 80-kWh battery, would deliver a New European Driving Cycle (NEDC) range of 552 km/343 miles. NEDC is a lab test used to measure vehicle fuel consumption, emissions and range. In 2017, it was replaced by the Worldwide Harmonised Light Vehicle Test Procedure (WLTP), which uses real driving data gathered worldwide vs. a theoretical driving profile. This should make it more comparable to the Environmental Protection Agency (EPA) test used in the US.

Out of 24 BEVs ranked by InsideEVs, only the Tesla *Model X P100D* and *Model S 75D* come close in performance, with a battery capacity of 75 and 100 kWh respectively, an NEDC range of 336 and 304 miles respectively, but a weight that is greater by more than 900 lb/408 kg and 1,500 lb/680 kg respectively. The Tesla *Model 3* Long Range matches the *FW-EVX* across the board, while the number one-selling Nissan *Leaf* offers a 235-mile NEDC range with a 40-kWh battery and 425 lb/193 kg less weight. (Note that Williams designed the Nissan *Bladeglider* EV.) However, nothing matches the *FW-EVX*'s peak power of 480 kW. The closest competitors, at 150 kW, are the 2018 Chevy *Bolt* (323-mi NEDC range with 60-kWh battery) and the 2019 Hyundai *Kona* (258-mile range with 64-kWh battery).

The performance of the *FW-EVX* also exceeds new, tougher standards in China, forecast as the largest market for EVs. To receive government incentives, long-range BEVs must have a range >400 km/249 miles and an energy density of 105 Wh/kg. The *FW-EVX* has a 552-km/343-mile range and more than twice the required energy density at 235 Wh/kg. »



Systems as structure

Lithium-ion batteries are housed in CFRP boxes within the chassis' monocoque battery compartment (left). Made using the 223 fold-to-form process, these exoskeletons protect the *FW-EVX's* 38 battery modules while providing torsional and bending stiffness for the chassis, enabling its CFRP side rails to be lighter. Those side rails (right) house aluminum-finned radiators, channeling air to cool the battery modules. Source | Jeff Sloan, *CW* (left), Williams Advanced Engineering (right)

This, perhaps, should be expected. Williams Advanced Engineering is, after all, the technology and engineering services sibling of the renowned Formula 1 team started by Sir Frank Williams (the FW in *FW-EVX*). Created in 2010, the Williams Advanced Engineering division opened a new facility in 2014 and now has more than 250 employees and 80 completed projects under its belt, with 40 underway.

Williams' experience in EV technology is extensive. It has developed world-leading expertise in both flywheel and kinetic energy recovery systems (KERS) for automotive, public transport and energy applications (see Learn More). As the sole supplier for the ABB FIA Formula E Championship — the world's first fully-electric international single-seater street racing series — Williams has also developed high-power-density batteries and electric motors where high-performance, endurance and predictability are non-negotiable.

The equivalent of more than 1,100 Formula E cars have traveled 240,000 miles on Williams batteries since the first race in 2014. A collision during that race also demonstrated the company's commitment to the highest safety performance. Other notable developments include a high-performance battery for VW Audi, and its leadership of the H1PERBAT consortium, chosen by the UK government to develop a hybrid battery that will deliver higher power using fewer cells that last longer and charge more quickly than current technology. In fact, Williams Advanced Engineering announced in September that it will form a joint venture with Unipart Manufacturing Group (Cowley, Oxford, UK) called Hyperbat Ltd. It will open the UK's largest independent battery manufacturing facility at Unipart's Coventry site in early 2019. The launch customer will be the limited production Aston Martin *Rapide E*.

As Williams has developed this range of EV technologies, it has also developed the trademarked and patent-pending 223 and RACETRAK composite processing technologies. Aimed at high-volume, low-cost automotive applications, these solutions were created in response to the challenge of how to maximize EV performance and efficiency. However, due to Williams' innovations in the fast processing of lightweight, carbon fiber-reinforced plastic (CFRP) structures, they are attracting interest from aerospace and wind energy companies, as well.

+ LEARN MORE

Read this article online | short.compositesworld.com/FW-EVX

Read more about Williams Advanced Engineering's fold-to-form CFRP battery boxes and HP-RTM wishbones | short.compositesworld.com/WEA

Read about the RACETRACK process in Engineering UK | theengineer.co.uk/williams-electric-vehicle-platform

Integrating systems into structure

F1 racecars are exemplars of streamlined efficiency — everything is designed to work together. Williams brings that ideal into the *FW-EVX* through a series of utilitarian yet elegant integrations.

The core of the *FW-EVX* structure is its 250-mm-thick "skateboard" monocoque, which stores the battery modules between two hollow, load-bearing, CFRP side rails (side sills). These rails also channel air from crush cans — that double as air intakes — at the front of the car through internal aluminum radiators to cool the batteries. This eliminates conventional radiators up front, minimizing the entire front structure of the car, as well as the aerodynamic drag of heat exchangers. The aluminum-finned radiators also work as controlled crush zones around the batteries, increasing impact protection.

The 38 battery modules located within the monocoque provide not only the EV's power but also structure. Each 136-mm-wide battery module contains 10 pouch-type lithium-ion batteries (think thin, as for a laptop) from LG Chem (Seoul, South Korea). Pouches are stacked and protected within a CFRP box. Each of the 38 battery module boxes are made using flat CFRP sheet and the highly automated 223 process. Portions of the sheet for the box faces are cured, leaving flexible uncured hinges in between. These hinges allow the folding of the partially cured sheet into a box, followed by final cure and bonding to produce a rigid enclosure. Each box is an impact-resistant, load-bearing exoskeleton, aiding in crash safety. The boxes are individually located and secured together to provide significant torsional and bending stiffness through the monocoque. This, in turn, handles some of the load that otherwise would be managed by the CFRP side rails, and thus, allows the design to be further lightweighted.

RACETRAK rCFRP wishbones

The *FW-EVX* uses CFRP wishbones made using unidirectional and recycled carbon fiber (rCF) in an HP-RTM process called RACETRAK. Source | Williams Advanced Engineering

rCF wishbones

The *FW-EVX* uses CFRP wishbones to cut weight 40% vs. conventional aluminum versions, yet cost is comparable to aluminum forgings thanks to the RACETRAK process. As reported in a May 2017 article by *Engineering UK* magazine, RACETRAK is based on high-pressure resin transfer molding (HP-RTM) and was developed with the National Composites Centre (NCC, Bristol, UK). The *FW-EVX* wishbone design combines three fiber formats with one resin. Unidirectional material wraps around an anchor point to increase strength with near-zero waste, while recycled carbon fiber (rCF) — up to 80% of the composite part, by weight — in the form of a nonwoven mat, helps reduce cost and increase sustainability. Epoxy and polyurethane resin are already in use for high-volume HP-RTM composite suspension parts (see Learn More). According to Iain Bomphray, Williams Advanced Engineering's chief technology specialist for lightweight structures, the rear wishbone was the thickest part ever made in the NCC's press. The resulting CFRP structural control arm (photo, above) can be molded in 90 seconds, with a 5-min total cycle time, including layup.

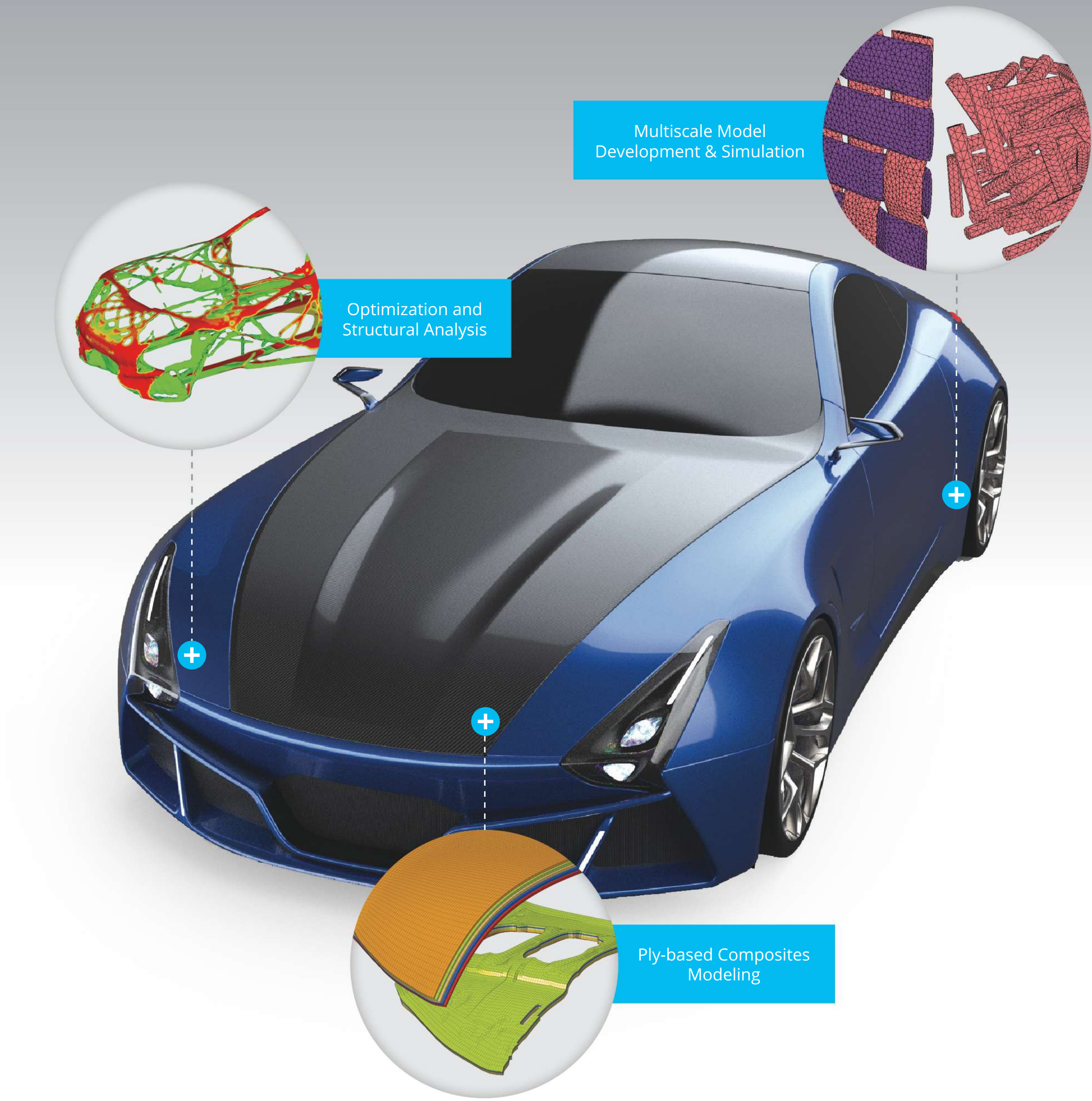
Flexibility for future development

Though it uses CFRP extensively, the *FW-EVX* platform was designed to also use aluminum in the monocoque and suspension. The materials and forming technologies selected are optimized and located to meet overall vehicle performance and efficiency goals. The platform was also designed to be flexible. For example, the battery module currently uses LG pouch cells, but can accommodate multiple battery formats. The off-the-shelf powertrain components, chosen for high performance, may also be readily exchanged for manufacturer-specified alternatives.

Meanwhile, Williams is working to further develop and test the *FW-EVX* platform. "We've applied our extensive knowledge in composites and systems to totally rethink how electric vehicles are designed and built," says Bomphray. "What sets us apart is not just our abilities in design and manufacturing, but getting all of the systems and structures to work together. We've been able to reduce aerodynamic drag and weight, as well as complexity, and invest those savings into greater power, safety and vehicle range." CW

ABOUT THE AUTHOR

CW senior editor Ginger Gardiner has an engineering/materials background and more than 20 years of experience in the composites industry.
ginger@compositesworld.com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