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DECEMBER 2019

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No 5 VOL 12

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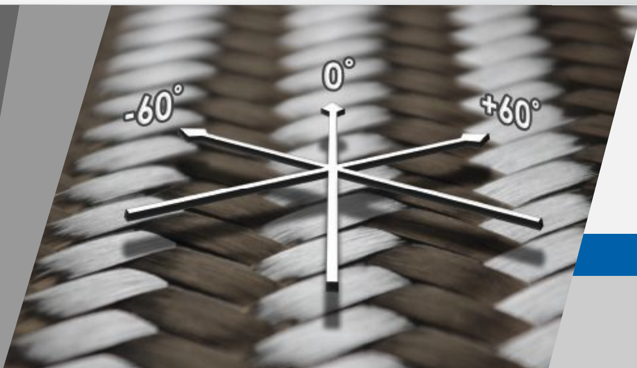

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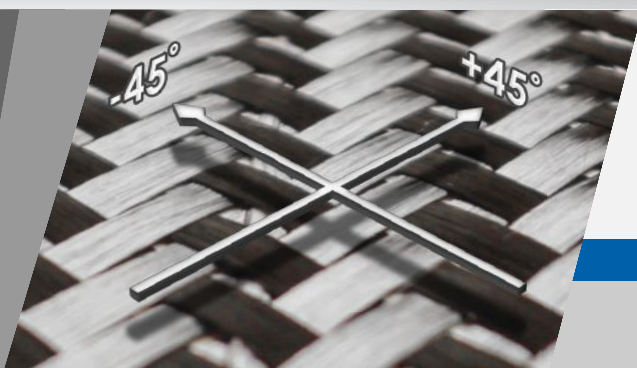

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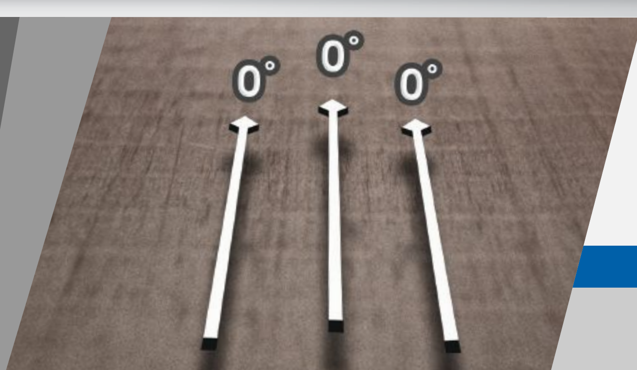

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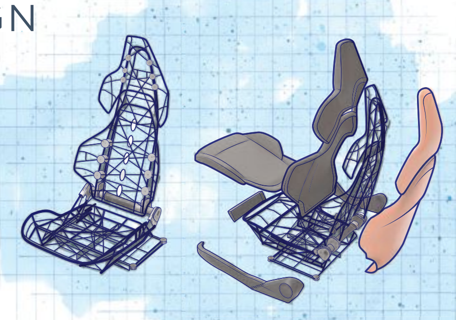
ON THE COVER

The Ultra Leichtbausitz (ULBS) seating concept was developed for future mobility applications. Shown here, the thermoset resin-impregnated fiber roving is wound around positioning fixtures, allowing fibers to be arranged to match each part's loads and desired functions.

Source / csi entwicklungstechnik

FOCUS ON DESIGN



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Spirit AeroSystems (Wichita, Kan., U.S.) announced on Oct. 31 that it had entered into a definitive agreement to acquire select assets of Bombardier (Montreal, Quebec, Canada) aerostructures and aftermarket services businesses in Belfast, Northern Ireland; Casablanca, Morocco; and Dallas, Texas, U.S., for cash consideration of $500 million. The Bombardier operations to be acquired (the deal will likely close in early 2020) employ more than 4,000 people and comprise approximately 3.4 million square feet. The backlog of work includes long-term contracts for the Airbus A220 and A320neo, along with Bombardier business and regional jets. Perhaps most significantly, the acquisition includes Bombardier's A220 composite wing fabrication operations in Belfast.

> Is a shift occurring in the aerospace supply chain hierarchy?

I will discuss why this is important, but first, a little refresher. Bombardier's commercial aircraft division spent much of the mid-2000s developing the *CSeries* aircraft, a single-aisle jet that was delivered in two configurations — one with a range of 3,400 nautical miles and 100-120 capacity, and one with a range of 3,350 nautical miles and 120-150 capacity. As soon as the plane was introduced, however, it ran into problems, mainly in the form of objections from Boeing, which filed a trade complaint in 2017, alleging that the subsidies provided to Bombardier by the Canadian government gave Bombardier an unfair advantage with the *CSeries* in the single-aisle market. Although the U.S. International Trade Commission ultimately ruled against Boeing, there was clearly tension building over the importation of Bombardier aircraft.

Bombardier's solution was to sell the *CSeries* to Airbus in 2018. Airbus then announced that the *CSeries* would not be assembled in Canada, but at the Airbus final assembly line in Mobile, Ala., U.S. — the plane, therefore, would become a product of American manufacturing. Airbus also renamed the *CSeries* to the A220.

However, Bombardier's commercial aerospace manufacturing facilities in Belfast, Casablanca and Dallas were not part of the sale of the *CSeries* to Airbus. Bombardier held onto these, but announced earlier this year that it was interested in divesting the Belfast and Casablanca locations. The list of potential buyers was short, and Spirit AeroSystems was at or near the top, so this acquisition does not come as a surprise.

The Belfast operations (there are actually six plants in Belfast) are notable because Bombardier manufactures there the composite wings for the A220. More importantly, these composite wings are made via liquid resin infusion, followed by a short cycle of autoclave consolidation. Composite wings for the Boeing 787 and 777X and the Airbus A350 are all fabricated using autoclave-cured prepregs. The use of infusion, therefore, represents a departure from the norm and, possibly, a harbinger of things to come. Because of this, the A220 wings are, arguably, the most important part of Spirit's acquisition.

Why? This puts Spirit AeroSystems squarely in the middle not only of current A220 wing production, but wing production for *future* single-aisle replacement programs as well — liquid infusion is an attractive process for high-rate aircraft production and is being aggressively developed by both Boeing and Airbus for next-generation commercial aerostructures, particularly wings.

Consider as well the work that Spirit is doing to develop next-generation composite fuselage structures. Last summer, at the Paris Air Show, Spirit introduced ASTRA (Advanced Structures Technology and Revolutionary Architecture), its demonstrator fuselage panel for single-aisle aircraft production at rates of 60 shipsets per month minimum. The panel is fabricated with autoclave-cured epoxy prepreg, but Spirit told me that it has also done work on a thermoplastic composite version as well. This is important because much of Spirit's current manufacturing capacity is devoted to fabrication of the aluminum fuselage for the Boeing 737. That plane will eventually be replaced, as will much of the aluminum fabrication capacity associated with it.

Spirit AeroSystems' acquisition of Bombardier's Belfast operations signals a major shift in the aerospace supply chain hierarchy. Further, it signals that Spirit AeroSystems sees itself as a vital part of a future in which composite materials and processes dominate *all* of the major structures manufactured for commercial aircraft.

JEFF SLOAN — Editor-In-Chief

The Rubik's Cube of working efficiently with different composite materials

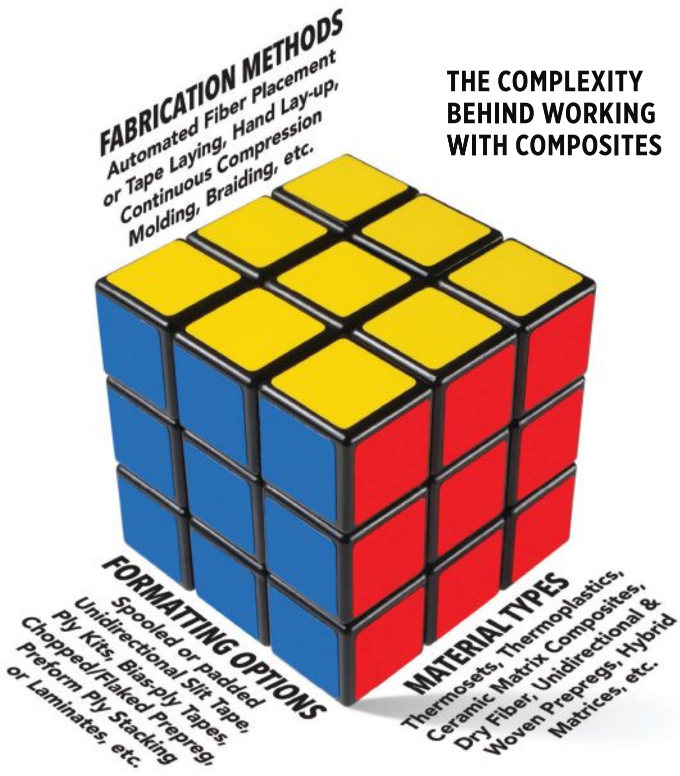
In the race to scale up production to meet commercial aircraft demand, there is no single way to make the best airplane. As aerospace OEMs consider all of their material and processing options, they will continue to find innovative applications for both thermoset (TS) and thermoplastic composites (TPC), not to mention other choices such as dry carbon fiber fabrics and ceramic matrix composites (CMC).

Determining the optimal combinations of materials and processes to build each part, with the required performance and quality, and at the lowest total cost of acquisition (TCA), can be like solving a Rubik's Cube. Each supply chain partner collaborates with the OEM to align a different side of the cube, with the overall goal of delivering a safe, high-performing, fuel-efficient, comfortable aircraft to the airline, on time and profitably.

> For every aircraft component and part, there is a cascading set of considerations.

Paradigms are constantly shifting as advanced materials and manufacturing techniques evolve. For every aircraft component and part — be it a wing, fuselage, stringer, interior part or engine — there is a cascading set of considerations. What materials are viable for the application? What are the different ways it can be formatted — for example, as wide-format rolls, plies, spooled slit tape, chopped flake or bias ply? What layup technology is compatible with the formatted material — such as hand layup, robotic layup (in the form of automated tape or fiber placement), preforms or closed compression molding?

Each material and process (M&P) path brings exciting possibilities to the table. Ceramic matrix composites offer the ability to replace metals in high-temperature applications. Thermoplastics are garnering a lot of interest with their recyclability, weldability, fast processing and overall material handling simplicity. They remain stable at room temperature and aren't as susceptible to environmental contaminants in the workplace as thermoset materials. Dry fabrics also give manufacturers freedom from refrigerated storage and open additional processing options. And, of course, thermosets continue to provide a tried-and-true solution for high-quality, consistent part formation — with well-established costs and proven scalability.



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Leveraging core competencies

One could argue that excellent execution is as important as the chosen M&P path itself. After all, it does no good to save cycle time by using an out-of-autoclave (OOA) solution if a ply ends up missing or is laid up in the wrong order, and the whole manufacturing process must be restarted. When each supply chain partner can focus on its specialized role and core competencies, with an understanding of how that role achieves the end product objective, everyone wins.

For example, an effective formatting partner should be able to deliver different materials custom-tailored to the requirements of the aircraft manufacturer or tiered supplier — with better quality, faster speed and lower TCA than could be achieved in-house. Today, this often includes slitting, spooling, knife cutting, waterjet cutting, machining, chopping, preform ply stacking or kitting of materials, in formats ready for downstream automated, semi-automated or manual fabrication processes.

An outsource manufacturing partner also can help OEMs experiment with different M&P options before scaling up to a high-volume, mass-production solution. With a robust, outsourced formatting infrastructure at their disposal, aircraft manufacturers have access to the manufacturing equivalent of a gym membership in which to “work out” theories, rule out what doesn’t meet expectations and ramp up what works, at a fraction of the cost and trouble it would take to set up their own “gym” or testing facility.

OEMs and tiered suppliers have the opportunity to outsource their material’s information management to formatting partners. Such management includes predictive analytics for vendor-managed inventory programs, automated prepreg out-time tracking and management of material testing and qualification data.

By investing in equipment, technologies and associates dedicated to these capabilities, material formatters free their supply chain partners of these responsibilities, allowing them to focus resources on their core competencies. And when the innovators of aircraft design and assembly can focus on doing just that, the sky’s the limit in terms of what next-generation aerospace advances they will come up with next! CW

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Ben Winters is general manager for Web Industries Inc. — CAD Cut Services, and has more than 25 years of experience in working with aerospace customers. Web Industries is a precision formatter of carbon fiber composites and other materials used in aerospace manufacturing. Winters and the Web team engage with OEMs and tiered suppliers early in product development to devise formatting solutions optimized for the customer’s mix of materials, machines and manufacturing processes. He can be reached at **bwinters@webindustries.com.**

Corvette: A multi-material success history

» The prevailing narrative in the composites community for the past decade is that the "vehicle of the future" will be multi-material — some combination of steel, aluminum and composites in the body panels and structure. At the Society of Plastics Engineers Automotive Composites Conference and Exhibition (SPE ACCE) in Novi, Mich., U.S., this September, attendees were treated to a display of the new 2020 Chevrolet *Corvette* (also designated *C8*, denoting the eighth generation version of the model), alongside a cutaway vehicle showing how truly multi-material — and multi-process — this car is.

In fact, the *Corvette* has been a multi-material vehicle since its inception in 1953, a legacy that goes back 66 years. General Motors (GM, Detroit, Mich., U.S.) designer Harley Earl created a sports car design aimed at competing against British and Italian designs. To save tooling costs, GM elected to produce all of the body panels, including the floorboards, from hand-laid fiberglass composites. Molded Fiber Glass Co. of Ashtabula, Ohio, was selected to manufacture the bodywork, with 300 vehicles built by hand in Flint, Mich., over a rolling steel chassis. Production was moved to St. Louis, Mo., the next year, and to Bowling Green, Ken., in 1981. Maximum production of the *Corvette* occurred in 1979 at 53,807, and has fluctuated between 20,000 and 40,000 since — all well above historical production levels for composites-intensive cars from other manufacturers.

> The *Corvette* has always been GM's platform for award-winning new materials and processes.

The *Corvette* has always been GM's platform for award-winning new materials and processes, and an industry leader in composite body panel technology. Hand layup was replaced by liquid compression molding in 1968, making the panels lighter and thinner. Sheet molding compound (SMC) debuted on the car in 1973, paving the way for SMC use across the industry to this day. Successive improvements in SMC also found their way onto the *Corvette*. While at Dow Chemical, I worked with GM back in the mid-1980s to qualify the first low-density SMC (1.3 versus traditional 1.9 specific gravity), enabled by the addition of hollow glass microspheres, for the floor and other non-appearance parts of the *Corvette*. Multiple iterations of low-density SMC, including for exterior Class A panels, have entered production since. The *C8* debuts the first ever SMC and liquid compression molding materials that float on water — they have a specific gravity of less than 1.0 — in the front and rear truck storage areas.

GM's initial foray into carbon fiber body panels was the hood on the 2004 Le Mans Edition of the *C5*, a program I was also involved in and that used autoclave curing for the outer panel and a hybrid glass/carbon SMC inner panel. The *C6 Z06* model introduced in 2006 had carbon fiber fenders, wheel liners and floorboards. The *ZR-1* version of the same vehicle added a carbon fiber hood and splitters. With the *C7 Stingray,* GM equipped all *Corvettes* with carbon fiber hoods and introduced a carbon fiber removable roof, which carries over to *C8*, although the *C8* reverts to a low-density SMC hood.

The *Corvette* was the first passenger car to get a fiberglass composite leaf spring — a transverse rear monoleaf spring produced via filament winding and compression molding — in 1981. For the *C4* introduced in 1984, GM added a front transverse spring, which allowed for a lower hood line. This suspension design was carried forth through the *C7* models, a run of 35 years. The *C8* mid-engine design eliminates the composite springs, yet the early *Corvette* success led GM to put composite springs on minivans in 1985, luxury vehicles in 1986 and on millions of mid-size cars from 1988 to the mid 1990s.

The *Corvette* has also pioneered advances in bumper systems, employing the first commercial bumper beam made from glass-mat thermoplastic (GMT) in 1984. By the 1990s, more than 16% of passenger cars worldwide used a GMT bumper beam, with a number of vehicle models globally employing the technology still. In 1989, GM switched the *Corvette* bumper beam to structural reinforced injection molding (SRIM), using a Dow polyisocyanurate, which led to SRIM beams on GM minivans at volumes of 115,000 per year, and eventually to the production of the SRIM Pro-Tec box used on GM pickups from 2001 to 2003.

The *C8* introduces a new technology and material into the rear bumper beam: a curved *pultruded carbon fiber* beam from Shape Corp. (Grand Haven, Mich., U.S.) that weighs more than 60% less than the aluminum extrusion used in the *C7*. Shape uses technology licensed from curved pultrusion technology developer Thomas Technik + Innovation (Bremervörde, Germany). Are we likely to see this technology proliferate in other bumper systems and at other OEMs? Based on the history of the *Corvette*, my guess is we will. 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 contracts on weak exports

October 2019 — 48.3

» Registering an October reading of 48.3, the Composites Index signaled a further contraction in business activity. Index readings above 50 indicate expanding activity, while values below 50 indicate contracting activity. The further away a reading is from 50, the greater the change in activity. Gardner Intelligence's review of the data found that in October 2019, total new orders expanded, while export orders contracted at its fastest rate in more than three years.

In addition to new orders, the Index also reported expansionary readings for production and employment; however, contractionary readings for supplier deliveries, exports and backlogs pulled the Index — calculated as an average of its components — lower during the month, resulting in the contractionary reading.

The combination of expanding total orders and contracting exports implies that domestic orders expanded briskly in October. Despite this, strongly contractionary backlog readings in the second and third quarters of the year suggest that some of the strength behind recent production readings may be from a reduction in backlogs rather than the fulfillment of new orders. In its September column, Gardner Intelligence stated its concern over the potential for weak future supplier delivery readings given the recent trends in production and orders data. October's supplier delivery reading fell more than five points and registered its first contractionary reading since late 2016. CW

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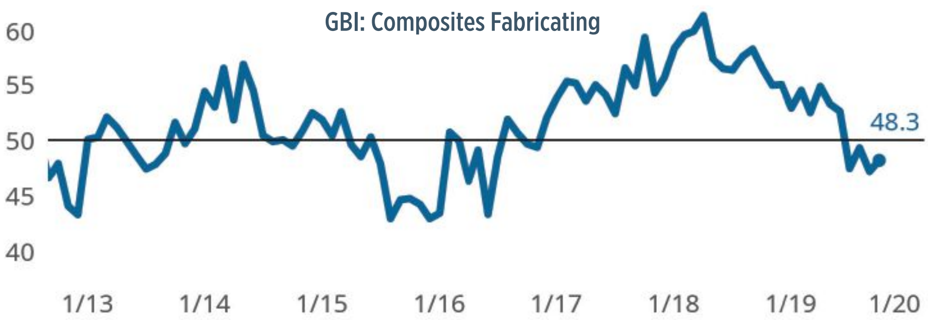
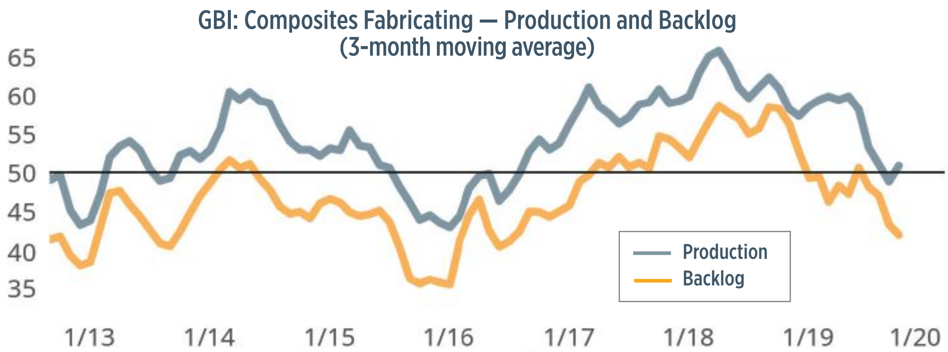


Fourth month of contracting activity

The Index contracted during October as expanding activity in new orders, production and employment were insufficient to offset contracting activity in supplier deliveries, exports and backlogs.



Falling backlogs are stabilizing production activity

Despite growing activity in domestic orders, the overall data suggest that fabricators are heavily relying on their backlogs in order to maintain stable production levels.

This month's composites industry trends include a Q&A featuring recycled composites company Vartega, the use of composites to enable NASA all-electric aircraft, new composite technologies from this year's SPE Automotive Innovation Awards and more.

Q&A with Andrew Maxey, Vartega

CW Editor-in-Chief Jeff Sloan talks to Andrew Maxey, CEO and founder of Vartega, a Colorado-based carbon fiber recycler. Maxey started Vartega five years ago in his garage as a newcomer to the composites industry. Since then, he's developed a chemical-based carbon fiber recycling and recovery process, has grown his company and recently moved into a new 10,000-square-foot facility in Golden, Colo., U.S.

They discuss carbon fiber waste, carbon fiber recovery and the still-growing market for recovered fibers. To listen to the full interview, go to **compositesworld.com/podcast** *or download CW Talks on Google Play or iTunes.*

Q: What is Vartega and how does it fits into the carbon fiber recycling supply chain?
A: We thought up Vartega about five years ago, and we're focused on carbon fiber recycling, specifically manufacturing and industrial scrap, keeping post-industrial carbon fiber out of the landfill. We work with companies throughout the value chain to do that, and we like to find homes for the recycled carbon fiber downstream as well.

Q: Can you define "industrial scrap" for our audience?
A: Initially, our technology development was around uncured prepreg materials. When we got started, we were focused on prepreg for aerospace applications, and as many of your audience know, the scrap from manufacturing of composites using prepreg can be quite high, typically about 30%. Those are the materials we focus on, though certainly end of life and cured composites are important as well, and we've got some work we're doing on those materials in the future. But what we realized is that there's such an abundance of these uncured materials that that was a great place for us to start.

Q: Would it be fair to say that your process is most amenable or adaptable for uncured prepreg, or do you feel like you can work on either side of the process chain?
A: Today we're definitely focused on uncured prepreg, and the thermoset systems, so typically epoxies, vinyl esters, BMIs — those are the materials that we're recycling on a day-in, day-out basis. That being said, we've done some proof of concept work on cured composites as well and are looking forward to continuing that development over the next couple of years.

Q: Your process is based on a solvolysis technology?
A: Yes, we've actually described it more as just a chemistry-based process. We do use industrial solvents for our recycling, but we also have a whole suite of chemistries and other processing conditions that allow us to do it.

Q: I want to talk more about recycling in a second. But first, let's talk more about you and how you got to this point. Tell us a little bit about how this got started five years ago. How did you decide to create Vartega and enter this part of the composites industry?
A: My interest in composites came from the sporting goods industry. I'm not a material scientist. I don't have a background in polymer chemistry. I have a passion for sports and I worked in a bike shop. Carbon fiber composites in the late 1990s were the big deal — they made bikes stronger and lighter, which meant that cyclists could go faster. That was intriguing to me. There was also a bit of an epiphany point for me, when I was working in the bike shop. I had a customer come in one day, and they had unfortunately had their carbon fiber bike on the roof rack on the top of their car, and they had driven it into their garage and trashed the frame. They brought it in, and regrettably, there's nothing we could do for them to warranty the frame. [...] I ended up with that frame and took it home and cut it apart to better understand what carbon fiber was, and I realized that this composite material was much different than metals like steel and aluminum that had been used in the cycling industry for a long time. [...] In fast forward, I'd gotten a degree in mechanical engineering and had done work with custom equipment, and also worked for a startup company. And we were doing work on low-value textiles, like natural materials like cotton and wool, as well as synthetics like polyester. And I realized that carbon fiber was just a high-value textile. After that company, I got into oil and gas and realized that we could use some of the processing techniques from the oil and gas industry to create a process to recycle carbon fiber. At that point, I didn't realize how big of a deal that would be, but I did a lot of market research and came to recognize that there was this unmet demand for low-cost carbon fiber downstream. And that's what led to Vartega.

Q: It's been about five years that you've been in business. What do you think are the biggest lessons you've learned so far?
A: One of the things that was important to me and to our team when we started the company was bringing the right folks on and having the right people involved in the process. It's something we knew from the beginning, but our leadership team's understanding of that has been

further reinforced. We've been so fortunate to bring on some amazing, talented people that have diverse backgrounds and diverse perspectives, from a technical standpoint as well as a personal and business standpoint. And that's allowed us to solve problems that I think have been difficult for the industry to solve in the past, and I think that will allow us to continue to develop and grow and address some of the outstanding challenges that we still face. We definitely have learned a lot about our team and about building a team and enabling our team to go out and solve these difficult problems.

Q: What's your assessment of the carbon fiber supply chain in general? I'm just wondering what your observations are about carbon fiber use and the application of carbon fiber in the fabrication of structures.
A: When I look at carbon fiber, I see immense opportunity because of all of the organizations involved, all the players involved. [...] There are a lot of different branches, I would say, of carbon fiber composites. And for us, for Vartega as a recycler, we really had to understand how to cut across the entire value chain to identify where we can make the biggest impact. In the upstream side, that's figuring out who we can recycle for and how we can help them reduce their costs and reduce their landfill burden, so they can improve their sustainability. On the downstream side, we want to help our customers improve their products either through performance improvement or lightweighting, especially for critical applications like transportation. Cost is always the driver of that. We've come to better understand that over the development of Vartega, and that's something that I think has been pretty profound for us, recognizing our strengths and where we can make some of the biggest impacts.

Q: You've said that one of the goals of your technology is the preservation of fiber continuity. That is, that you wanted a system that gives the customer the opportunity to salvage the fiber without having to chop it up, which is an unfortunate byproduct of some recycling technologies. I'm wondering why you think that's important, to maintain fiber continuity?
A: The opportunities for continuous carbon fiber are quite broad. And oftentimes, when talking to customers, they'll have great applications and ideas, but discontinuous or chopped carbon fiber doesn't always fit with those applications and ideas. [...] The recyclers that are out there have done a great job of demonstrating discontinuous carbon fiber and the applications for it. I think we're seeing a growth in those areas, especially with thermoplastics. If we consider all the work that goes into making a virgin carbon fiber tow, a continuous tow, and then just to chop that up to put into thermoplastics, it's really unfortunate. It's a lot of energy going into something that we have better sources of material for. That's the frame of reference we have today, to focus on those applications where the feedstocks are available. And we have discontinuous carbon fiber scraps available for recycling that are well-suited for those discontinuous applications like thermoplastics for injection molding, for example.

Q: Can you summarize for us what the fiber forms are that you are producing, or the kinds of processes you're targeting with your fiber?
A: We do a chopped carbon fiber. We can also produce and offer a milled carbon fiber, but the bulk of what we're doing today is a chopped carbon fiber for reinforcement and thermoplastics, and typically, relatively short chop length. What we're doing that's unique is we've developed some intellectual property around consolidating

Source | Vartega

that carbon fiber and getting it into a format that's easy for our customers to use. We're putting sizing back on, we're optimizing those chemistries for the resin systems and in base polymers that the fibers are going to go into.

Q: You're working on another product that calls for the development of a modular carbon fiber recycling cell, and you're calling it "hardware as a service." This is something that the customer would install at their facility to process uncured carbon fiber prepreg. How did you develop this model, and what's been the reaction?
A: [...] What we've hit upon with the hardware as a service model is locating the recycling close to the source of the supply. That reduces the logistics, and it's something that's enabled by our chemistry-based approach and our technology [...] and provides a very easy way for [our customers] to reduce their landfill burden.

AEROSPACE

NASA makes progress with all-electric experimental aircraft

The Mod II configuration of NASA's X-57 *Maxwell*, the agency's first all-electric X-plane, upon delivery to NASA's Armstrong Flight Research Center in Edwards, Calif., U.S. in October. Source | NASA

The first all-electric configuration of NASA's X-57 *Maxwell* experimental aircraft, which was delivered in October to the Armstrong Flight Research Center in Edwards, Calif., U.S. for ground testing, is intended to help develop certification standards for emerging electric aircraft markets, including urban air mobility (UAM) vehicles.

The project's goal is to further advance the design and airworthiness process for distributed electric propulsion technology for general aviation aircraft, which can provide multiple benefits to efficiency, emissions and noise.

The X-57's Modification II (Mod II) vehicle, the first of three configurations as an all-electric aircraft, features the replacement of traditional combustion engines on a baseline Tecnam P2006T aircraft, with electric cruise motors. While X-57's Mod II vehicle undergoes ground and then flight testing, preparation efforts for the project's Mods III and IV phases are also reportedly underway.

According to Jeff Viken, research scientist at NASA

CW MONTH IN REVIEW

Notes about newsworthy events recently covered on the *CW* website. For more information about an item, key its link into your browser. Up-to-the-minute news | www.compositesworld.com/news/list

GE Haliade-X 12 MW turbine blade delivered for testing
The 107-meter offshore wind blade will undergo fatigue testing at the Wind Technology Testing Center in Boston, Mass., U.S.
11/5/19 | short.compositesworld.com/Haliade_MA

Spirit AeroSystems to acquire select assets of Bombardier aerostructures, aftermarket businesses
The deal, expected to close the first half of 2020, includes Bombardier facilities in Belfast, Northern Ireland; Casablanca, Morocco; and Dallas, Texas, U.S.
10/31/19 | short.compositesworld.com/SA_acquire

Kordsa works with Ford Otosan to develop composite leaf springs for heavy trucks
A prepreg compression molding prototype achieves 75% weight savings while boosting performance.
10/31/19 | short.compositesworld.com/KordsaFord

OceanGate to build two new deep-sea submersibles
The company is planning construction for two new carbon fiber composite submersibles, Cyclops 3 and 4, to be rated for 6,000 meters.
10/31/19 | short.compositesworld.com/Cyclops3_4

Solvay opens thermoplastic composite centers in U.S. and Belgium
In addition to two new centers, Solvay has signed an agreement with Lockheed Martin and several Belgian companies to grow aerospace composites in Belgium.
10/29/19 | short.compositesworld.com/Solvay2019

4M Carbon Fiber, Montefibre Carbon to partner for carbon fiber production
The companies plan to form a U.S.-based joint venture that combines 4M's low-cost production technology with Montefibre's ultra-large-tow carbon fiber PAN precursor.
10/22/19 | short.compositesworld.com/MF_4M

Hexagon awarded fuel systems order for hydrogen buses
The Solaris Urbino 12 hydrogen buses will reportedly have a driving range of up to 350 kilometers on one fill, with weight savings of 20% compared to previous models.
10/23/19| short.compositesworld.com/Hexagonbus

GKN Aerospace delivers RTM demonstrator tool for Wing of Tomorrow
The 4-meter mid-scale tool enables large-scale use of resin transfer molding to manufacture a composite wing spar with reduced costs and weight.
10/22/19 | short.compositesworld.com/GKNAero

Stajvelo e-bike built with Solvay long-fiber thermoplastic material
An injection-molded composite e-bike features thermoplastic composites.
10/21/19 | short.compositesworld.com/Stajvelo

Covestro uses Maezio thermoplastic composites for prototype future mobility interiors
A recently unveiled premium concept focuses on multifunctional design, comfort and light weight.
10/18/19 | short.compositesworld.com/Maezio_int

Langley Research Center (Hampton, Va., U.S.), the aim of the X-57 project is to be able to fly at a 150 KTAS cruise speed on 30% less power than the original aircraft of the same model — a Tecnam P2006T — and also gain the benefits of the efficiency of electric propulsion.

"To reduce airplane drag and increase efficiency, the Mods III and IV wing has been reduced to 42% of the wing area of the original Tecnam aircraft, while still flying the same mission at a slightly greater weight," says Viken. "The wing aspect ratio has been increased to 15, and the electric propulsion motors are located at the wing tips to reduce the induced drag. The thickness of the small X-57 wing is only 4.5 inches at the root."

According to Viken, the project demanded a unique wing structural design, and some of the latest innovations in materials are being used. The wing primary structure consists of an all-composite construction built by Xperimental LLC (San Luis Obispo, Calif., U.S.). Three spars make up the backbone of the wing with a mid-chord main spar designed to take all the primary bending loads. The fore and aft spars help stiffen the wing in bending and torsion and provide hard points for the nacelles and flaps. All spars are constructed from Hexcel (Stamford, Conn., U.S.) high-temperature and pressure-cured prepreg IM2A unidirectional carbon fiber, with a Patz Materials and Technologies (Benicia, Calif., U.S.) PMT-F4 epoxy resin system.

To increase the torsional stiffness of the narrow chord wing, the skins are made of Hexcel's HexTow HM63 carbon fiber, which is said to be the highest tensile strength, high-modulus carbon fiber available. The ±45-degree skin fiber is nonwoven, noncrimped biaxial cloth produced for maximum material properties. The epoxy resin used for the skins is the MGS L285 (Hexion, Columbus, Ohio, U.S.) resin system. The wing tip nacelles and the nacelles for the distributed spanwise propulsion will be constructed from Toray (Morgan Hill, Calif., U.S.) T700SC plain weave bi-directional carbon fiber fabric.

NASA plans to share the experimental aircraft's electric-propulsion-focused design and airworthiness process with regulators and industry to aid in the advancement of certification approaches for aircraft utilizing distributed electric propulsion.

"NASA's X-57 *Maxwell* project is broader than the development of an electrified airplane," says Viken. "In addition to the project's main goal of developing certification standards for emerging electric aircraft markets, NASA is trying to also demonstrate that when you integrate electric propulsion technology into a vehicle design, that you can better optimize the vehicle."

AUTOMOTIVE

Composites gain prominence at SPE auto plastics parts competition

The Automotive Division of the Society of Plastics Engineers (SPE, Bethel, Conn., U.S.) recently concluded two rounds of judging on its 49th annual Automotive Innovation Awards Competition. On Nov. 6, the group held its 49th annual Automotive Innovation Awards Gala in the Detroit suburbs, where its members handed out trophies to finalists, category winners and the Grand Award winner, which were selected after prequalification and two rounds of judging by industry experts and members of the media.

This year, winning nominations and their development teams were honored by SPE in the categories of additive manufacturing, aftermarket and limited-edition/specialty vehicles, body exterior, body interior, chassis/hardware, environmental, materials, powertrain and process/assembly/enabling technologies. Additionally, SPE gave out awards to its Hall of Fame, Lifetime Achievement and Vehicle Engineering Team Award winners.

For a full list of winners, see **short.compositesworld.com/SPEaward19**.

While not every composite part entered in the competition always survives to win its category or the Grand Award, many of these nominations are remarkable for the way materials science, process development and engineering innovation were combined to create a new part that either did something previously impossible in alternative materials or that greatly improved on the functionality, mass, packageability and cost of similar parts in benchmark materials — usually metals. This year's competition featured a significantly larger than usual number of composite entries representing a wide range of different composite materials and process technologies.

For example, General Motors (GM, Detroit, Mich., U.S.) nominated nine parts in five categories — all of them innovative and composite, and all from the 2020MY *Corvette*. The technologies included a beryllium-graphite filled sheet molding compound (SMC) with a vinyl ester matrix that was formulated and molded by Molded Fiber Glass Cos. (MFG, Ashtabula, Ohio, U.S.) for the vehicle's rear bulkhead window frame to not only survive heat right over the mid-mounted engine, but also to deaden sound.

MFG also formulated and compression molded a 1.2 specific gravity (SG) toughened SMC with both carbon and glass fiber reinforcement in an unsaturated polyester/vinyl ester (UP/VE) matrix for the rear surround frame. Both front and rear storage trunks on the *Corvette* sport low-density (0.9 SG) SMC (in fiberglass-reinforced UP/VE matrix) from MFG. The material floats on water, permits tall walls with deep-draw sides to be molded without issue, and saved both cost and 4.5 kilograms of mass. A slightly heavier (0.95 SG) toughened UP/VE SMC was formulated by MFG for rear induction ducts that eliminated the need for resonators and are said to be the first such ducts to be integral to the body frame.

Aerospace technology in the form of filament winding was used to produce the inner reinforcing structure on this sports car liftgate. The technology was not only fast enough to meet automotive production volumes but also was said to be ideal for difficult packaging and load cases. Source | SPE Automotive Division

An injection molded glass/PA 6/6 bracket on the rear differential module developed for the 2020 *Jeep Cherokee* replaced aluminum at lower mass and cost and better NVH. The composite had to meet stringent requirements and provide seamless integration into then-current production. Source | SPE Automotive Division

Among the largest parts in this year's competition (163 by 175 by 61 centimeters) was this compression molded SMC rear surround frame, which forms the dimensional foundation for all rear exterior and interior panels on the 2020MY Chevrolet *Corvette* sports car, providing the flexibility to build multiple model variants off a single design. Source | SPE Automotive Division

The radius-pultrusion process was used to produce the auto industry's first curved pultruded composite bumper beam for the rear of the *Corvette.* Shape Corp. (Grand Haven, Mich., U.S.) produced the parts using a carbon fiber-reinforced polyurethane-acrylate matrix. The curved beam better matches rear styling and package space and is assembled to the body-in-white.

A liquid compression molded (LCM) composite underbody tunnel closeout contributes 10% or more to the vehicle's torsional rigidity in this tunnel-dominated architecture. Normally, composites are used to reduce mass, but in the case of the precision wheel-balance system used on the *Corvette*, a unique high-density (5.8 SG) composite featuring extruded fluoropolymer reinforced with post-industrial, corrosion-resistant steel alloy with tailored magnetic properties is used. Reportedly, the continuous tape-based wheel weights can be dispensed in smaller increments of weight, improving ride and reducing tire wear, halving assembly time, lowering costs and replacing metallic wheel weights in steel, zinc and lead.

The *Corvette* wasn't the only composite-intensive GM vehicle in the competition. The automaker also nominated its CarbonPro carbon fiber-reinforced thermoplastic composite pickup box on the 2019MY GMC *Sierra Denali* and *AT4* pickups, which took home the competition's overall Grand Award. Continental Structural Plastics, a Teijin co. (Auburn Hills, Mich., U.S.), was the molder and tier integrator.

In addition, Hyundai Motor Co. (Seoul, Korea) has established a reputation for developing innovative and unusual polymeric materials to solve tricky engineering problems. This year, the company was back with polypropylene (PP) door panels on 2017MY Hyundai *Elantra* sedans that were reinforced with glass wool. The filler, which involves recovering fiberglass insulation from the construction industry and grinding it with sand, is said to improve long-term scratch resistance and dimensional stability, while reducing mass and cost. Seoyon E-Wha (Seoul, Korea) was molder/tier integrator and toolmaker.

A unique composite liftgate inner reinforcement structure on 2020MY Toyota *Supra* sports cars by Toyota Motor Corp. (Toyota, Japan) replaced steel at lower mass and coefficient of linear thermal expansion (CLTE) but higher stiffness/weight ratios and dimensional stability. It is produced by Magna International Inc. (Aurora, Ont., Canada) in filament wound polyurethane (PUR)/fiberglass composite (with PUR cores and skins).

An innovative composite brake pedal on 2020MY Porsche *911* sports cars and *Taycan* electric vehicles from Volkswagen AG (Wolfsburg, Germany) also was nominated. It's produced by Boge Rubber & Plastics (Damme, Germany) using unidirectional thermoplastic tapes, long-fiber thermoplastic (LFT) and fiberglass fabric-reinforced organosheet — all with a polyamide 6 (PA6) matrix. By replacing LFT/organosheet with the tape/LFT/organosheet combination, mass was reduced, driving haptics were improved and cost was neutral or lower, depending on model.

Another innovative Boge part was nominated on 2020MY Jeep *Cherokee* sport-utility vehicles (SUVs) by FCA NA LLC (Auburn Hills, Mich., U.S.), and replaced diecast and machined aluminum on the front bracket of the rear differential module. Injection molded in 50% glass fiber-reinforced PA 6/6, the part reportedly saved $1 per vehicle, while reducing mass 30%, but also eliminated corrosion and provided 10 times higher damping, which, in turn, improved noise/vibration/harshness (NVH), and significantly reduced tooling costs over the life of the program.

Kordsa expands into composites market

Kordsa (Istanbul, Turkey) has a long history supplying cord products to the global tire market, but it has only recently entered the composites marketplace. And since doing so, the company's composites footprint has grown substantially.

Kordsa's strategic shift to composites began in 2016 with the establishment of a $30 million Composite Technologies Center of Excellence in Turkey to research, develop and assess composite materials and processes, drawing on knowledge and experience from academia, students, chemists and process engineers.

Then, in mid-2018, Kordsa acquired Fabric Development Inc. (FDI, Quakertown, Pa., U.S.) and Textile Products Inc. (TPI, Anaheim, Calif., U.S.), both technical fabrics manufacturers with close ties to the aerospace market. More recently, in early 2019, Kordsa acquired Advanced Honeycomb Technologies (San Marcos, Calif., U.S.), followed in mid-2019 by the acquisition of Axiom Materials (Santa Ana, Calif., U.S.), a prepregger and ceramic matrix composites specialist also tightly woven into the aerospace supply chain.

If you detect a pattern in these acquisitions, it's because there is a pattern. Murat Arcan, COO composites at Kordsa, says the firm sees significant potential for growth in composite intermediates and is determined to build a robust enterprise focused on that part of the composites supply chain.

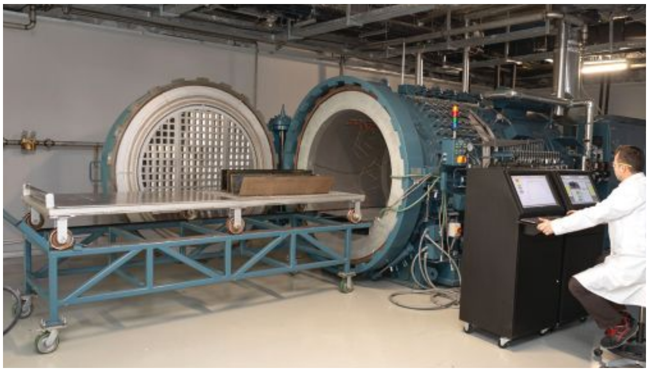
Arcan notes that Kordsa, which is 46 years old, became a major tire cord supplier by investing heavily in materials and manufacturing expertise, and established manufacturing operations in the U.S., Brazil, Indonesia and Thailand. He says the company is among the world's largest tire cord suppliers, serving an industry where the material qualification process can range from three to eight years. Sound familiar?

Kordsa, he said, made the decision in 2015 to diversify and started looking at adjacent industries in which it could leverage its materials, process and supply chain expertise. "The chemical know-how in our tire cord technology led us to composites," Arcan says. Aerocomposites were particularly attractive, he says, primarily because the material qualification cycle in that industry is so similar to the tire industry's. Kordsa, he says, also saw opportunities in the automotive and industrial markets.

The work done at Kordsa's technical center, in the Composite Technologies Center of Excellence, helped the company identify the composites industry supply chain segments, and where it might fit in. "With the power of the Composite Technologies Center of Excellence, a pioneering model in industry-university cooperation, we can go from idea to product under one roof," Arcan says of the facility, noting that the company's research helped it identify fabrics reinforcements, core materials and prepregs as attractive product types. "We want to develop a pipeline of companies in Europe and the U.S. focused on intermediates in aerospace and automotive," he says.

Construction of that pipeline began with the acquisition of FDI and TPI, which, Arcan says, gave Kordsa access to the composites-intensive Boeing 787 program. Then, with the acquisition of Axiom, Kordsa expanded its reach into aircraft engines. "If you are in aerospace, you have to be in engines as well," he says, adding, "The competency the company has built the last 16 months is second to none."

Kordsa testing lab. Source | Kordsa



Kordsa's autoclave capability. Source | Kordsa

Long term, Arcan says Kordsa wants to build a critical mass of composite intermediate products suppliers and become a "reliable business partner" to carbon fiber manufacturers and aerospace OEMs alike. Arcan argues that carbon fiber manufacturers, in the past, were forced to build prepreg capability in order to meet the quality requirements of their customers. Kordsa, he says, wants to remove that burden.

Indeed, it's clear that Kordsa wants to position itself as a major link in the supply chain for the next generation of commercial aircraft sure to enter the market in the next decade, including single-aisle replacements for the Boeing 737 and the Airbus A320. "I hope, going forward," Arcan says, "that if the decision is to stay with composites [in aircraft manufacturing], then we are very well positioned."

All of Kordsa's acquisitions have been in the U.S. so far, but Arcan says to expect similar activity in Europe in the near future, with Asia also on the long-term horizon. "We want to create a second Kordsa in composites," Arcan states. "We are not done."

Overmolding on the cheap

An innovative injection/compression overmolding approach combines smaller injection-molded inserts with compression-molded parts.

By Scott Francis / Senior Editor

Fibrflex laptop cover

This laptop cover features an injection molded perimeter that is consolidated with a preform made of Fibrtec's Fibrflex thermoplastic carbon fiber towpreg in the compression mold to form the completed cover. Additional small features for another part of the laptop were formed in the center of the mold, making full use of the tool.

Source | Fibrtec

» Injection overmolding of unidirectional fibers and preforms is an attractive process for many good reasons. It's fast, consistent and repeatable, and it can be performed with a machine that is relatively easy to acquire, program and control. Injection molding's disadvantage, however, is it requires tooling that is typically very expensive — certainly more expensive than tools for compression molding. Further, overmolding requires that the composite be encapsulated within the tool, and if it's a larger part, that means larger tooling. Add it all up and the cost of composites overmolding can exceed its benefits.

Robert Davies, CEO of Fibrtec (Atlanta, Texas, U.S.), has developed an interesting solution to this particular overmolding dilemma. His system uses a hybrid injection/compression overmolding process of his own design to combine smaller injection molded parts or inserts within a larger compression molded part. In essence, the approach flips the script on the overmolding strategy. Rather than injection mold around a composite preform, Davies' solution involves compression molding around an injection molded part.

"What [Fibrtec] decided to do was injection mold the bosses, features, ribs and those kinds of things, and position them in place into the same compression molding tool that the laminate was going to be consolidated in," says Mike Favaloro, president and CEO of composites consultancy CompositeTechs LLC (Amesbury, Mass., U.S.), who spoke about the process at the Composites Overmolding conference in Novi, Mich., U.S., in 2018.

"Since you have to consolidate the laminate anyway, why not consolidate the laminate with the injection molded parts in place?" he adds.

In Fibrtec's process, the ribs, bosses and similar features are injection molded offline using thermoplastic resins, lower-cost tooling and conventional injection molding machines. The injection molded insert is then robotically placed in a compression mold with a preform.

"You can make the inserts for the compression molded part fairly inexpensively and rapidly," says Davies. "The key is putting the preform in the compression tool with inserted injection molded features."

Fibrtec's typical thermoplastic compression molding process uses a preform made of its

Fibrflex thermoplastic towpreg and a heated compression mold. Fibrflex is composed of resin-coated individual tows that are woven or braided, and then cut to the general shape of the tooling to form the preform.

For the injection/compression overmolding process, injection molded features are placed into holes or slots in the compression mold for precision indexing. The Fibrflex fabric preform is then placed into the mold, where it is heated to process temperature and pressure is applied. After a short time — seconds to minutes depending on the application — the part is cooled and ejected.

"The inserts are made of the same resin that is in the composite, so when they're melted and pressed together, they become homogeneous," explains Davies.

When it comes to resin systems, Fibrtec has used polyetheretherketone (PEEK), polycarbonate/acrylonitrile butadiene styrene (PC/ABS) blend and polyamide (PA) 6 for the process.

Davies' approach allows for the injection molding of these parts to be executed on a small, inexpensive machine at a fraction of the cost of the larger, more specialized injection molding machines that would be needed to enclose an entire composite assembly in order to overmold it. In addition, features such as bosses and ribs can be grouped in the injection molding tool, allowing for multiple parts to be created during each mold cycle either as multiples of the same part or as groups of parts. According to Davies, the smaller inserts can be injection molded several times a minute, whereas injection molding the whole part on a larger, special-purpose machine could take several minutes for one part.

For larger parts, the process makes a lot of sense. The approach allows injection molding to be used for what it does best, namely making small, highly detailed, discrete features on small, inexpensive machinery. The actual overmolding occurs during the compression process in a way that takes advantage of what compression does best — consolidation.

Davies says he originally developed this process in 2008 using carbon fiber and PA 6 to create a laptop cover. The customer's original design was for an all injection molded part, but a more durable cover was needed for tech service field work, which prompted Fibrtec's compression overmolding solution. However, one of the caveats for the project was that the housing could not be reconfigured because of how the electronics were integrated within the part. The composites would have to be adapted to the original housing design and incorporate the injection molded features.

"The old adage applies — necessity is the mother of invention," Davies quips.

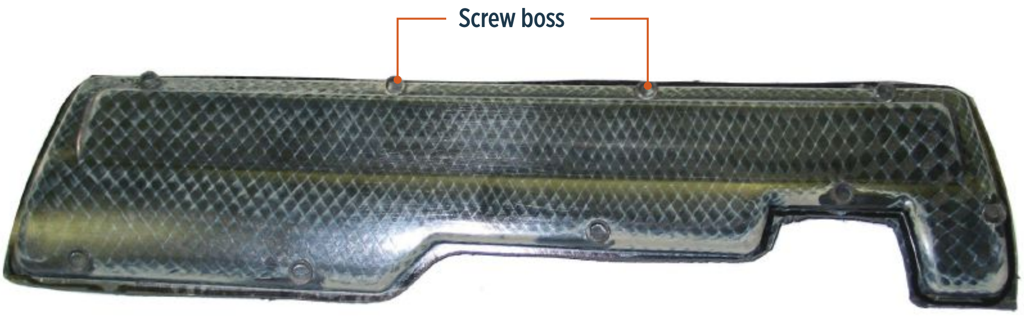
For the laptop project, Fibrtec used a couple of molds for the injection molded features. One mold made several groups of parts, such as the screw bosses and other smaller features. The parts were cut from the runners and kitted for the composite compression molding operation later. Another

■ **Consolidation through compression molding**

Injection molded bosses, ribs and features are positioned in place in the compression molding tool with the laminate during consolidation. Source | Fibrtec

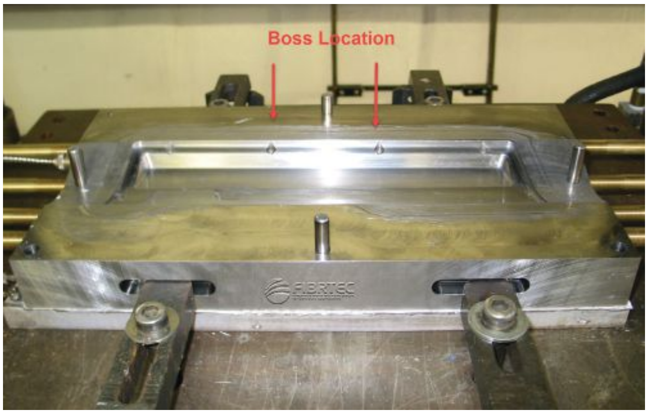
■ **Putting the pieces together**

The runners in the injection molded insert (top) are removed and the part is compression molded with the Fibrflex thermoplastic composite material (below) to form the finished component. Source | Fibrtec



Injection molded screw boss insert

The screw boss insert (bottom right) was injection molded and then consolidated with the composite laminate during the compression molding stage. Source | Fibrtec



mold was used for the perimeter portion of the back side of the LCD. The perimeter was molded in one piece with additional small features formed in the center portion of the mold, making full use of the tool. The additional features were cut from the runners and kitted prior to transferring to the compression molding operation. The injection molded inserts were then consolidated along with the laminate in the compression mold. The laptop is said to have successfully endured six-axis drop tests from up to 6 feet.

Fibrtec's injection/compression composite overmolding process reportedly offers significant advantages over conventional injection overmolding, including reduced cycle time, reduced tooling cost, increased tailorability, reduced scrap and improved performance. Fibrtec also claims that the weld between the two materials is as good or better than what can be accomplished with injection overmolding.

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Additional advantages include the ability to put reinforcement selectively where it is needed, minimizing cost impact and reducing scrap. The injection mold runners can be left on the insert assembly after the injection molding step and can serve as additional material for the compression-overmolding step to create a "functional surface." In other words, the runners can form ribs.

Fibrtec has gone on to use the process for military applications. For example, Davies says it was used to create a side cover for the XM25 Counter Defilade Target Engagement System (CDTE), a 25-millimeter grenade launcher used by the U.S. Army. PEEK was used for the composite matrix and for the inserts in the part. The company also used the process to create an improvised explosive device (IED) detector, using PA 6 for the resin system. A metal version of the handheld ground penetrating radar system weighed around 16 pounds, while Fibrtec's injection/compression overmolding process yielded a 6- to 7-pound composite version.

While Fibrtec isn't employing the process in any of its current projects, Davies hints that he might use it again, should the need arise.

"You do get a high-performing part," he says. "The resin inserts and the composite do become homogeneous. You can make the inserts faster with this process, freeing the injection presses for other work. The compression molding can also be rapid, and the overall cost of tooling and capital expenditure can be less, perhaps ideal for intermediate volume applications. It all boils down to enabling design flexibility, lowering cost and increasing performance." CW

ABOUT THE AUTHOR

Scott Francis, senior editor for *CompositesWorld*, has worked in publishing and media since 2001. He's edited for numerous publications including *Writer's Digest*, *HOW* and *Popular Woodworking*.

Carbon fiber/epoxy for automotive mass reduction, mass production

IACMI precompetitive research explores carbon fiber-reinforced prepreg, SMC with novel matrix for structural passenger car applications.

By Peggy Malnati / Contributing Writer

Finding solutions for automotive composites

IACMI Project 3.2 evaluated carbon fiber-reinforced composites infused with a novel epoxy-based resin system to develop structural composite parts with complex geometry to replace metals in highly loaded, safety-critical applications on primary body structures of high-volume passenger vehicles. One of the first applications evaluated was use of a carbon fiber/epoxy prepreg on the B pillar of a test vehicle. The high-performance prepreg material directly reduced mass by 3 kilograms and enabled down-gauging of surrounding sheet metal. Source | Ford Motor Co.

» Automakers in most geographies face challenging 2025 mandates on reduced tailpipe emissions and/or improved fuel economy for passenger vehicles. However, developing fundamentally new automotive technology to meet these requirements is costly, so consortia to allow supply-chain members to share costs for precompetitive research are being used in many countries.

In the U.S., one such organization is the Institute for Advanced Composites Manufacturing Innovation (IACMI—The Composites Institute, Knoxville, Tenn., U.S.). Among the organization's initiatives, IACMI members from industry, academia and government work on multi-pronged projects — involving integrated materials/process development, modeling/simulation, multi-material joining and recycling — to solve engineering problems, improve vehicle mass, reduce energy consumption and emissions and create new U.S. jobs.

Project 3.2 and the impossible resin system

Project 3.2 was one of the first projects IACMI took on when it formed in June 2015, although technology used in the project had actually begun development a few years prior to IACMI's creation, with a collaboration between Ford Motor Co. (Dearborn, Mich., U.S.) and what was then Dow Automotive

Two workstreams to application readiness

More recently, Project 3.2 has focused on carbon fiber-reinforced SMC with the novel epoxy for structural/inner panels on both a decklid (left) and a liftgate (right). Although the project is now ending, it has produced interesting technology that is commercial-ready and points to areas where further work is needed. Source | Ford Motor Co.

(now The Dow Chemical Co., Midland, Mich., U.S.). When IACMI formed and Project 3.2 started, Ford and Dow brought their previous work on a novel epoxy resin system into the program. Once joined with IACMI, the program broadened to eventually include several phases representing new uses for this innovative resin: a prepreg B pillar, an all-sheet molding compound (SMC) decklid and an SMC/aluminum liftgate.

Called VORAFUSE, the resin family developed by Dow for Ford is designed for use in prepreg and SMC, and to process on compression molding equipment, which is widely available in the North American auto industry. Per Ford's requirements, the resin's glass-transition temperature (T_g) is 150-160°C, it molds at 145-155°C, and it cures in less than two minutes at 150°C (although sub-1-minute cure is available), making it fast enough for high-volume (100,000-plus/year) vehicle production. It achieves post-mold cures of more than 95%. The system is free of solvent and volatile organic compounds (VOCs).

"The CTQs [critical-to-quality requirements] defined by Ford are unique and have never been achieved in a single commercial product before," explains Dave Bank, fellow, Dow Polyurethanes R&D. "For this reason, novel chemistry and a host of highly non-traditional products were required to meet these demanding specs."

"The thermodynamic separation of shelf stability and polymerization in the resin/curative blend yields a dry paste that can be infused into carbon fiber without advancing cure and yielding a dry, non-tacky molding compound," adds Bank. "Yet, when molding conditions reach 150°C, the chemistry is 'hot' and cure advances quickly." Dow submitted 21 patent applications and so far has been granted four for the technology.

Phase 1: Prepreg B pillar

After VORAFUSE was brought into Project 3.2, IACMI began work on an automotive application that would become Phase 1 of the overall project. Team members included Ford, Dow, DowAksa US LLC (the Tucson, Az., U.S.-based arm of DowAksa B.V., a 50/50 joint venture between Dow Chemical and Aksa Akrilik Kimya Sanayii A., Çiftlikköy-Yalova, Turkey); Michigan State University (East Lansing, Mich., U.S.); Purdue University (West Lafayette, Ind., U.S.); University of Tennessee-Knoxville (Knoxville, Tenn., U.S.); Continental Structural Plastics (CSP, Auburn Hills, Mich., U.S.); and Oak Ridge National Laboratory (Oak Ridge, Tenn., U.S.). »

A closer look at the SMC liftgate

An exploded view of the SMC/aluminum liftgate (with metallic hardware) for the five-door/hatchback version of the Ford *Mondeo*. Source | Ford Motor Co.

In the first phase, researchers developed continuous (braided and non-crimp fabric) carbon fiber-reinforced prepreg impregnated with the epoxy. VORAFUSE P6300 resin was formulated for compatibility with DowAksa A42 D012 24K standard-modulus carbon fiber. The team's goal was to use the carbon fiber/epoxy prepreg to develop structural composite parts with complex geometry to replace stamped metal in highly-loaded, safety-critical applications on primary body structures of high-volume vehicles.

For the technology demonstrator, the B pillar on one side of a Ford *Fusion* test vehicle was used. Viability was first evaluated via simulation and then physical parts were molded and subjected to all required tests — including full-scale vehicle crashes. Parts passed with flying colors, reducing mass by 3 kilograms per side compared to incumbent metals. Uncured scrap was recycled to form the pillar's complex rib structures. The high-performance composite allowed for down-gauging of surrounding sheet metal, which could then be specified in less costly alloys, offering additional weight and cost savings.

Having passed all of Ford's requirements, the material's first commercial use was for a front roof header and a front floor closeout panel on the carbon composite-intensive Ford *GT* supercar.

Not surprisingly, the carbon fiber/epoxy prepreg carries a cost premium, so is best for vehicles with significant mass-reduction mandates that can pay a premium for significant weight savings opportunities.

Phase 2/Workstream 1: All-SMC decklid

Building on the prepreg successes, project researchers next explored discontinuous carbon fiber-reinforced SMC with the novel epoxy resin in complex 3D structures that featured safety-critical functions. In one demonstrator, the carbon fiber/epoxy SMC was used as the inner/structural panel of a bonded decklid (trunk lid), and in another demonstrator it was used for the inner/structural panel of a much larger and more complex bonded liftgate (rear hatch/door containing window glass, wiper motors, lights, etc.). In both

SIDE STORY

Additional features of the VORAFUSE system

- It is shelf-stable at room temperature for 50-plus days but offers snap-cure at or above 150°C. It doesn't require freezer storage prior to kit cutting and molding as long as storage temperature doesn't exceed 40°C.
- Its tack-free chemistry is ideal for automated handling. Because it lacks the stickiness of traditional prepreg, it won't cause buildup and related issues with robots and other automated-handling equipment.
- It contains a novel internal mold release (IMR) agent so processors can mold 1,000 parts before having to apply external mold release to tool surfaces. Epoxy normally is antithetical to IMR because it's such an effective adhesive for metals.
- Uncured product can be recycled into high-value parts by chopping and feeding material back into molding systems as a discontinuous fiber-reinforced compound that's ideal to mold complex geometries like ribs/bosses. Unlike conventional epoxy prepreg and SMC, all uncured scrap can be reused, making the material more sustainable and saving scrap losses that increase part costs.

workstreams, original design constraints, hardware, joining techniques and structural adhesives were left unchanged. Challenging mechanical targets of more than 300 MPa tensile strength and more than 40 GPa tensile stiffness — comparable to incumbent cast magnesium and aluminum — were used. SMC also needed higher flow than prepreg, so a slightly different grade, VORAFUSE M6400, was developed.

For the decklid demonstrator, which represented an incremental advancement over current glass fiber/SMC technology, the carbon fiber/epoxy SMC replaced conventional structural fiberglass-reinforced unsaturated polyester SMC for a decklid inner on a *Lincoln MKS* prototype vehicle. The carbon fiber/epoxy SMC inner panel was bonded to a low-density (LD, 1.25 SG) glass fiber/polyester SMC outer panel, which replaced a standard-density (1.9 SG) glass fiber/polyester SMC incumbent. Both old and new outer-panel materials were Class A compatible. Original tooling was reused to mold both carbon fiber/epoxy SMC inner and the glass fiber/polyester outer panels. Shrink — while slightly different between both resin systems — was close enough not to cause fit and finish issues (in other words, no significant dimensional changes were observed).

Virtual prototyping subjected the bonded assembly to a number of challenging load cases, including torsional rigidity, front corner stiffness, waterfall deflection and latch loads. Dozens of inner and outer panels were next molded, bonded and tested — including challenging 89-kilometer-per-hour rear impacts. Assemblies passed both virtual and physical testing without issue.

> Project 3.2 is now wrapping up but has produced interesting technology, some of which is commercial-ready.

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Decklid mass was reduced 30% (from 10.5 to 7.33 kilograms) versus the benchmark. However, had budgets allowed the inner panel to be retooled — which could have been designed thinner given its higher mechanical performance compared to the incumbent — then researchers calculate that mass could have been reduced at least 35% with 2-millimeter walls, and even further with 1.5-millimeter walls.

The carbon fiber/epoxy SMC passed all Ford requirements and now can be used on commercial platforms, although cost would be higher than with conventional glass fiber/polyester SMC.

Phase 2/Workstream 2: SMC/aluminum liftgate

For the last project, researchers turned to a truly challenging scenario: replacing lightweight metal with carbon fiber/epoxy SMC to produce a hybrid (metal/composite) bonded assembly for larger and more complex liftgates on Ford *Mondeo* five-door/hatchback test vehicles. To minimize changes to vehicle-build sequences, researchers designed the assembly to be added to the body-in-white (BIW) prior to electrophoretic rust-coat (E-coat) treatment and associated paint-bake cycles.

Carbon fiber/epoxy SMC replaced magnesium for structural/inner panels that were bonded to incumbent aluminum outer panels. Since new tooling had to be created to produce the composite panel, the part was redesigned. Panel thickness was varied according to stiffness/strength requirements and to add ribbing. Also, metallic reinforcements were used in high-load attachment areas for gas struts, latches, hinges and locks, all of which made the composite panel somewhat thicker — something that package space allowed.

These multi-material assemblies were subjected to demanding requirements, including torsional and bending loads, lateral stability, corrosion resistance, long-term durability and rear-crash tests. They also had to meet stringent dimensional-stability requirements with respect to margins and flushness.

While the hybrid system easily passed most requirements, there were fit and finish issues owing to coefficient of linear thermal expansion (CLTE) mismatches between composite inner panels and aluminum outer panels, which led to residual-stress buildup in bonded joints and panel distortion after cool down. Subsequent work with Purdue University's simulation team focused on improving predictions of modulus, strength and cure kinetics for the 1K epoxy adhesive (chosen for its ability to survive E-coat temperatures) in hopes of reverse-engineering an adhesive that would work better. Warpage was reduced an order of magnitude, but slightly missed the target. Several solutions are possible: a 2K/room-temperature-cure or induction-cure adhesive could be tried or a new high-temperature adhesive could be developed. Longer term, replacing aluminum with carbon fiber composite on the outer panel would eliminate the problem, as would producing the liftgate offline and adding it later in the vehicle-build sequence. However, both options add cost.

Project 3.2 is now wrapping up but has produced interesting technology, some of which — the B pillar prepreg and SMC decklid — is commercial-ready, and some of which points to areas where further work is needed.

"Working with IACMI and our industrial and academic partners allowed us to dive much more deeply into technology from first principal, to develop foundational science and draw upon a much broader knowledge base than we could have done alone," summarizes Project 3.2 Leader Patrick Blanchard, technical leader-advanced polymer systems, Ford research & innovation. "We look forward to identifying new commercial opportunities and R&D activities to continue working with our IACMI partners." CW

ABOUT THE AUTHOR

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Removing the barriers to lightweighting ships with composites

EU consortia propel large demonstrators, new technology and affordable certification.

By Ginger Gardiner / Senior Editor

FIBRESHIP hull demonstrator

This 20-tonne section of an 85-meter fishing research vessel measures 11 by 11 by 8.6 meters and reduces weight 70% compared to steel. Designed in composites by Technicas y Servicios de Ingeniría (TSI), this demonstrator is part of the FIBRESHIP project, fabricated to prove design and production capability for lightweight marine vessels more than 50 meters long.

Source | FIBRESHIP, TSI

» Glass and carbon fiber-reinforced polymer (GFRP and CFRP) composites have been used to build marine vessels for decades, including numerous 40- to 60-meter minehunters and even larger vessels, including the Swedish Navy's 72-meter-long Visby Class Corvette and the 75-meter-long sailing yacht *Mirabella V*. The 141-meter motor yacht *Swift 141* (renamed *Yas*) is a Dutch steel frigate rebuilt using GFRP/CFRP in below-deck soles and three-deck superstructure (see Learn More), including a composite-to-steel deck joint.

And yet, composites are rarely used in shipbuilding. This is mainly due to the Safety Of Life At Sea (SOLAS) regulations issued by the International Maritime Organization (IMO, London, U.K.), which required that

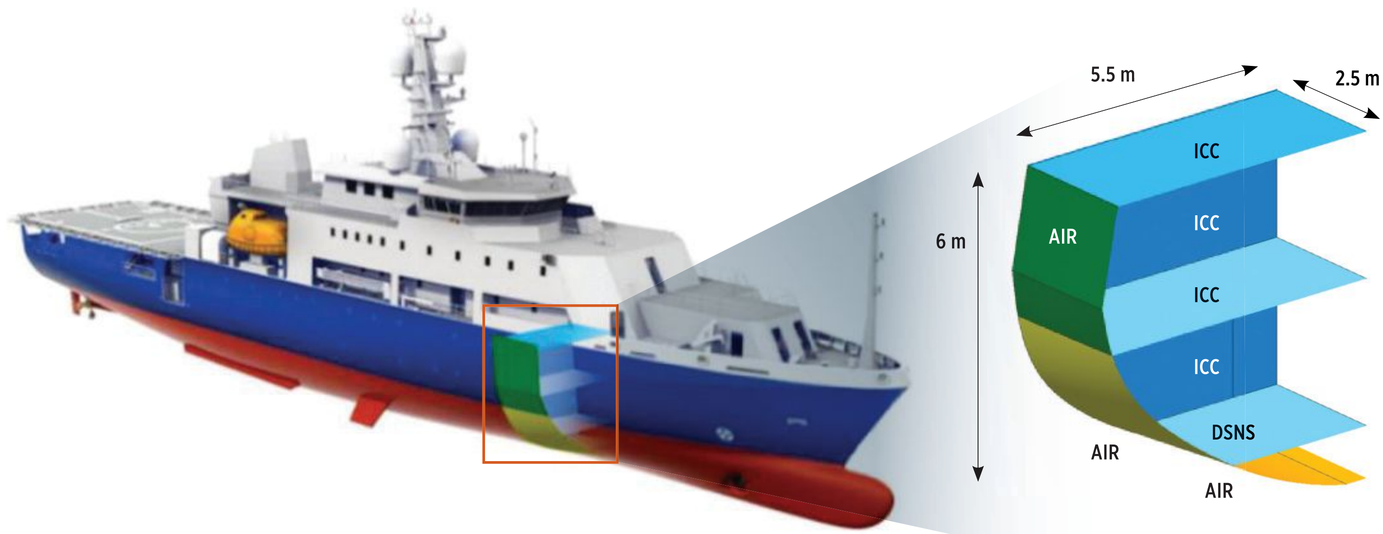


FIG. 1 RAMSSES 80-meter composite vessel

Damen Shipyard (DSNS) is developing an all-composite offshore patrol-type vessel in the RAMSSES project. Its 6-by-6-by-3-meter full-scale hull section demonstrator will be built in 2020 using resin infusion in collaboration with InfraCore Co. (ICC) and Airborne International (AIR). Source | Damen Shipyard and RAMSSES

commercial ships be built in steel until the MSC/Circ. 1002 was issued in 2002 permitting alternative designs.

"The regulation mandates a risk analysis to be performed, showing that the alternative design and construction is equivalent to steel," explains Stéphane Paboeuf, head of the Composites Materials Section of the classification society Bureau Veritas (BV, Nantes, France). "This process is long, expensive and the final decision could still be negative." Thus, although composites offer many advantages for shipbuilding, the challenges of fire safety and regulations have posed barriers to use.

Meanwhile, ship owners, operators and builders are seeking solutions for improved sustainability, including lighter weight to reduce fuel use, greenhouse gas emissions and vessel draft — the latter for shallow inland waterways. Composites' inherent corrosion resistance to curtail maintenance is also attractive.

In 2017, IMO issued MSC.1/Circ., a new set of guidelines for using FRP composites in commercial ships. As IMO's evaluation of these guidelines in 2021 draws near, an amazing amount of activity is taking place. Two European consortia, FIBRESHIP and RAMSSES, supported by the 378-member European network for Lightweight Applications at Sea (E-LASS), are leading this wave of demonstration projects, which includes composite decks, rudders, hulls, modular cabins and superstructures, patch repairs to steel and composite-to-steel welded joints. Together, they aim to overcome the barriers for lightweight composite ship construction by not only demonstrating the fire and structural performance of large structures and whole vessels, but also by developing new routes for certification and production methods, new joining technologies and design tools. They are also sharing information via ongoing workshops, knowledge repositories and materials/design databases. A new market may be opening for marine composites, but what solutions will it require?

FIBRESHIP and RAMSSES

FIBRESHIP and RAMSSES were started in June 2017, funded by the European Union's Horizon 2020 program. FIBRESHIP has 18 members and will run until May 2020, while RAMSSES has 36 members and ends in May 2021. Both include companies from across the supply chain spanning R&D centers, universities, materials and technology suppliers, parts fabricators, ship architecture and engineering firms, shipyards, ship owners and classification societies. The latter are responsible for developing specific rules for individual ship builds based on IMO's general guidelines. They are authorized by flag states (each ship bears a country's flag) to audit ship construction and ensure these rules are followed. "It is important that all of the stakeholders and end-users are involved," says Alfonso Jurado, head of R&D at Tecnicas y Servicios de Ingeniería (TSI, Madrid, Spain) and FIBRESHIP project coordinator.

"FIBRESHIP's main objective is to develop design and production capability for large marine vessels (more than 50 meters long) with less weight," Jurado continues. "This is also the main motivation for my company." TSI is designing the composite structure of an 85-meter length overall (LOA) fishing research vessel (FRV), which will serve as a demonstrator and, so far, achieves almost 70% reduction in structural weight versus the steel reference vessel. "This is amazing, offering the real possibility of help for the shipping sector," he says. A 20-tonne section of this FRV, measuring 11 by 11 by 8.6 meters (see image, opposite page), was constructed by partner iXblue shipyard in La Ciotat, France, and exhibited at FIBRESHIP's second public workshop in June 2019 (see Learn More).

Jurado explains that the FRV is the first of three general composite ship cases FIBRESHIP is developing. The next two are 260-meter LOA container ships and 204-meter ROPAX, the latter combining the cargo capacity of a roll-on/roll-off vessel with the » passenger facilities of a ferry. "The FRV was chosen as demonstrator because it is smaller with a more conventional marine structure, and thus the most feasible to be built in the near future," he says. "Ship owners have also shown a real interest in such a vessel." Meanwhile, RAMSSES has 13 demonstrators in progress, 10 of which include composites, and is also pursuing an all-composite vessel.

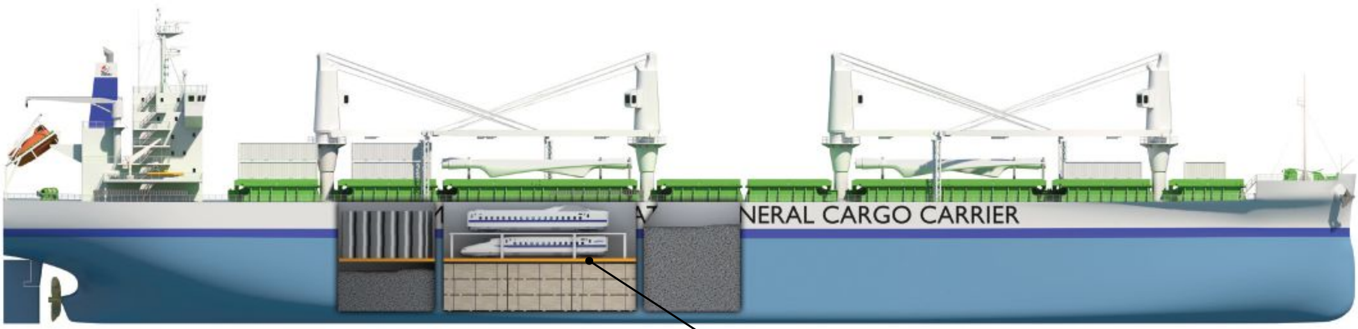
Jurado notes that the companies participating in these projects see the potential for such novel designs and new lightweight products to provide a competitive advantage for their businesses as well as each country's shipping industry. But progress won't be secured by large demonstrators alone. "We must also have support from the regulatory authorities," he adds. "A first step is to engage IMO and adapt the current SOLAS regulation to the new requirements and demands of the shipping industry. Without this, we cannot go forward, because insurance companies will not underwrite the fiber-reinforced composite ships if they do not fulfill minimum requirements and the certification of safety, for example."

"FIBRESHIP is pursuing a long-term approach by developing new rules, while RAMSSES is developing a short-term approach by using existing rules and methods," explains Paboeuf at BV, which is the only classification society partner in RAMSSES, and one of three in FIBRESHIP alongside Lloyd's Register (London, U.K.) and RINA (Genoa, Italy). "In RAMSSES, we are developing a Fast Track to Approval (FTA) procedure based on reusing project data to standardize tests and provide guidance for design and approval." This procedure is to be simple and easily readable by shipyards, naval architects and suppliers. Acceleration versus the current process will come through supports being developed in RAMSSES demonstration projects, including:

- a database of pre-approved solutions and materials test results to avoid repetitive testing,
- fire risk scenarios covering a range of similar applications to limit the number and extent of risk assessments, and
- analysis and modeling tools, including numerical or statistical models that may replace physical testing in the future.

"In FIBRESHIP, we are working with Lloyd's Register and RINA to develop a set of prescriptive rules specifically for large vessels built with composites," Paboeuf continues. "For structural performance, we are defining new safety coefficients for local and global loads." RAMSSES and FIBRESHIP also propose to replace the current fire rating levels such as A60, B30 and B15 with a new convention REIxx, where R specifies fire resistance (load-bearing capacity in fire), E designates integrity (the prevention of smoke and flame spread) and I defines fire insulation. "The goal is to better align the structural fire ratings with the composite materials being used," explains Paboeuf.

In addition, the two projects are also dealing with risk assessments due to flame spread, smoke production and fire risk in the space of origin, but also at ship global safety level. "For fire performance, we are



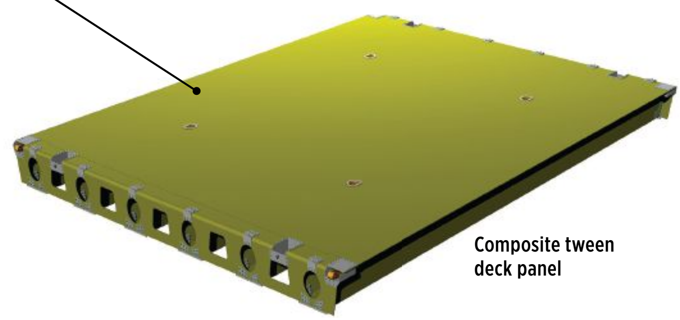


FIG. 2 Composite tween deck

Oshima Shipbuilding's new 65k open-hatch general cargo carrier design will use Compocean's prototype composite panel structure (above) which saves 50% weight compared to steel and will comprise multiple infused FRP hat stiffeners (bottom left) bonded to an FRP top plate with bolted connections from the composite to the steel ship structure. Source | Compocean and DNV GL

developing a local equivalence approach, which deals with fire safety at a local level based on the fire ratings of the bulkheads and other structural divisions in each space of the vessel," says Paboeuf. "The second approach, global equivalence, deals with fire at a vessel level, taking into account all systems (active and passive fire protection, detection, evacuation, etc.) that impact the fire safety of the vessel as a whole, not just each divided space."

"Wider adoption of composites in shipbuilding will be step by step," he says. "It will begin with small parts such as decks and superstructure, or equipment such as shaft lines and propellers, before progressing to construction of whole vessels, which at first will be mostly special purpose ships such as research and seismic testing vessels and high-speed patrol craft."

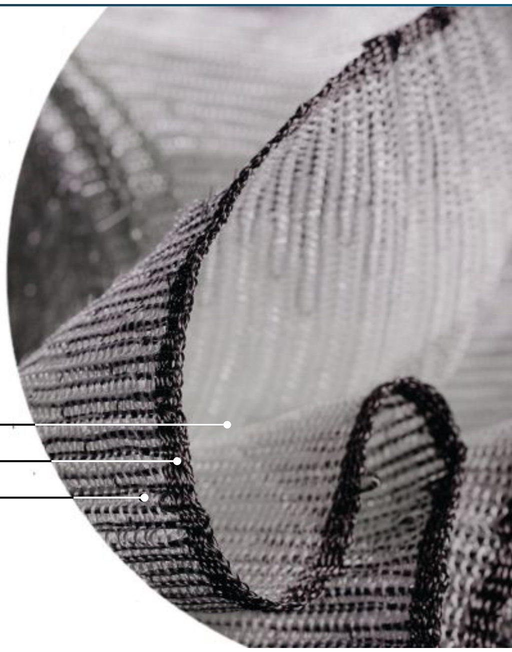
All-composite vessel demonstrators

In addition to the 85-meter FRV being demonstrated by FIBRESHIP, an 80-meter-long offshore patrol-type vessel is being developed within RAMSSES to be the first, all-composite SOLAS ship. Led by Damen Shipyard Group (Gorinchem, Netherlands), this work carries forward results from its Bluenose project started in 2014. Within RAMSSES work package 17, Damen is leading the demonstration of a 6-by-6-by-3-meter full-scale composite hull section of this vessel made using vacuum infusion, explains Matthias Krause, R&D engineer at the Center of Maritime Technologies (CMT, Hamburg, Germany) and co-coordinator of the RAMSSES project together with CETENA (Genoa, Italy). "Evonik has developed a novel resin for this demonstrator hull section and 6-meter-high tooling has been fabricated. Damen is also working with Airborne International (The Hague, Netherlands), an aircraft industry supplier that has also built large infused structures." Evonik (Essen, Germany) has explained its role to improve the impact resistance and fatigue behavior of the glass fiber/vinyl ester infused hull (see Fig. 1, p. 27).

Another partner in this demonstrator is InfraCore Co. (Rotterdam, Netherlands), which is developing new applications for the InfraCore technology used by sister company FiberCore Europe (Rotterdam) in more than 1,000 composite bridges and lock gates worldwide. "We originally joined Damen in this project to build a 12- to 14-ton helideck," explains InfraCore operations manager Laurent Morel. "We are now working with them to build the decks, bulkheads and hull structure. We will use both horizontal and vertical infusion to produce the hull section in one shot. So far, we have infused to a height of 9.8 meters." Once completed, this demonstrator will be tested for structural and fire performance, with results and lessons learned fed into the RAMSSES's new FTA modules.

Lightweight decks

Composites have already been demonstrated in the first roll-on/roll-off car carrier to use a composite cargo deck, designed and »



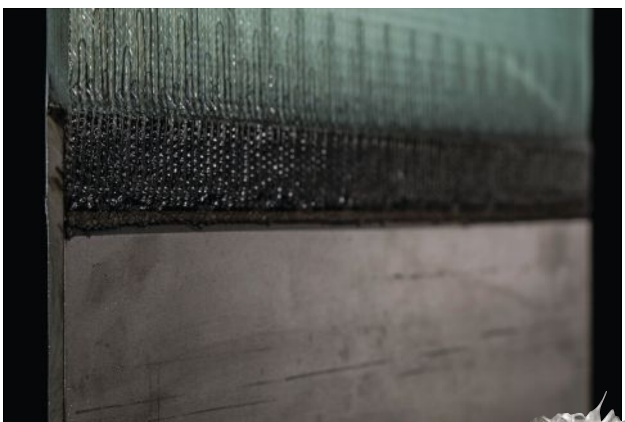


FIG. 3
HYCONNECT welded steel-FRP joint

FAUSST hybrid steel-glass fiber fabric (top) is press welded to a steel plate or other connector and can then be integrated into a composite structure via resin infusion (center). Such hybrid composite structures are then easily welded into steel ship framing (bottom).

Source | HYCONNECT

built by Uljanik Group (Pula, Croatia) as part of RAMSSES work package 14 (see Learn More), as well as a lightweight sundeck for a 110-meter-long river cruise ship (see Learn More) and a composite tween deck for a 200-meter-long general cargo carrier. “A tween deck is a removable deck you can install to divide the cargo hold to facilitate different types of cargo,” explains Arnt Frode Brevik, manager at Compocean (Sandvika, Norway), a supplier of composite solutions that emerged from the oil and gas industry.

“We have been working with Oshima Shipbuilding (Nagasaki, Japan) and DNV GL for several years to develop a lightweight tween deck with the goal of cutting the weight by 50% versus steel,” says Brevik. This resulted in a 9-by-2-meter GRP prototype that was tested for impact and maximum loads and then exhibited at NOR-Shipping 2017.

Compocean has now extended this development to a new project with Oshima, DNV GL and ship owner Masterbulk Pte Ltd. (Singapore) to build a full-scale 27-by-12-meter prototype composite tween deck, which will be installed next year and tested until late 2021 (see Fig. 2, p. 29).

“Oshima was seeking to optimize items to reduce fuel and handling costs,” says Brevik. “Although there aren’t many tween decks per ship, it is an easy part to begin with when introducing new materials because it’s not part of the ship’s primary structure.” The design is based on a polyester resin-infused glass fiber plate with hat stiffeners underneath. “We use a mix of ±45-degree, 0-degree and 0-degree/90-degree layup for all parts but in different ratios. The deck structure also needs to integrate a lot of lashing points to secure the cargo.” The plate will be bonded to the hat stiffeners using a structural adhesive while bolting will be used in combination with the lashing system. A bolted steel end-bracket will join the composite to the steel ship structure. “We will also pursue a design with purely adhesive joints in the future,” adds Brevik.

Having received final approval from DNV GL for the full-scale tween deck design, Compocean has produced the molds and started fabrication testing. “The full-scale composite deck will be built by a partner in Malaysia who will transport it via barge to the ship,” says Brevik. The next step is to aim for much more weight reduction, for example, composite hatches on top of cargo openings (flat plates on top of green “boxes” in ship rendering on p. 29). “There are seven big hatch covers on this type of carrier,” he notes. “To get these approved by DNV GL will pose some new challenges, but success with the tween deck will help.”

Lightweight superstructure, modular cabins

RAMSSES has six work packages focused on composite superstructures and components used above the main deck, most with demonstrators and test results to be presented in 2020. Work package 16, led by Naval Group (Paris, France), is demonstrating a lightweight composite superstructure module joined to a steel deck. The shore-based demonstrator represents a standard block for an offshore patrol-type vessel. “Shipbuilding in metallic materials is based on construction in blocks to decrease time and costs," explains Jurado. "Building such blocks using composites presents issues with the need for large molds as well as joining techniques and joint safety requirements. FIBRESHIP has studied this and developed some recommendations on joining of composite-based blocks, including the assembly sequence." In RAMSSES, Naval Group has investigated three types of sandwich structures including GF/polyester/balsa core, FR epoxy/PET foam core and GF/polyester/3D fiber-reinforced foam core. It is also developing a structural health monitoring (SHM) system inside the joint and composite panels.

Work package 18, led by Chantiers de l'Atlantique (Saint Nazaire, France) is developing a modularized solution for passenger cabins. "These typically come without a floor because they are welded onto the ship's steel decks," says Krause. "The idea is to make them from composites, pre-outfitted with all auxiliary systems such as heating and air, electrical, etc. By including a composite floor, these could be inserted into a steel framework (like a drawer) versus welding onto a solid steel deck, thus saving a lot of weight." Although the project is assessing composites to reduce production and assembly time for walls, ceilings and bathroom units, because replacing the steel deck would save an estimated 125 kilograms per square meter, composite floors are a main focus. Hutchinson (Paris, France) has proposed using its ZALTEX mineral fiber-reinforced composite foam, which resists temperatures from -190°C to 1,000°C.

> The largest challenges are the need for new regulations, fire safety aspects, bonding techniques and cost reductions.

Work package 13, led by cruise ship builder Meyer Werft (Papenburg, Germany), is also aimed at efficient processes for assembly, but targeting bulkheads. The goal is to build two demonstrators — one onshore, one offshore (sea trial) — where composite walls will be joined to steel frame structures and then subjected to 80 mechanical tests. Project partner InfraCore has performed analyses to define requirements for heat and noise insulation, eigenfrequency (vibration), deformation and maximum width and height for composite walls. "We have been asked to develop multifunctional inner and outer walls," explains Morel at InfraCore. "To save time, cost and weight, we must integrate insulation and a good interior finish with the lightweight structural panel. There are up to 6,800 square meters of these walls on every cruise ship. We have an opening to put these onboard a cruise ship in mid-2020, which could be the first SOLAS-approved composite walls on a cruise ship worldwide."

In work package 10, Podcomp (Öjebyn, Sweden) is developing an alternative indoor/outdoor panel using *bio-based* composites that must be fire-retardant and competitively priced. Three sandwich concepts based on GF/polyfurfuryl alcohol (PFA) prepreg from Composites Evolution (Chesterfield, U.K.) and different core materials were examined. Only one concept passed cone calorimeter and other fire tests performed by RISE Research Institutes of Sweden (Borås). It is now being optimized for weight and cost.

After trying aluminum and friction-stir welding, Baltic Workboats (Nasva, Estonia) is now moving forward with composites to develop pre-fitted, stiffened panels for the deck house/superstructure of aluminum work boats (work package 15). Panel design, connection with other panels and to the rest of the deckhouse structure, structural analysis procedures and insulation solution will be demonstrated, as well as onboard installation techniques.

Another solution for lightweight superstructure is being developed by BaltiCo (Hohen Luckow, Germany), a ship equipment producer that has a new startup to build complete boats using robot-placed carbon fiber draped around truss structure. "You build the skeleton of the structure you want to produce, placing GFRP cross-structure or ribs about every half meter, and then a robot winds carbon fiber around it," Krause explains. The goal is an ultra-lightweight modular system using a highly automated process. Demonstration will include production and assembly of two self-supporting hull and deck modules in a non-SOLAS lightweight solar-powered catamaran.

Welded FRP-steel joints

"We believe the future of shipbuilding is in combining FRP composites, steel and other materials into hybrid structures," says Dr. Lars Molter, a 10-year veteran at CMT. "We looked at bonding, but there isn't a standardized joint design you can use in all ships and there are no general rules on how to apply adhesive bonding in SOLAS vessels. Also, you must control the environment and bonding process." He notes this is difficult amid the welding and cutting that typically dominates shipyard construction. "We asked DNV GL what they would approve for dissimilar-material joints," says Molter. "They said primary structure would typically require a mechanical attachment; pure bonding would not be certified easily without redundant fasteners."

Molter and CMT responded with the German-funded FAUSST (Fiber and Steel Standard joint) project, which developed a hybrid knitted fabric that transitions from 100% glass fibers to 100% steel fibers. The latter is welded to a steel connector (e.g., flat plate, rectangular profile, etc.), which can then be easily welded into a ship's »

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Read more about HYCONNECT | short.compositesworld.com/HYCONNECT steel structure (Fig. 3, p. 30). The glass fiber end is joined to the composite structure using resin infusion. “This joint design offers 100% NDT inspection because you can use UT [ultrasound] or X-ray on the weld,” says Molter. FAUSST performed mechanical, environmental and fatigue testing on this type of joint and also obtained approval in principle from the classifications societies, but there was still much work to do to transform the technology into a commercial product. Thus, Molter left CMT and founded HYCONNECT GmbH (Hamburg, Germany) in 2018.

“We have met with shipyards, DNV GL and BV and are developing a product which can be certified,” says Molter. “You simply order your composite parts with this joint system and then you can weld them into your ship. That is our vision. We design the composite-to-steel joint and then deliver a product which has fabric welded to a steel connector (plate, profile, etc.).”

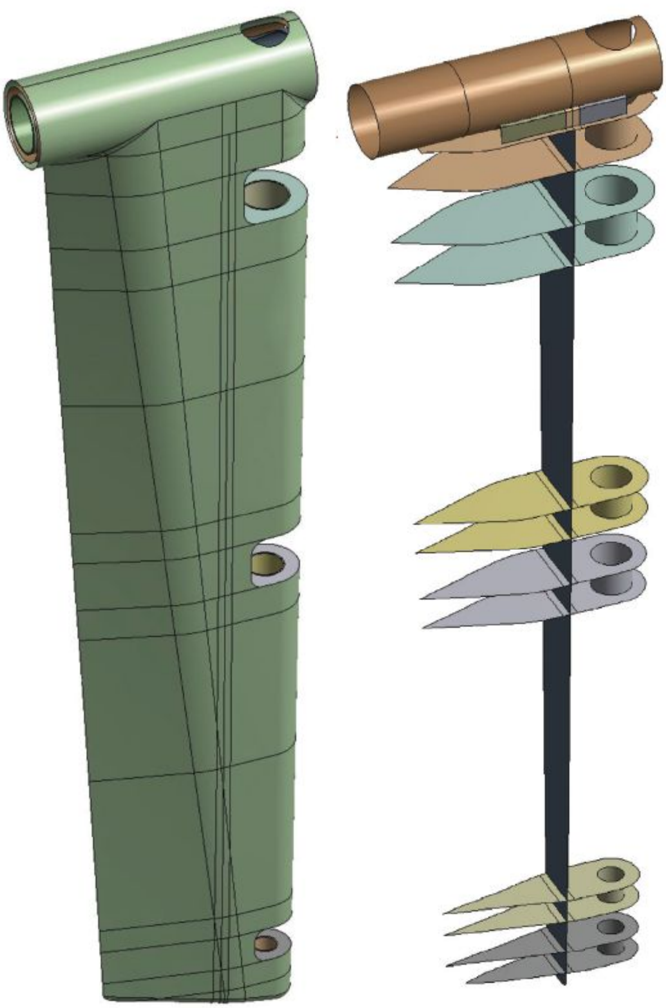

FIG. 4 Composite rudder flap

Becker Marine Systems and InfraCore are developing a lightweight, resin-infused rudder flap for the largest container ships. Measuring 11.8 meters long and 0.9 meters wide with a 2.9-meter chord, the full-scale flap must withstand 100 tons per square meter of load. A 2-meter high demo will be tested in 2020.

Source | Becker Marine Systems

He explains that the joint design and fabric will be certified in a stepwise system: “By applying more layers of FAUSST fabric, there is a linear increase in load-carrying capability.” For example, the base product could be four layers of FAUSST with a 1-meter flat bar welded to it, rated for a certain tensile and bending load. Then there would be some products available to the left (e.g., two to three layers total for a lower load rating) and right (e.g., six layers total for a higher load rating). “We are still finalizing these details, but the goal is a standardized and easy-to-use system,” notes Molter.

HYCONNECT has adapted the fabric technology to handle the difference in stiffness and coefficient of thermal expansion (CTE) between steel and composites; the use of knitted fibers for mechanical interlocking with unidirectional fibers for carrying load through the joint; and the technique required for high-quality press welding of the steel fibers to the steel connector (see Learn More). “This solution is based on continuous testing,” says Molter. “Because FAUSST consists of standardized ready-made subproducts, it can be supplied quickly, within days.” Prototypes are currently being produced for selected customers, and HYCONNECT will begin full production in 2020.

Composite rudders

Ship rudders are also being developed as FRP-steel hybrids. As part of RAMSSES work package 12, Becker Marine Systems (BMS, Hamburg, Germany) is demonstrating a lightweight composite flap for a steel rudder designed for large container ships. Such rudders typically weigh more than 200 tons, says Jörg Mehldau, head of R&D at BMS. “By adding a hinged aft flap, you can significantly reduce the rudder area.” BMS pioneered this flap rudder, which dramatically reduces ship turning radius and improves course-keeping and maneuverability, enabling berthing without tugboat assistance. A composite flap not only reduces weight but also enables more functional shapes as well as more hydrodynamically- and load-optimized designs.

“The composite flap we are developing was inspired by the aviation industry,” notes Mehldau. For RAMSSES, the full-scale test case is aimed at one of the largest container ships (400 meters long), a flap measuring 11.8 meters long and 0.9 meters wide with a chord of 2.9 meters (see Fig. 4). “We calculated the forces on this rudder and flap using formulas based on DNV GL rules for this ship’s type, weight and maximum speed,” says Mehldau. BMS then conducted preliminary design and engineering analysis, as well as trade studies for manufacturability and cost. “We first favored filament winding but it was too expensive,” he notes. “For each new ship hull, the rudder is a single design.” Thus, resin infusion was chosen, as was an alternative design from InfraCore. “It was the best for production flexibility, cost and structural performance combined,” Mehldau explains.

“To me, this was a natural fit for InfraCore because the composite lock gates we have built are very similar,” says Morel. He notes container ship rudders must withstand loads of roughly 100 tons per square meter with a surface area of 150 square meters. This matches well with InfraCore’s infusion-based technology used in bridge decks spanning up to 142 meters. Instead of bonding a high-density structural core to faceskins, InfraCore uses a low-density foam core only as a permanent formwork for multiple Z-shaped, two-flanged web structures. These are overlapped, faced with multiaxial fabrics and co-infused to form a robust construction. InfraCore will build a 1:6 scale demonstrator, using glass fiber and polyester resin materials already certified by DNV GL to keep costs low.

Morel notes that the reduced-weight InfraCore composite flap is cost-competitive, "because steel ship rudders are quite complicated to manufacture." Mehldau agrees, "Together with less maintenance and operational cost advantages, we see a successful business case." The 2-meter-high demonstrator will be finished by second quarter 2020, followed by testing.

"We will test this using a lab test bench and air cushions, which can apply up to 8 bar of pressure equal to at least 80 Mpa of load," says Mehldau. "We will measure strains and deflections to verify our simulations and perform a break load test." A lab-scale demonstrator will also be tested via sea trials on a research ship in the Elbe River by CETENA (Genoa, Italy) which serves as project coordinator for RAMSSES along with CMT.

Forward momentum

"The outlook for composites in ships is good because many of the marine sector stakeholders have shown interest in FIBRESHIP, RAMSSES and other projects," says Jurado. "The largest challenges are the need for new regulations, fire safety aspects, bonding techniques and reduction of shipbuilding costs." For the latter, he cites automated manufacturing in shipyards as a key issue as well as mold construction and composite materials sourcing and storage. "Composites are already growing in ships," says Krause at CMT, "but we started this work 20 years ago, so it is a slow process. However, we now have this critical mass and the industry is more connected via E-LASS."

Jörg Bünker, head of R&D, application service for SAERTEX LEO FR products at SAERTEX (Saerbeck, Germany), agrees: "The drivers to reduce weight are strengthening. Within the next five to seven years, more composite materials will be sold into ships. This is the right time for more projects because IMO needs to see this interest and effort from the industry. Suppliers must show new solutions and shipyards must show where composites can be used, but no one can do it alone." CW

ABOUT THE AUTHOR

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Composite insert as a structural reinforcement for A pillars

A Porsche structural A pillar reduces weight and increases strength with a hybrid part combining thermoplastic composites, steel and structural foam.

The 3D hybrid A-pillar extends upward from the vehicle rocker panel, accommodates the door hinges and holds the windshield in place at the side.

Source | LANXESS AG

The Porsche (Stuttgart, Germany) 911 *Cabriolet* that rolled out this year is the first vehicle manufactured with a lightweight, hybrid metal-composite A pillar designed for use in convertibles and roadsters.

The hybrid metal-composite pillar contains an insert made from high-strength steel, supported on the inside by a formed blank of polyamide 6-based LANXESS (Pittsburgh, Pa., U.S.) Tepex dynalite 102-RG600(6)/47% continuous fiber-reinforced thermoplastic composite, and by a ribbed structure made from polyamide 66-based, short glass fiber-filled Durethan AKV30H2.0. This structure is bonded by friction with L-5235 structural foam developed by L&L Products (Romeo, Mich., U.S.). LANXESS says its Tepex line of thermoplastic composite materials is particularly suited for structural components in passenger cars, to meet their stringent safety requirements.

The strength and rigidity of the hybrid insert ensures that the A pillar is just as good at withstanding rollovers as previous designs featuring high-strength steel tubes; however, it is 5 kilograms lighter. The weight reduction is said to be achieved in the "greenhouse" area of the vehicle, lowering the car's center of gravity and thereby improving vehicle dynamics.

"The excellent mechanical performance of the hybrid A pillar demonstrates that hybrid inserts based on steel sheet, Tepex blanks, polyamide 6 or polyamide 66 variations of Durethan as a back-injection material and on a structural foam such as L-5235 also offer considerable potential for use in structural lightweight vehicle body design. That applies to electric vehicles in particular, as their heavy batteries give them a high impact mass," explains Henrik Plaggenborg, head of Tepex Automotive at the LANXESS High Performance Materials (HPM) business unit. "The weight reduction also extends the range of the electric vehicles that use this technology."

Other potential applications for the hybrid composite elements include reinforcing crossmembers and side members, B and C pillars, load-bearing battery parts or door components that are critical to safety.

The hybrid composite elements were developed and are manufactured by L&L Products at its site in Strasbourg, France. The first step in the manufacture of the reinforcing elements involves forming and overmolding the Tepex blanks in a single operation using the hybrid molding technology. The resultant composite component is then coated with an epoxy-based foam bonding system that expands in response to heat. The coated part is mounted on the body and goes through the cathodic dip coating (KTL) process with it. The high temperatures of the KTL process cause the structural foam to expand and bond with the high-strength sheet steel, which is also affixed to the A pillar casing, to produce the reinforcing hybrid insert. This last step takes place in an entirely automated manufacturing process that was developed by Porsche and is subject to ongoing quality control.

The insert and A pillar development process was supported by LANXESS' HiAnt customer service operation. "Services included simulating the forming (draping) of the Tepex blanks, simulating filling for back-injection and calculating warpage. We also determined material characteristics to simulate the mechanical behavior of the A-pillar and made these figures available to Porsche," says Jean-Marie Olivé, expert in application development at HPM. CW

Composites Events

Dec. 6, 2019 — Paris, France
ASD Days Paris
asddays.aero/fr

Dec. 20-21, 2019 — Telangana, India
ICAPPM 2019
icappm.com

Jan. 20-23, 2020 — Dayton, Ohio, U.S.
IACMI Winter 2020 Members Meeting
iacmi.org/event

Jan. 27-30, 2020 — Cape Canaveral, Fla., U.S.
44th Annual Conference on Composites, Materials, and Structures
advancedceramics.org/events

Jan. 29-31, 2020 — Tokyo, Japan
TCT Japan 2020
tctjapan.jp

March 3-5, 2020 — Paris, France
JEC World 2020
jec-world.events

March 5-6, 2020 — Detroit, Mich., U.S.
Graphene Automotive 2020
usa.graphene-automotive-conference.com

March 11-13, 2020 — Barcelona, Spain
6th Annual World Congress of Smart Materials-2020
bitcongress.com/TOPwcsm2020

March 15-19, 2020 — Houston, Texas, U.S.
Corrosion 2020 Conference & Expo
nacecorrosion.org

March 16-19, 2020 — Fort Worth, Texas, U.S.
AeroDef 2020
aerodefevent.com

March 30 - April 2, 2020 — Colorado Springs, U.S.
36th Space Symposium
spacesymposium.org

April 20-24, 2020 — Birmingham, U.K.
MACH 2020
machexhibition.com

April 21-23, 2020 — Moscow, Russia
COMPOSITE-EXPO
composite-expo.com

April 21-23, 2020 — Detroit, Mich., U.S.
WCX 2020 SAE World Congress Experience
sae.org

April 26-29, 2020 — Denver, Colo., U.S.
TRFA 2020 Annual Meeting
trfa.org

April 29 - May 1, 2020 — San Diego, Calif., U.S.
CW ACMA Thermoplastic Composites Conference
cvent.com/events/thermoplastics-composites-conference-2020

May 4-7, 2020 — Seattle, Wash., U.S.
SAMPE 2020
nasampe.org/events

May 12-13, 2020 — Madison, Wis., U.S.
SPE Thermoset TOPCON 2020
spethermosets.org/topcon

May 12-14, 2020 — Atlanta, Ga., U.S.
Techtextil North America
techtextil-north-america.us.messefrankfurt.com

May 19-21, 2020 — Chicago, Ill., U.S.
UTECH North America 2020
utech-north-america.com

June 1-4, 2020 — Denver, Colo., U.S.
AWEA WINDPOWER 2020 Conference & Exhibition
engage.awea.org/events

June 22-26, 2020 — Nantes, France
ECCM19
eccm19.org

Sept. 21-24, 2020 — Orlando, Fla., U.S.
CW CAMX 2020
thecamx.org

Oct. 13-14, 2020 — Bremen, Germany
ITHEC 2020: 5th International Conference and Exhibition on Thermoplastic Composites 2018
ithec.de/home

Nov. 10-12, 2020 — Stuttgart, Germany
Composites Europe
composites-europe.com

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short.compositesworld.com/events

New Products

» COMPRESSION MOLDING

200-ton down-acting hydraulic compression press

French Oil Mill Machinery Co. (Piqua, Ohio, U.S.) has designed a 200-ton, four-post hydraulic compression press for composites molding. The press is fitted with 40-inch square heated platens machined from solid steel plate then fitted with shaded watt density cartridge heating elements. The heating is divided into two control zones to provide a steady state operating temperature of up to 500°F.

The down-acting press design reduces installation costs and provides a low work height. A heavy-duty, double-acting 30-inch stroke JIC cylinder applies up to 200 tons of force. The cylinder is connected to the press moving bolster to aid in any misalignment and to extend the life of the cylinder seals and bolster bushings. Strain rods were machined from solid steel 1045 as a matched set to ensure correct proportional loading and exact parallelism of matching components.

The hydraulic system consists of a self-contained oil hydraulic unit with a steel constructed reservoir with hydraulic pump combination driven by an energy-efficient motor. This pump-motor combination is said to enable fast closing, opening and adjustable tonnage of the press. The hydraulic unit is floor-level mounted next to the press.

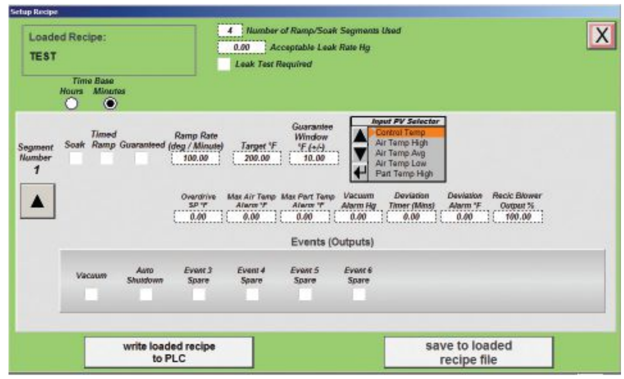
The compression press control system is microprocessor-based, designed to improve quality through better processing accuracy, repeatability, versatile process control programming and monitoring of data for analysis. The system is said to be operator-friendly and easily used to control most molding applications.

Components of the system include an Allen Bradley PLC, a color touchscreen operator interface, pushbuttons on the press for operation and a NEMA-type enclosure mounted to the hydraulic system next to the press. The interface screen provides for display and programming of the machine recipe and includes temperature setpoint, pressure setpoints and time. The screen displays:

- real-time data of all press data points,
- actual vs. setpoint for time, platen temperature and pressure values throughout the cycle,
- recipe configuration for pressure and temperature parameters for automatic cycle,
- manual mode setpoint control,
- visual alarms for temperature and pressure faults, and
- display and programming of temperature loop P.I.D. parameters.

In accordance with safety regulations and best practices, the press sides and rear have an extruded aluminum frame with expanded metal inter guards. Light curtains restrict unsafe access to the press front.

As with all presses from French and its subsidiary TMP, this 200-ton press was tested and passed customer inspection prior to shipment. All parts and labor are guaranteed by the company against defects and workmanship, and French says its in-house service technicians and engineers are available for start-up assistance, service and any necessary troubleshooting. frenchoil.com



Source | Wisconsin Oven

» PROCESS CONTROL SYSTEMS & SOFTWARE

Upgrade for oven-based composites curing system

Wisconsin Oven (East Troy, Wis., U.S.) has launched an updated version of its established Wisconsin Premium Control System (WPCS) for data acquisition and control of the oven-based composites curing process. Featuring upgrades demanded by aerospace and other customers, WPCS offers high-level monitoring and control of all variables critical to consistent composites curing. The system, which can accommodate more than 100 thermocouples, monitors variables such as temperature and vacuum, and generates detailed reports that meet the requirements of AMS2750. WPCS also allows control based on air temperature or part temperature, with single or multi-zone options available, and leading, lagging, and controlled ramping.

Wisconsin Oven officials note that the upgraded WPCS features a relatively large volume of input options for temperature and pressure operating conditions. The system can be configured to control the recirculation blower, exhaust blower, vertical lift door, powered load cart, cooling systems, vacuum pumps and other equipment. Features include the ability to monitor, average and switch control from hottest to lowest temperature; the ability to control based on air or part temperature; the ability to monitor average temperature with high- and low-temperature awareness; guaranteed soak when all setpoints are in range; thermal overdrive to expedite heat-up without overshoot; and bleed-based, bag-by-bag vacuum control, with leak detection.

Other capabilities include full-featured alarming — active and historical for all process items; e-mail alarm notification; thermocouple status monitoring; automatic thermocouple burnout switching control; and onboard data logging and archiving. During a batch run, WCPS logs all alarms, thermocouple and vacuum readings, recipe name, recipe start/end date, minimum and maximum value during soak, any user-configurable batch fields and any changes to the process during a run. The time setting for the interval data can be user configured. WPCS can produce customized reports for automatic distribution within or without the fabricator's network.

The base WPCS system includes: Universal analog inputs (T/C, RTD, voltage or current), 4-20ma analog outputs, digital inputs (24 VDC) relay outputs, 17-inch touchscreen operator interface, Ethernet switch, NEMA12 enclosure, 24 VDC power (AC systems also available) and onboard data logging and archiving.

Available options include: Uninterruptible power supply (UPS), barcode scanner and remote access switch (Webport). wisoven.com

» VACUUM BAGGING EQUIPMENT

Energy saver system for vacuum generators

Source | Anver

Anver Corp.'s (Hudson, Mass., U.S.) Energy Saver technology is now available on all of the company's electric- and air-powered vacuum generators for use in composites processing. Anver says its Energy Saver technology quiets the vacuum lifter, reduces power usage and reduces pump wear and tear while keeping the lifter running safely. This technology reduces compressed air and electric power usage, which Anver says results in reduced total cost of ownership (TCO) and improved profits.

When a preset vacuum level is reached, the Energy Saver system shuts off the vacuum pump motor or the compressed air supply to the venturi pump, conserving electric power or compressed air and reducing noise. The vacuum level is constantly monitored, and the pump immediately re-energizes when a vacuum drop is detected, allowing the pre-set level to be quickly recovered.

Anver developed its Energy Saver technology to reduce operating costs and improve the working environment wherever the company's electric and venturi air operated vacuum generators are used. The Energy Saver system instantly recovers safe vacuum levels when necessary, protecting the integrity of the products the lifters are handling. **anver.com**

» TEMPERATURE CONTROL

Digital PID temperature controller

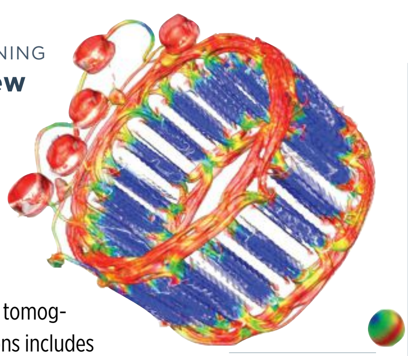
BriskHeat (Columbus, Ohio, U.S.), a provider of flexible heating, insulating and temperature control solutions, has announced cULus and CE approvals on its portable SDX digital PID temperature controller. UL approval has been granted for the United States and Canada.

The SDX is said to enhance accuracy, showing both setpoint and actual temperature. Designed for high quality in a tabletop controller, its small size is said to ease setup, and its universal voltage ranges from 100-240 VAC with a 15-amp relay. Users can choose between Type-J or Type-K thermocouples or RTD temperature sensors.

The controller provides accurate PID control across a wide temperature range to regulate cloth and silicone heating blankets, tapes and cables, jackets and heating mantles. Applications include research and development, laboratory testing, food processing, emulsifying cosmetic components, industrial heating and drying, adhesive curing, gas handling, viscosity control and freeze protection, for the composites industry, plastics industry and more. **briskheat.com**

» SOFTWARE & SCANNING

CT data drives new level of fiber analysis



Source | Volume Graphics

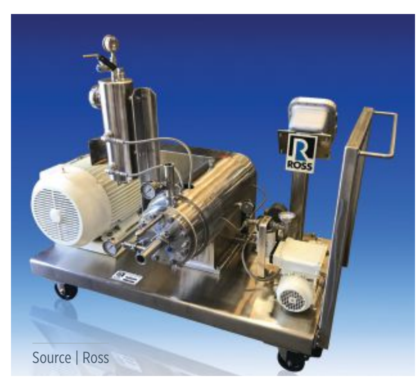
The latest version of **Volume Graphics'** (VG, Charlotte, N.C., U.S.) software solution for rendering and analyzing data derived from computed tomography (CT) scanning operations includes VGSTUDIO, VGSTUDIO MAX, VGMETROLOGY, VGinLINE and myVGL. VG's software is designed to receive CT data from inline or discrete scanning systems and then builds 3D projections of the composite part from multiple angles. These projections include interior structures down to the fiber level, revealing inclusion, porosity, cracks, delamination and other flaws. The software also can compare actual dimensions to nominal CAD dimensions.

CT technology is typically used on smaller parts, with VG's software providing imagery of specific fiber placement or overall fiber orientation. In general, image and analysis are completed within minutes. VG's software can render and analyze CT data from composites reinforced with fibers of all types, including carbon fibers, glass fibers, aramid fibers and natural fibers. The software is also compatible with ceramic matrix composites (CMC) and fiber-reinforced concrete. **volumegraphics.com**

» METER/MIX/DISPENSE EQUIPMENT & ACCESSORIES

High-shear mixer

Ross's (Hauppauge, N.Y., U.S.) patented MegaShear is an ultra high shear rotor/stator mixer said to be ideal for high-throughput emulsification, dispersion and homogenization.



Source | Ross

According to the company, the 11,300 ft/min tip speed and proprietary geometry of the MegaShear mixing head generate a level of shear usually reserved for high-pressure homogenizers. Compared to a comparably-sized homogenizer, the MegaShear mixer is reported to be less expensive and also less sensitive to clogging and changes in viscosity.

The Ross MegaShear Model HSM-706M-50, pictured, features a 50-horsepower motor and creates high-quality dispersions, suspensions and emulsions for the composites industry and other applications. **mixers.com**

» TESTING, MEASUREMENT & INSPECTION SYSTEMS

Software streamlines digital engineering for aircraft manufacture

NLign Analytics (Cincinnati, Ohio, U.S.) has released its NLign Product Suite 7.0, including NCheck software for digital engineering for aircraft manufacturing and sustainment operations. NCheck connects frontline depot, field and shop floor aircraft inspection personnel with a central database, reportedly ensuring production quality, improving production rates and decreasing costs.

Product Suite 7.0 has been designed to complete the aircraft lifecycle digital thread by streamlining inspection data capture, communication and analysis, enabling large amounts of diverse design, manufacturing and operational data to be leveraged to improve aircraft availability, quality and production rates.

In addition to NCheck, Product Suite 7.0 software modules also include NThread and NLign. Aircraft inspection, rework and repair data is often contained in paper documents, spreadsheets or disconnected electronic files. NThread links as-manufactured data with as-maintained data, providing a complete digital thread from design through the sustainment phase of a product's lifecycle. Organizations working toward Model Based Enterprise (MBE) practices are adopting the software as a core technology that supplies the central fiber of the digital thread.

NLign provides an interactive 3D environment to analyze both manufacturing and maintenance data. This is said to enable the user to quickly detect and quantify issues like recurring cracks, fatigue, corrosion or increasing wear, and then aids in root cause analysis efforts to identify the problem's source. Additionally, NLign allows quick access to information relevant to a specific troublesome location on a structure, such as previous repairs and analysis. **nlign.com**

» THERMOSET RESINS

High-temperature PEEK polymer

According to **Solvay,** (Alpharetta, Ga., U.S.) the company's KetaSpire PEEK XT, introduced at the K 2019 trade show in Düsseldorf, Germany, is the industry's first true high-temperature polyetheretherketone (PEEK). This material reportedly offers the chemical resistance of standard PEEK plus significantly higher strength and stiffness at elevated temperatures.

Compared to standard PEEK, KetaSpire PEEK XT is said to have a 20°C (36°F) higher glass transition temperature, at 170°C (338°F), and a 45°C (81°F) higher melting temperature. The material is said to exhibit significantly higher strength and stiffness at elevated temperatures compared to standard PEEK, with a 400% higher tensile modulus and nearly 50% higher tensile strength at 160°C (320°F).

According to Solvay, other high-temperature polyketones, including polyetherketone (PEK), polyetherketoneketone (PEKK) and polyetherketone ether ketone ketone (PEKEKK), alter the 2:1 ether-to-ketone ratio of a true PEEK polymer, losing some of PEEK's chemical resistance. KetaSpire PEEK XT maintains this ratio, enabling it to achieve superior chemical resistance to other high-termperature polyketones while exhibiting similar thermal properties.

In addition, KetaSpire PEEK XT is said to show superior electrical properties at 250°C (482°F) compared to standard PEEK, increasing dielectric strength by 50% and volume resistivity by an order of magnitude.

The material is available globally in neat, 30% glass fiber and 30% carbon fiber-reinforced injection molding and extrusion grades, as well as in fine powder form for compression molding and as coarse powder for compounding. Applicable industries include oil and gas, electrical/electronics, wire coatings and automotive. **solvay.com**

» THERMOSET RESINS & ADHESIVE SYSTEMS

Foam materials for injection or compression molding

Hexion Inc.'s (Columbus, Ohio, U.S.) Bakelite FoamSet materials are injection and compression moldable foam materials for lightweight construction applications. They are said to provide heat stability with low thermal expansion, strength for screw connections, fire resistance and reduced smoke and toxicity.

Other advantages reportedly include high flame retardance, good thermal insulation properties, high temperature resistance, low specific gravity, high specific strength and stiffness, high chemical resistance and a self-foaming formulation without requiring additional technology.

The materials are supplied as free-flowing granules and are processable by injection and compression molding as well as by continuous extrusion. Users can achieve ranges in thickness between 1.5-30 mm and at a density of 0.85 g/cm^3. According to the company, storage stability of more than one year is guaranteed.

Hexion says Bakelite solutions offer efficient and time-saving foaming thermosetting materials at 50% weight reduction. Based on its glass fiber-reinforcement, the Bakelite FoamSet products offer foamed materials with maximized mechanical performance and high fire resistance. Possible applications include floorings, fire protecting applications, isolating- and force-transferring mounting systems and lightweight construction. **hexion.com**

Source | Hexion

» METER/MIX/DISPENSE EQUIPMENT & ACCESSORIES

Controlled containment system

The CCS Controlled Containment System from **Hemco Corp.** (Independence, Mo., U.S.) has been designed to safely contain and control airborne particulate from sampling procedures. Typical applications are said to include dispensing from drums and weighing procedures.

Source | Hemco

The system's strip curtain entrance allows easy removal of drums and other equipment into and out of the enclosure. A downward flow of HEPA filtered air maintains a cleanliness level at drum or working height while all exhaust air exits out through HEPA filters in the rear wall at floor level. The interior is under slight negative pressure to ensure that no contaminant escapes out of the enclosure.

The CCS system locates directly on the existing facility floor. Optional features include roll and set casters for mobility, electrical and plumbing service fixtures, tables with work surfaces and enclosure floors.

hemcocorp.com

» RESIN ADDITIVES & MODIFIERS

Epoxy toughening agent enhances adhesion for automotive applications

CVC Thermoset Specialties (Moorestown, N.J., U.S.), an Emerald Performance Materials company, has launched HyPox RA875, its newest carboxyl-terminated acrylonitrile-butadiene (CTBN) epoxy adduct toughening agent. HyPox RA875 is said to enable improved peel strength at room temperature and temperatures down to -40°C, as well as enhanced adhesion to oily substrates when compared to core-shell rubber (CSR).

According to CVC Thermoset Specialties, automotive structural adhesives formulated with HyPox RA875 demonstrate improved adhesion to the oily substrates common to automotive applications. HyPox RA875 is also said to reduce rejections due to adhesive failure, improving production.

In addition, HyPox RA875 is designed to strengthen adhesives by maintaining properties of high crosslink density, such as high modulus and failure strength, excellent adhesive strength and low creep, while reducing the brittleness of the epoxy.

HyPox RA875 is part of CVC Thermoset Specialties' line of elastomer-modified epoxy resins designed to merge the benefits of CTBN-toughened chemistry with the convenience of conventional one- or two-part epoxy handling and performance.

cvc.emeraldmaterials.com

» THERMOPLASTIC SOLUTIONS

Bio-derived thermoplastic elastomers for overmolding

PolyOne (Avon Lake, Ohio, U.S.) has launched its reSound OM (overmolding) thermoplastic elastomers (TPEs), the latest addition to its sustainable solutions portfolio. These new formulations, which comprise between 40% and 50% content derived from sugarcane — are said to offer hardness levels and performance comparable to standard TPEs.

According to the company, reSound OM addresses the goal of OEMs — particularly those who manufacture consumer products — to materials into their product designs that are both environmentally responsible and meet functional requirements.

The product portfolio consists of four overmolding grades compatible with rigid polypropylene, as well as one grade suited for overmolding onto ABS. All grades are formulated for durability, and are said to deliver property retention and UV resistance that are comparable to traditional TPEs.

The new grades also feature easy colorability for applications such as cosmetics packaging, personal care products and consumer electronics. With an opaque natural color, all reSound OM materials can either use traditional TPE colorants or be paired with sustainable colorants from PolyOne. **polyone.com**

Source | Nordson

» METER/MIX/DISPENSE EQUIPMENT & ACCESSORIES

Dual linear-servo two-component dispenser

Nordson Corp. (Amherst, Ohio, U.S.), a supplier of precision technologies for material dispensing, has developed a product family of small-volume dispensers for one- and two-component ambient-temperature materials.

Of these meters, the Nordson Sealant Equipment Micro-Meter 2K series comprises durable two-component meters for dispensing small volumes of material with precision ratio and volumetric output control. The Micro-Meter D2K is a small, light and easy-to-mount two-component meter that reportedly does not sacrifice any volumetric accuracy in the dispensing process. The Micro-Meter D2K is a dual linear-servo, two-component dispensing meter for potting, encapsulating, gasketing, bonding, composite filling and micro-dispensing.

The Micro-Meter D2K's benefits are said to include precision, application flexibility, control and adjustability. Positive rod displacement metering technology proportions materials to the exact volumetric ratio specified by manufacturers. Configurations provide flexibility to accommodate changes in application or material requirements. The dual servo-drive option combines adjustable and variable flow rate with positive rod-driven repeatability in shot or bead output. Pre-pressure of both the resin and catalyst materials results in the best mix control and reduces any lead-lag issues of mixing thick and thin materials. Ratio changes can be supported through software inputs with no changes to hardware, allowing cure time and hardness to easily match the application needs.

In addition, the Micro-Meter D2K is said to promise ease of assembly and integration with automation. Its simplified mounting plate requires only six bolts, basic service procedures do not require removal from the robot, dowelled assemblies assure reassembly does not create robotic offset needs, optimized hose routings are provided with inlet valve orientation options, and a grease zone allows robotic movement and inversion without dripping lubrication.

The dispenser is 31" (78.74 cm) tall, with a depth of 6" (15.24 cm) and a width of 7.5" (19.05 cm). Its dry weight, including stainless steel valves, is 38.6 lb (17.5 kg). Additional specifications include:

- ratio range (volume) of 12:1,
- an adjustable ratio design,
- viscosity range of liquids and pastes from 1 to 750,000 cps,
- volumetric output of 0.10 to 25 cc,
- working pressure up to 1,500 psi (103 bar),
- low rate of 15 cc/sec,
- adjustable and variable flow rate type,
- volume repeatability of 0.5% and
- ratio repeatability of 1.0%.

The full Micro-Meter product family offers dispensing solutions for small volumes of material ranging from 0.05 to 25 cc. Each product offers application flexibility to accommodate changes in material requirements, versatility to fit into existing production environments, positive rod metering for unmatched repeatability, volume-optimized cylinders for optimal control and flexible inlet valve design for quick installations and retrofitting. The Micro-Meter complements Nordson Sealant Equipment's Pro-Meter family of dispensers.

nordson.com/en/divisions/sealant-equipment

» RESIN ADDITIVES AND MODIFIERS

Epoxy hardener for SMCs

Evonik (Marl, Germany) has launched VESTALITE S, a diamine-based epoxy hardener designed to improve the technical properties and workability of high-performance sheet molding compounds (SMCs). Applications include e-mobility and automotive lightweight construction.

According to Evonik, conventional standard SMCs manufactured with polyester resin typically have mechanical properties such as a bending strength of 200 MPa, flexural modulus of elasticity of 10,000 MPa, and an impact resistance of 90 kJ/m^2 at a density between 1.7 g/cm^3 and 1.85 g/cm^3. This material is used, Evonik says, for the manufacture of automotive interior trim and hubcaps, although demand is increasing for even lighter materials with improved mechanical properties.

Based on its proven SMC base formulation, Lorenz Kunststofftechnik GmbH (Wallenhorst, Germany) has developed an epoxy SMC that meets all the requirements for lightweight construction and flame resistance, and which includes VESTALITE S as a key component, Evonik says. This SMC material reportedly exhibits high storage stability before hardening, but still permits fast curing within three minutes. These SMCs are also said to have no styrene emissions and very low VOC emissions, making them suitable for automotive interior components.

Source | Evonik

The composite material is made of epoxy reinforced with glass fiber and fillers, has a density between 1.5 and 1.7 g/cm^3 and is said to have good flow properties. Its bending strength is > 350 MPa, its flexural modulus of elasticity is > 18,500 MPa, and it has an impact resistance of > 150 kJ/m^2. The material is also said to be flame-resistant and has high impact resistance even at temperatures of -30°C, eliminating risk of brittleness or breakage.

Evonik says that its material and mechanical properties make the epoxy SMC ideal for use in battery housings in electric and hybrid vehicles.

evonik.com/designed-polymers and lomix.de

» CORE MATERIALS

Composite core and sprayable barrier coats

Source | Composite Technologies International

Composite Technologies International's (Anniston, Ala., U.S.) AmeriCore is said to be a first-of-its-kind core made of 100% composite materials. AmeriCore has minimal resin demand and chemically bonds with the laminate, forming a single component that makes delamination a non-issue. AmeriCore is also compatible with most resin systems and is easy to use. AmeriCore is scored and scrimmed and conforms to curved surfaces, reducing the possibility of air pockets and weak spots. With optimal shear strength and stiffness, AmeriCore is said to be an ideal replacement for other core reinforcements within composite laminates. AmeriCore is resistant to fire and smoke, is said to have high screw retention, absorbs little to no water and will not decompose. Using AmeriCore is also said to provide an economic benefit by eliminating time-consuming steps in the manufacturing process while also improving the quality and consistency of finished goods. It can add quick, consistent bulk thickness and help reduce the variation in a chopper gun process.

Composite Technologies International has also recently announced Fiber Shield, a sprayable barrier coat and print blocker. Fiber Shield is said to be a user-friendly product that enhances the cosmetics of gel coat surfaces, improves thermal-shock resistance and helps reduce manufacturing times. Designed for both hand-laid and infused laminates, Fiber Shield minimizes air entrapment and reduces or eliminates the need for finishing rework. Fiber Shield also extends the life of molds by protecting against laminate heat and shrinkage. For components that are frequently exposed to water such as boats and pools, Fiber Shield's 100% vinyl-ester-based version provides osmotic-blister resistance.

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3D filament winding enables vehicle seating concept

Multi-company collaboration uses xFK in 3D and additive manufacturing to develop an ultra-lightweight seat for hypercars and future mobility platforms.

By Scott Francis / Senior Editor

» Sustainability and environmental responsibility are becoming increasingly prevalent drivers of technology trends in the automotive industry. Low-energy and low-emission vehicles have become a priority for the international automotive sector, and trends toward alternative transportation technologies such as electromobility and urban air mobility (UAM) are gaining momentum. OEMs are looking to emerging materials and processes to enable these prospective modes of travel, but change in the automotive sector is often slow going. For new materials and processes to be fully adopted, they must not only be qualified, they must be cost-effective and they must enable high-volume production.

Recently, an innovative project with potential for the automotive sector — as well as emerging markets such as hypercars and air taxis — demonstrated how new materials, processes and technologies, and close collaboration between companies, might enable next-generation modes of transportation. The goal of the project was to completely rethink a car seat using cutting-edge generative technologies, and to do this using only as much of the right material as needed in the right place — and to yield results quickly. The resulting ultra-lightweight, metal-composite hybrid vehicle seat prototype was developed, from design to manufacture, in just seven months, through a simulation-driven design approach, agile project management methods and close cooperation and system integration between the companies involved.

Winding bushings

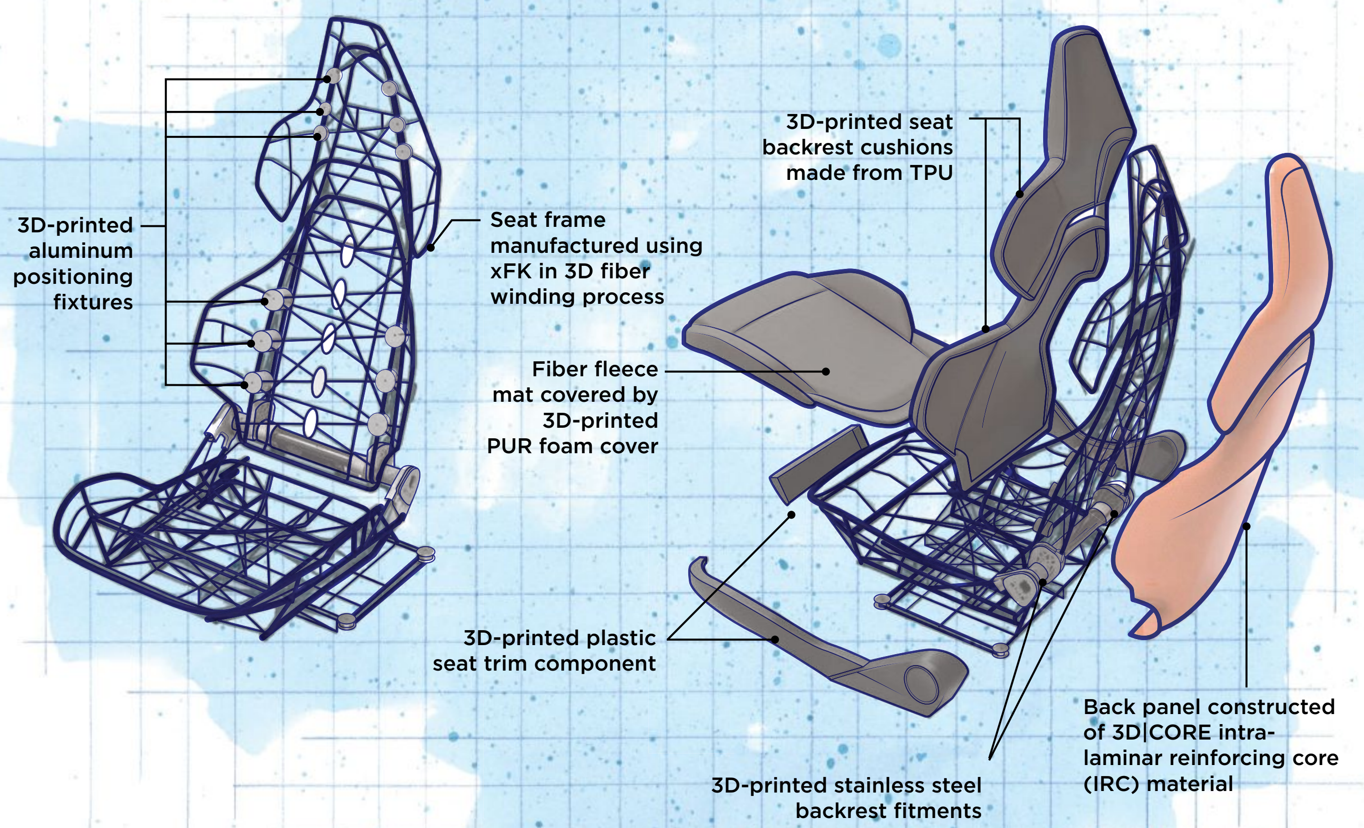
In the ULBS seating concept, a thermoset resin-impregnated fiber roving is wound around a positioning fixture, allowing fibers to be arranged to match each part's loads and desired functions.

Source | csi entwicklungstechnik

Building a better seat

The Ultraleichtbausitz (ULBS) ultra-lightweight seat feasibility study was developed through a collaboration between multiple companies using a combination of technologies. The project's vision was, in the group's words, "to create an ultra-lightweight-seating concept, outstanding in the market in terms of its weight optimization." Initiating companies csi entwicklungstechnik GmbH (csi, Neckarsulm, Germany), Alba Tooling & Engineering (Forstau, Salzburg, Germany) and Automotive Management Consulting (AMC, Penzberg, Germany) developed the prototype seating concept in collaboration with Covestro (Leverkusen, Germany), LBK Fertigung (Friedberg, Germany), Robert Hofmann (Lichtenfels, Germany) and 3D|CORE (Herford, Germany).

The collaborative project resulted in a seat prototype with a



DESIGN RESULTS **Ultra-lightweight seat hardware prototype**

- The ULBS seat prototype weighs approximately 10 kilograms, which includes the cushion, structural frame, functional inserts and the seating console
- 20% lighter than comparable lightweight seats on the market
- Minimizes material waste — less than 1% of the fiber roving used for the seat frame is discarded

weight of a little over 10 kilograms, which includes the cushion, structural frame, functional inserts and the seating console that allows it to be mounted to a vehicle. The seat is 20% lighter than comparable lightweight seats on the market, many of those being aftermarket seats. According to ULBS project leader Stefan Herrmann, who is responsible for lightweight design at csi, there are currently no competing seats on the market that weigh less than 12 kilograms.

"However, a direct comparison is often not apples-to-apples, because aftermarket seats often do not include the seating console in the weight definition," says Herrmann. "Also the seating comfort of the ULBS is a lot higher compared to seats with similar weight. Existing seats are often bucket seats, which are even lower weight but not that comfortable, or traditional supersports seats, which have a lot higher weight."

The ULBS features several innovative technologies, of which the fiber roving skeleton structure based on process technology xFK in 3D plays the most prominent role. The fundamental importance of the award-winning technology for endless fiber roving deposition lies in its freedom of design, in the simulation-driven and material-optimized fiber placement exactly in load-direction as well as in the simple, cost-efficient and waste-free application of fiber material. 3D-printed parts have been used for the load transfer in this framework structure. In areas with the highest loads, such as the backrest fitments, the seat uses 3D-printed structures made of stainless steel with high strength and high modulus. In lesser loaded areas, aluminum 3D-printing is used.

csi entwicklungstechnik, an engineering company that specializes in vehicle body-in-white (BIW) structures, as well as automotive interiors and exteriors with business areas including carbon »

Ultra lightweight seat

The Ultra Leichtbausitz (ULBS) seating concept was developed through a collaboration between multiple companies using a combination of technologies.

Source | csi entwicklungstechnik

Filament wound seat frame

Much of the weight reduction in the ULBS project results from AMC's fiber winding process technology xFK in 3D. Source | csi entwicklungstechnik

fiber-reinforced polymers (CFRP) and additive manufacturing, oversaw and coordinated the project based on the idea initiated by AMC. The styling, surfacing, concept, simulation, design engineering and project management for the project were provided by csi.

Herrmann explains: "csi was responsible for the work packages in the domain of the digital process chain — styling, engineering design, surfacing design, CAE simulation, topology simulation, validation simulation and virtual confirmation of the project."

He stresses that what makes the ULBS project noteworthy is not only the use of innovative materials and manufacturing methods, but the development of a complex part that comprises new component designs within a short seven-month timeframe using close collaboration among partners.

Winding a frame

Much of the weight reduction in the ULBS project results from AMC's xFK in 3D, a highly flexible, configurable, cost-effective and sustainable fiber composite technology for winding components.

xFK in 3D has already been used for a variety of products and applications for various industries and market segments. SGL Group (Wiesbaden, Germany) displayed several automotive and bicycle parts manufactured via this technology at JEC World 2018. One of the displayed parts, a carbon fiber bicycle chain ring developed by AMC, is said to cut weight up to 70% compared to an aluminum version.

The xFK in 3D process winds load-bearing structures in a waste-free manner using thermoset resin-impregnated continuous fibers. A fiber roving saturated with epoxy resin is wound around a positioning fixture, or winding bushings, which allows fibers to be arranged to match each part's loads and desired functions.

"One major benefit of xFK in 3D is the elimination of weak points regarding load transfer and load introduction in structures," says Herrmann. He explains that weak points are often not in the continuum of the structure, but in the areas where loads are introduced into the structure, especially where neighboring components are connected to the structure. The xFK in 3D technology enables load transfers across connections and allows fibers to be aligned according to the desired component functions and load cases, and manufactured in three dimensions.

The filament winding process yields additional benefits as well. The process helps to minimize material waste — less than 1% of the fiber roving is wasted.

New technologies

The ULBS prototype uses a combination of new technologies including a back panel shell made of intralaminar reinforcing core (IRC) material, and 3D-printed seat backrest cushions made from thermoplastic polyurethane (TPU).

Source | csi entwicklungstechnik

csi recognized xFK in 3D's strengths and designed the ULBS seat frame to be constructed under the consultancy of Dr. Clause Georg Bayreuther, technology head of AMC.

"Working with csi engineers, AMC consultants and Alba's tooling experts developed this concept and structure for the seat frame to be manufactured using the xFK in 3D process," says Peter Fassbaender, technology consultant and initiator of xFK in 3D technology.

Alba manufactured the tooling for the CFRP seat frame and provided engineering support. Also, although the seat frame was wound from carbon fiber, natural fibers or basalt fibers are also good candidates.

A hybrid material structure

In addition to the frame, the ULBS prototype includes several other new innovations. Alba, which supplied the tooling for the frame, also supplied the tooling, engineering and manufacturing for the foam body of the seat and executed the seat's assembly. A fiber fleece mat covers the seat's CFRP frame, which is then covered by a 3D-printed PUR foam cover. The seat cushion area is made from traditional foam.

Further weight reduction was accomplished through the use of 3D|CORE, an intralaminar reinforcing core (IRC) material, in the back panel shell structure of the seat backrest. IRC is a structural sandwich core that comprises extruded polystyrene (XPS) and polyethylene terephthalate (PET) foam core bodies in an integrated honeycomb pattern. During the production of composite parts, the honeycomb structure is filled with resin, resulting in high intra-laminar strength. The 3D|CORE is assembled between two layers of glass fiber to create a preform, which is infused with thermoplastic epoxy resin using vacuum-assisted resin transfer molding (VARTM).

Covestro supplied its Dispercoll adhesive as a binder for the fiber fleece mats, as well as the 3D-printed backrest cushion. According to Herrmann, Dispercoll's mechanical properties provide good abrasion resistance, which is important because surface contact between the cushion and frame can subject the fleece to wear over time.

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"If you have a single fiber roving, when you put that into a textile, you get micro-movements between the hard CFRP parts and the fleece mats. The seating frame components can rub against the textile and destroy it," explains Herrmann.

Traditional seats typically have a larger surface area supporting the cushioning, and do not have this problem.With xFK in 3D, however, there is a smaller contact surface area due to the frame structure.

"When xFK in 3D structures push against the fleece fabric, you must have a specific and durable binder; this is what Dispercoll provides in this context," adds Herrmann.

Covestro also supplied what is said to be the world's first 3D-printed cushion. While conventional and tooling intensive foam is typically used in seat backrests, the use of the 3D-printed seat backrest cushions, which are made from TPU (thermoplastic polyurethane), further increases the flexibility and adaptability of the ULBS seat with regard to its aesthetics, functional integration options and comfort.

A seat for the future

The ULBS project accomplishes several goals. The resulting concept, while not yet on the market, has the potential to serve numerous niche markets such as hypercars, air taxis, ultra-lightweight vehicles, micromobility, helicopters, multicopters and aviation. While admittedly more expensive than production car seats, the ULBS demonstrates several technologies that minimize waste, thereby reducing material costs. In comparison to other carbon fiber technologies, xFK in 3D yields a very low amount of waste. In fact, the entire project is aimed at using minimal resources and only as much material as absolutely necessary. The ULBS also offers the possibility of using renewable and sustainable resources such as natural fibers in the frame structure, cushions and textiles. CW

ABOUT THE AUTHOR

Scott Francis, senior editor for *CompositesWorld,* has worked in publishing and media since 2001. He's edited for numerous publications including *Writer's Digest*, *HOW* and *Popular Woodworking.*


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