CW CompositesWorld

Reaping the benefits: COMPOSITES USE GROWS IN AGRICULTURAL EQUIPMENT

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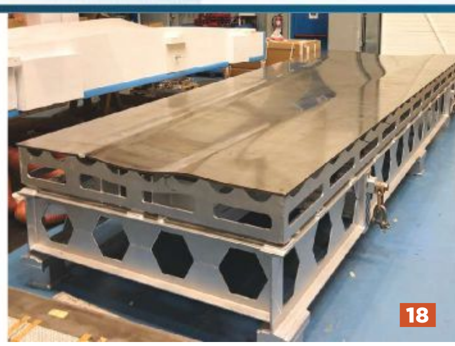
COLUMNS



FEATURES

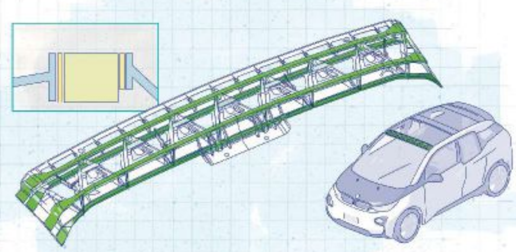
» DEPARTMENTS

» ON THE COVER

As agriculture continues to grow and evolve in order to feed burgeoning human populations, the agricultural equipment used to manage crops and livestock also is changing, and that is affecting the kinds of materials being used. See p. 22.

Source / CNH Industrial N.V.

FOCUS ON DESIGN



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NOVEMBER 6 2019

CALL FOR NOMINATIONS

-> HALL OF FAME AWARD -> MOST INNOVATIVE USE OF PLASTICS AWARDS

The Automotive Division of the Society of Plastics Engineers (SPE®) is announcing a "Call for Nominations" for its 49th-annual ***Automotive Innovation Awards Gala,*** the oldest and largest recognition event in the automotive and plastics industries. This year's Awards Gala will be held Wednesday, **November 6, 2019** at the Burton Manor in Livonia, Mich. Winning part nominations ***(due by September, 15, 2019)*** in 10 different categories, and the teams that developed them, will be honored with a **Most Innovative Use of Plastics** award. A **Grand Award** will be presented to the winning team from all category award winners. An application that has been in continuous use for 15 years or more, and has made a significant and lasting contribution to the application of plastics in automotive vehicles, ***(nominations due by May 31, 2019)*** will be honored with a **Hall of Fame** award.

SPONSORSHIP OPPORTUNITIES

This annual event currently draws over 800 OEM engineers, automotive and plastics industry executives, and media. A variety of sponsorship packages - including tables at the banquet, networking receptions, advertising in the program book, signage at the event and more are available. Contact Teri Chouinard of Intuit Group at teri@intuitgroup.com.

For more info and to submit nominations, go to: **www.speautomotive.com/innovation-awards-gala.**

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INNOVATIVE PART COMPETITION CATEGORIES:

- Additive Manufacturing
- Aftermarket
- Body Exterior
- Body Interior
- Chassis/Hardware
- Environmental
- Materials
- Process, Assembly & Enabling Technologies
- Powertrain
- Safety

& Hall of Fame

» It's Thursday, March 14 as I write this. It is the last day of JEC World 2019, and the show ended just more than three hours ago. It has been, as usual, an eventful three days at the world's largest composites trade event. Also, as usual, JEC has provided a valuable opportunity to see and speak with people from a variety of segments of the composites industry supply chain, including materials suppliers, fiber suppliers, machinery manufacturers, fabricators and OEMs. In this way, JEC provides a rare chance to chase down rumors, see new technology, reconnect with friends and colleagues and otherwise take the "pulse" of composites manufacturing.

JEC provides a chance to take the "pulse" of the industry.

By journalistic standards, I should spend several days away from JEC before I attempt to put the show in perspective, but those same journalistic standards also demand that I adhere to deadlines. So, here is my in-the-show, sleep-deprived, partially baked take on what JEC World 2019 tells us about the state of composites manufacturing today.

Aerospace: There is, perhaps, no end market that is at once so full of promise and yet so unsettled as the aerospace market. With the Boeing 787, 777X and Airbus A350 in production, and with the A380 heading toward retirement, the entire aerospace supply chain is looking to the future, and the next aircraft programs to be developed by the two big primes. The question is not if composites will be employed on next-generation aircraft, but what kind, where and how (will they be fabricated)? Complicating matters is the fact that Boeing and Airbus are following different M&P paths that converge and diverge, depending in part on the application, material strategy, manufacturing strategy and manufacturing volume.

All eyes now are on Boeing, which is expected to announce — maybe at the Paris Air Show in June — the New Midsize Airplane (NMA, or, 797), a single-aisle, mid-range plane designed to take the place once held in the company's aircraft portfolio by the now-retired 757. Assuming the NMA becomes reality, where in its design might composites be used? If the 787 and 777X are an indicator, then it will have AFP-made, autoclave-cured wings and fuselage structures. However, if Boeing decides to mature its composites M&P, it might consider increased use of thermoplastic composites as well as vacuum-infused structures. However, you can't talk about the NMA without also considering the 737, which many people suggest could be redesigned as part of a broader NMA-737 development effort. If that happens, the NMA could be used as an M&P stepping stone to the 737 reboot.

For its part, Airbus appears to be waiting for Boeing's NMA announcement to make a decision of its own about putting an extended A320 on the drawing board. And if that occurs, Airbus has R&D efforts in place that seem to signal that the company is more willing to consider use of thermoplastic composites in fuselage structures and infused materials in wing structures.

Automotive: The autocomposites waters are even muddier. If, at one time, you envisaged an automotive industry awash in composites structures, you can wake up. It's not happening. Plainly, there is too much inertia amongst automotive OEMs for them to adopt composites, even if it makes sense from a lightweighting or even cost perspective. In automotive, the customer rules, and unless customers start demanding the advantages conveyed by composites, adoption will be incremental. That said, the electric vehicle market offers parts and applications heretofore unseen in the automotive world that could, easily, be dominated by composites. The poster child for this, at JEC, was the composite battery enclosure, which was everywhere at the show and offers unmatched weight, strength and FST properties. Also highly visible at the show were composite leaf springs, pressure vessels and lift gate systems.

Finally, I cannot let go unnoticed an impressive proliferation at JEC of manufacturing automation systems designed to minimize labor, reduce errors, boost productivity, speed throughput and increase quality. These systems covered everything from cutting and kitting to filament winding to ply placement to nondestructive inspection.

Keep an eye out in the magazine and at *CompositesWorld.com* for full reports on new products and technologies introduced at the show, as well as highlights from our coverage in Paris.

Au revoir.

JEFF SLOAN — Editor-In-Chief


LEVERAGE THE FUTURE OF
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An ode to the A380

» In mid-February, Airbus announced it will make the final delivery of the A380, the world's largest commercial aircraft, sometime in 2021. This followed the cancellation of orders from Emirates Airlines, the largest customer of the plane since it was first delivered in late 2007 to Singapore Airlines. Once the remaining orders are filled, Airbus will have produced 251 aircraft, but will fail to break even on the development costs. A common argument for the lack of demand for the plane is a fundamental change in the aviation industry, moving from a large international airport hub-and-spoke model to a point-to-point model, which involves smaller twin-aisle jets efficiently moving people across oceans without having to make connections to reach their destinations. The high cost of the A380, and its large size limiting the airports that had infrastructure to handle it, may have doomed it from the beginning.

The A380 was composed of more composites content than any passenger plane that came before it.

Standing more than seven stories tall with capacity for more than 500 passengers in a three-class configuration, the A380 was touted as much more fuel-efficient than Boeing's largest offering, the 747. Although I have yet to climb aboard an A380, many friends have commented to me how comfortable and quiet the aircraft is in flight. Though the cancellation of orders from Emirates was obviously a setback for Airbus, Emirates converted its canceled orders to other Airbus planes, notably the composites-intensive A350 XWB.

In 2002, three years before the first A380 aircraft took flight, I had the opportunity to write the feature story about the materials and processes on the A380 for the September issue of *High-Performance Composites*, the predecessor to *CompositesWorld*. We had been granted extensive access to Airbus management and to the supply chain, which provided us with lots of information — so much that I requested (and was granted) a double-length feature of 10 magazine pages, a length which had not been done prior, and I don't believe since. There was just so much to tell, and I believe it was the most comprehensive story ever written about composites on the A380. Even then, we followed with four additional in-depth articles over the next couple of years on some of the more novel processes and applications used on the A380.

The A380 was composed of more composites content than any passenger plane that came before it, with 16 percent of the structural weight from advanced polymer composites. I contend it is more multimaterial and more multiprocess than any commercial aircraft ever built, and when one considers the massive size of the components (the carbon fiber center wing box, the first ever for a commercial plane, alone weighed more than 9 tons), it stands as a groundbreaking achievement in aviation. An additional four percent of the structural weight came from the use of GLARE (glass laminate aluminum-reinforced epoxy) in the upper fuselage panels and leading edges of the vertical and horizontal stabilizers.

What were some of the other innovations? To start, the use of automated tape laying (ATL) on large airfoil skins in the horizontal and vertical stabilizers. The A380 horizontal rear stabilizer is approximately the dimension of the main wing of the A310 twin-aisle, 220-passenger aircraft, so this was a big step up from previous aircraft. Success here, I believe, led to the confidence to produce the main wing skins of the Boeing 787 and the A350 XWB. The rear pressure bulkhead of the A380, measuring 6.2 by 5.5 meters, was produced using resin film infusion and non-crimp carbon fiber fabrics — breakthroughs in materials and processing for a part this size.

The upper cabin floor beams, spanning the full width of the aircraft (5.92 meters) without stanchions, were produced using a novel prepreg pultrusion process developed by JAMCO in Japan. The same process provided stringers and stiffeners for the vertical tailplane, which were much smaller and already proven across multiple Airbus aircraft. The leading edge of the main wings, also called the D-nose, was produced from glass fiber-reinforced PPS thermoplastic. Although this technology had been initially used on the A340-600, the size of the A380 provided plenty of challenges. The parts married autoclaved PPS skins to compression-molded ribs and stiffeners via thermoplastic welding, rather than adhesives or mechanical fasteners. Resin transfer molding (RTM) and vacuum-assisted RTM (VARTM) featured extensively in the aft fuselage and vertical tail plane, in spars, frames and other structures. Automated fiber placement (AFP) simplified fabrication of the aft fuselage skin panels.

I could go on, but the point is clear: While many will consider the A380 a commercial failure, the success of the A350 XWB and Boeing 787, both groundbreaking in their own ways, owe a great deal to the materials and processes advanced by the A380. 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.

Index moves higher on new orders rebound

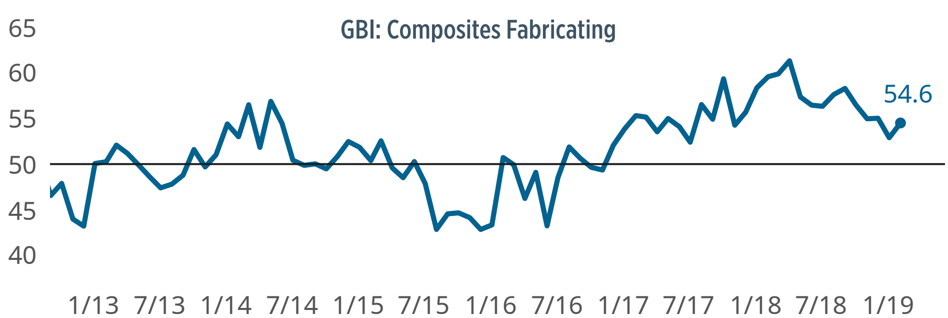
February 2019 — 54.6

» The February GBI: Composites Index rebounded from January's recent low. The latest reading is 8.8 percent lower compared to the same month one year ago, when the Composites Index was approaching an all-time high in early 2018. Gardner Intelligence's review of the underlying data indicates that the Index was propelled higher during the month by new orders, production, supplier deliveries and employment. The Index — calculated as an average — was pulled lower by backlogs and exports. Of all the components, only exports contracted during the month.

February marks the first time in nearly a year that new orders expanded faster than any other component. When the Index experiences a significant expansion in new orders, there are often immediate as well as delayed effects to other components. As experienced during the month, the relatively faster growth in new orders as compared to production resulted in an immediate increase in backlogs. Gardner will be monitoring production and supplier deliveries in the coming months to assess causal effects to the Index resulting from the current change in new orders. CW

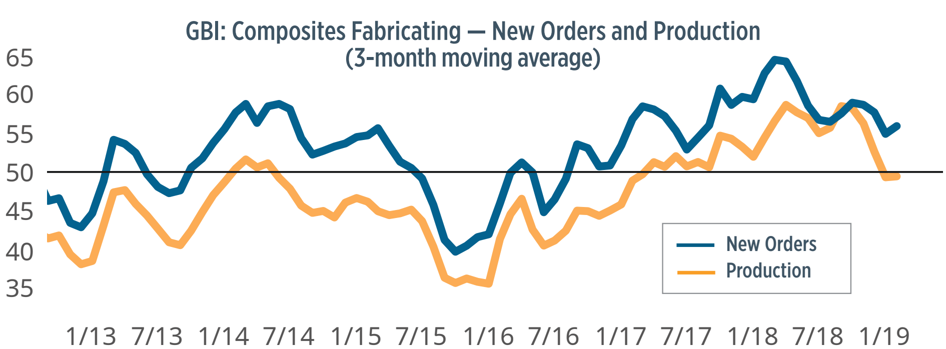
ABOUT THE AUTHOR

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



New orders expansion sent Index higher

New orders was the fastest expanding component in February. During the month five of the six components expanded.



Surprise expansion in new orders results in improved backlogs

February's expansion in new orders resulted in growing backlogs. Strong growth in new orders often has an immediate or at times slightly delayed effect on production and backlogs.

Environmental testing of composites

» Although mechanical testing of polymer matrix composites (PMCs) is most commonly performed in ambient laboratory conditions, additional testing is often performed in other environmental conditions to determine properties of interest. Additional test environments typically include higher or lower test temperatures as well as elevated levels of absorbed moisture in the test specimens. The selection of these environmental conditions for testing is based on established limits of the composite material's usage as well as the environmental conditions expected in service.

In general, the mechanical properties of PMCs can be affected significantly by exposure to elevated temperature. However, the combination of elevated temperature and absorbed moisture, referred to as *hot/wet* conditions, often produce the most critical environmental conditions for which the most severe reductions are produced in several important mechanical properties.

The determination of appropriate environmental conditions for elevated temperature testing of PMCs starts with the determination of the material's glass transition temperature, T_g. As explained in my October 2018 column, the T_g of a polymer is the temperature corresponding with a two to three order of magnitude reduction in its stiffness. Additionally, since hot/wet conditions are of even greater concern, *wet* T_g testing is performed using moisture-conditioned test specimens, often resulting in a significantly reduced temperature. The *material operational limit* (MOL) is often established based on the *wet* T_g temperature. As a general guide for material selection purposes, the MOL typically is selected to be 28°C/50°F below the *wet* T_g temperature[1]. However, smaller temperature reductions below the *wet* T_g temperature may be acceptable when supported by sufficient elevated temperature testing covering the full range of high-temperature environments expected for a particular application.

Testing under hot/wet conditions often is the most critical environmental condition for PMCs.

As expected, the "matrix-dominated" mechanical properties of PMCs, such as stiffness and strength under shear and transverse (90°) tension loading, are most affected by hot/wet environmental conditions. While polymeric fibers such as aramid are also significantly affected by these conditions, carbon and glass reinforcing fibers are not. Therefore the "fiber-dominated" mechanical properties of carbon and glass fiber composites, such as the longitudinal (0°) tension stiffness and strength, are relatively unaffected by these environmental conditions. Interestingly, the longitudinal (0°) compression strength, often thought of as a fiber-dominated property, exhibits a significant decrease at hot/wet testing conditions. The reason? The fiber-direction compression strength depends on the matrix material to support the fibers and resist fiber microbuckling failure. Additionally, hot/wet testing conditions can produce an *increase* in some mechanical properties due to the matrix material becoming plasticized and exhibiting higher toughness. As an example, the open-hole tensile strength (ASTM D5766[2]), a measure of the notch sensitivity of a PMC, may increase under hot/wet conditions since the formation of matrix damage is inhibited by this toughness increase.

At ambient temperature, a PMC can take months or years to reach this "wet" condition, defined as a state of moisture equilibrium throughout its thickness. Since moisture diffusion rates increase significantly with temperature, composite test specimens may be moisture conditioned in shorter times at elevated temperatures. However, there are limits on the moisture-conditioning temperature, as excessive conditioning temperatures can produce property changes in the polymer matrix that are not representative of moisture conditioning at ambient humid conditions. For example, the Composite Materials Handbook (CMH-17) suggests a maximum conditioning temperature of 82°C/180°F for epoxy-based composites cured at 177°C/350°F. For lower-temperature-cure epoxies, lower conditioning temperatures are suggested[3]. As described in ASTM D5229[4], there is no specified time period for moisture conditioning, as moisture equilibrium is established by the mass of the specimen changing by less than 0.02 percent between successive measurements. Further, the use of pressurized steam or water immersion are discouraged, as they do not produce the same state of moisture saturation as would occur at ambient temperatures with humid air and do not produce significant reductions in conditioning time.

Although testing under hot/wet conditions often is the most critical environmental condition for PMCs, mechanical testing is also commonly performed at sub-ambient temperatures. Since no lower-temperature MOL exists analogous to that based on the wet T_g for elevated temperatures, testing is often performed at the lower-limit temperature established for a particular application. Within the aerospace industry, for example, a lower-limit temperature of -54°C/-65°F is used for many applications. At this sub-ambient temperature, mechanical testing is typically performed with specimens in either an ambient or *dry* moisture condition, the latter defined as being in moisture equilibrium with an environment at 5 percent or less relative humidity[3]. The reason? The absence of absorbed moisture coupled with a cold test temperature produces a more brittle material behavior in the polymer matrix, resulting in reduced toughness and greater susceptibility to matrix damage. As a result, some fiber-dominated mechanical properties, such as the open-hole tensile strength (ASTM D5766[2]), may exhibit reduced values under cold testing conditions. If a dry test condition is desired, specimens are placed in a drying oven at temperatures similar to those used for moisture conditioning.

Finally, in addition to testing in alternate environmental conditions, mechanical testing also may be performed to evaluate the sensitivity of PMCs to other fluids to which they may be exposed to in a particular application. Such fluids may include fuels, lubricants, deicing fluids and cleaners used in service. To assess the fluid sensitivity of a PMC, test methods that are sensitive to changes in matrix-dominated properties are commonly used. The ±45° tensile shear test, ASTM D3518[5], is commonly used for this purpose. This test is relatively simple to perform and produces a matrix-sensitive nonlinear shear-stress-versus-shear-strain curve that allows for thorough comparative assessments.

The open-hole compression test, ASTM D6484[6], is typically performed using a quasi-isotropic laminate and is an important design value for many applications. The test shows sensitivity to matrix degradation, thus is useful for fluid sensitivity assessments. The short beam shear test, ASTM D2344[7], is the simplest and most affordable option for assessing fluid sensitivity. For all of these possible tests, results obtained from specimens subjected to fluid exposure are compared to unexposed control specimens tested at both ambient and hot/wet conditions to assess the severity of exposure to a particular fluid. The Composite Materials Handbook (CMH-17)[3] provides further details of fluid sensitivity testing methods with a focus on aerospace applications. CW

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Check out the most recent reports on global wind energy growth, a newly unveiled architectural cladding composite, a research program exploring new ways to manufacture high-performance carbon fiber composites and more.

ENERGY

GWEC reports 51.3 GW of new wind capacity in 2018

Source | GWEC

The Global Wind Energy Council (GWEC, Brussels, Belgium) reported in late February that the global wind energy industry installed 51.3 gigawatts of new capacity in 2018. Since 2014, the global wind market's growth has been stable, installing more than 50 gigawatts of new capacity each year.

Despite a 3.9 percent decrease in the global onshore market in annual terms, there was promise shown by growth in developing regions such as Latin America, Southeast Asia and Africa, which were responsible for 10 percent of new onshore installations in 2018, totaling 4.8 gigawatts.

The global offshore market grew by 0.5 percent in 2019, with new installations of 4.49 gigawatts, reaching a total installed capacity of 23 gigawatts. For the first time, China installed more offshore capacity than any other market (1.8 gigawatts), followed by the United Kingdom (1.3 gigawatts) and Germany (0.9 gigawatts). GWEC forecasts that offshore wind will become an increasingly global market. If governments remain committed, and projects and investments continue, annual installations in Asia could reach 5 gigawatts or more each year, according to GWEC. In the U.S., GWEC expects the developing offshore wind market to reach 1 gigawatt by 2022 or 2023.

GWEC forecasts that new installations will reach 55 gigawatts or more each year until 2023. Stable volume is predicted to come from mature regions in Europe and the U.S., while significant growth is forecast to be driven by developing markets in Southeast Asia and the global offshore market.

According to GWEC's report, total installed wind capacity reached 591 gigawatts at the end of 2018, a growth of 9.6 percent compared to the end of 2017. Total installed onshore wind grew by 9 percent, while total offshore wind grew by 20 percent, reaching 23 gigawatts.

These latest figures released by GWEC form the statistical release of the *Global Wind Report*, GWEC's flagship publication. The full report is set for release on April 3.

BIZ BRIEF

Lohia Group (Kanpur, India) has announced its acquisition of Light & Strong Ltd. (Gedera, Israel), a company specializing in aerospace and military carbon fiber and glass fiber composite components production. The move is inspired by the success of private sector companies in the defense and aerospace sector under the Make in India initiative.

Lohia Group reportedly plans to leverage Light & Strong's existing client base, which includes the Israeli Ministry of Defense among others, to build its own presence in the sector.

The company says it is committed to supporting the composite requirements of the indigenous aerospace and defense sector, and that Light & Strong will allow Lohia Group to integrate its manufacturing expertise with cutting-edge technology to help make India the exporter of choice for global OEMs.

AEROSPACE

FACC receives STC approval for its Passenger Luggage Space Upgrade program


Source | FACC

FACC (Ried im Innkreis, Austria) has announced that its Passenger Luggage Space Upgrade product for aircraft interiors has been issued a Supplemental Type Certification (STC) by the European Aviation Safety Agency (EASA, Cologne, Germany) for installation in A320 aircraft.

The stowage compartments are said to improve the functionality of aircraft cabins by increasing stowage space by 67 percent — they can now reportedly store up to five carry-on suitcases instead of three — while reducing weight.

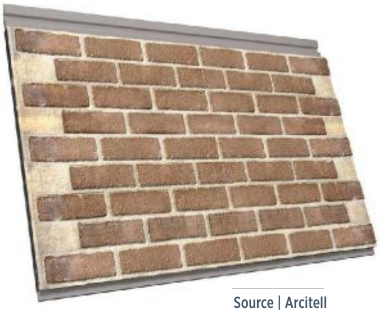
The overhead bin doors are manufactured in a hot press mold curing process, made of a lightweight sandwich structure comprising a phenolic-based, glass fiber-reinforced prepreg combined with an aramid fiber honeycomb core. The milling part is painted with a polyurethane-based, flame-retardant aerospace topcoat. Installed hardware components are injection molded with high-performance polyetherimide (PEI).

By issuing the extension certificate for STC and major repairs, EASA confirms that FACC has established the requisite expertise and processes in accordance with legal requirements in order to develop and approve major changes and repairs to aircraft. The STC is part of the required EASA certificate of airworthiness and entitles FACC to carry out substantial modifications to an aircraft by means of the component developed by its design organization. The launch customer for the FACC upgrade program is Austrian Airlines.

"With the latest certification, we are now able to offer all airlines a Passenger Luggage Space Upgrade as a retrofit for the classic cabin of the A318, A319, A320 and A321 Airbus models," says Robert Machtlinger, CEO of FACC. "In addition to the modern look, our new system offers considerably more stowage space for luggage. Another major advantage is easier and faster handling, resulting in shorter boarding times and cost savings."

ARCHITECTURE

Architectural cladding composite unveiled


Source | Arcitell

Arcitell (Sugarcreek, Ohio, U.S.), a manufacturer of residential siding products, revealed its innovative alternative to traditional building claddings at the recent 2019 edition of the International Builders Show (IBS) in Las Vegas, Nev., U.S., held Feb. 19-21. Qora, a lightweight fiber-reinforced polymer (FRP) panel that authentically replicates traditional brick, stone or wood siding, is designed to simplify the building process and, given its panelized format, provide an answer to the construction industry's ongoing labor concerns. Qora will be available in the southeastern U.S. and Texas.


Source | Arcitell

"Qora was born from the belief that Arcitell could produce a cladding product without trade-offs — and our persistence to not stop until that material existed. By creating this joint effort between Canton, Ohio-based Belcap Inc., a member of the Belden family of holdings, and Dublin, Ireland-based Acell Industries, we plan to do just that," says Jeff Adams, president and CEO.

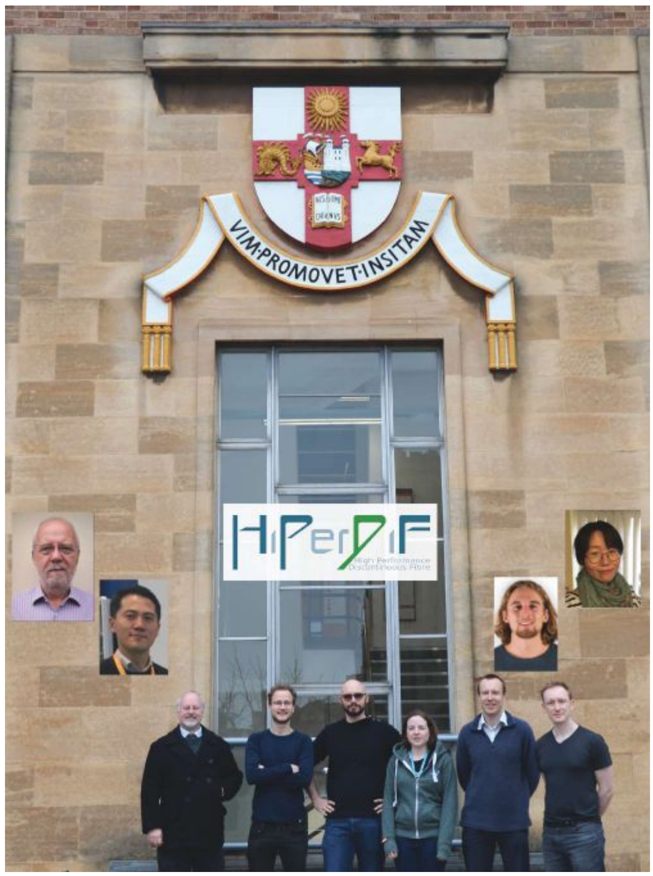
According to Arcitell, Qora offers simplicity and workability for builders seeking an easier way to meet consumer demand for architectural brick, stone and cedar. The panels — made up of a core of Acell mineral rigid foam, face sheets of glass fiber-reinforced molding compound made with a proprietary phenolic resin supplied by partner Hexion (Columbus, Ohio, U.S.) and the decorative outer face — are pressed and chemically bonded for long-term durability and performance. The decorative panel face incorporates pigments and fillers, often sourced from actual brick, stone and wood.

"Today's builders and contractors need a product that simplifies the construction process without sacrificing beauty, performance or anything else their customers demand in a cladding product. Qora cladding delivers on each of those points," says Ben Skoog, vice president of sales and marketing. Most Qora cladding panels weigh between 2 and 3 pounds per square foot — a fraction of the weight of comparable traditional materials, which allows Qora to more easily mitigate cracking, foundation impacts, and other issues associated with heavy cladding.

U.K. research program explores aligned, discontinuous fiber prepreg

A research program in the U.K. is attempting to achieve a fundamental step-change in the composites industry. The High Performance Discontinuous Fibre project (HiPerDiF), which began in December 2017 and runs through 2020, is a program funded by the U.K.'s Engineering and Physical Sciences Research Council (EPSRC). It is exploring an alternate way to produce high-performance carbon fiber composites: start with *discontinuous*, rather than continuous, fibers. The program, led by Professor Ian Hamerton of the Bristol Composites Institute (ACCIS) at the University of Bristol, has an impressive roster of project partners, including Airbus, Toyota, BAE Systems, ELG Carbon Fibre Ltd., Hitachi Chemical Co. Ltd. and several composite material suppliers including Solvay and Hexcel.

The HiPerDiF researchers argue that simplifying and automating manufacturing processes will increase composite part production volumes. And, if greater production volumes means using more carbon fiber, recycling processes are key to recovering and reusing the fiber. In other words, the goal is to develop a high-volume method that can readily, as the group says, "remanufacture" recycled short fibers and produce parts with mechanical properties comparable to continuous fibers, with those parts in turn (if coupled with a thermoplastic matrix) able to be recycled several times.



The HiPerDiF project team, from left to right, includes Professor Kevin Potter, Dr. Juhyeong Lee, Professor Ian Hamerton, Lourens Blok, Dr. Marco Longana, Dr. Samantha Huntley, Dr. Thomas Rendall, Rhys Tapper, Dr. Thomas Pozegic and Dr. HaNa Yu. Source | HiPerDiF

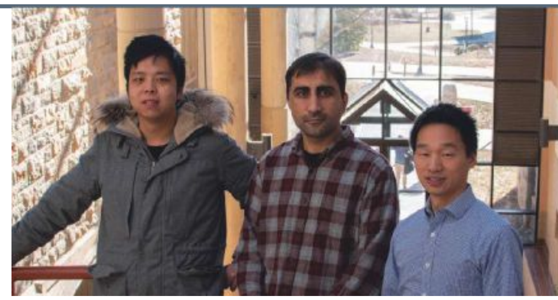
The program's co-investigative lead, Dr. Marco Longana, explains that HiPerDiF technology is a high-volume manufacturing method, invented at the University of Bristol by Dr. HaNa Yu under an earlier program (HiPerDuct, or High Performance Ductile Composite Technology), that is used to produce high-performance aligned discontinuous fiber-reinforced composites (ADFRC). He points out that if discontinuous fibers are accurately aligned and their length is significantly longer than the critical fiber length, then the tensile modulus, strength and failure strain of the obtained composites are comparable to those of continuous fiber composites.

The manufacturing technology, which can handle a range of synthetic and natural fibers with lengths between 1 and 12 millimeters, involves suspending the fibers in water and pumping the water/fiber mixture through a nozzle or nozzles directed toward a gap between two parallel plates. Longana explains that the fiber alignment relies on the sudden momentum change of the fiber suspension when it impacts the furthermost plate. The fibers then fall on a stainless-steel mesh conveyor belt, and the water is removed by suction. This aligned fiber preform is dried via infrared, then combined with either a thermoplastic or thermoset resin to form a prepreg. According to the paper explaining the process, the initial machine prototype produced specimens with 67 percent of the fibers within a ±3-degree range from unidirectional. By processing 3-millimeter, high-strength carbon fiber, a stiffness of 115 GPa, a strength of 1,510 MPa, and a failure strain of 1.41 percent was achieved, with specimens under tensile load.

The HiPerDiF technology can be used to tailor mechanical behavior of composite materials, via hybridization with glass fibers. The researchers also note that reclaimed fiber, while preserving its stiffness, suffers due to sizing removal, alteration of the fiber surface caused by char formation and loss of surface activation that affects fiber/matrix adhesion. HiPerDiF is therefore well-suited for assembling reclaimed fibers into an economically valuable material with high mechanical properties. Hamerton adds that one of the key characteristics that differentiates this work from other projects is the ability to generate high-performance composites from recyclate, potentially recovering both mechanical characteristics and value. This program bodes well for reducing the costs of composites and carbon fiber.

AUTOMOTIVE

Porous carbon fiber made from block copolymers may enable energy storage



Three of the researchers on the project, left to right: Tianyu Liu, Assad Khan and Guoliang Liu. Source | Virginia Tech

Researchers at Virginia Tech's (Blacksburg, Va., U.S.) College of Science have used block copolymers to create carbon fibers with uniform porous structure, with the aim of using the material for energy storage in automobiles and aircraft.

Guoliang Liu, an assistant professor in the Department of Chemistry, wanted to create carbon fibers designed to have micro-holes uniformly scattered throughout, similar to a sponge, that would store ions of energy. After tweaking a conventional method of chemically producing carbon fibers, Liu and his colleagues have developed a process to synthesize porous carbon fibers for the first time with uniform size and spacing. He details this work in an article in the journal *Science Advances*.

Liu used a multistep chemical process using two polymers — polyacrylonitrile (PAN) carbon fiber precursor and polyacrylonitrile-block-methyl methacrylate (PMMA), a place-holding material that is later removed to create the pores. In the past, chemists have mixed PAN and PMMA separately into a solution, creating porous carbon fibers with differently sized and spaced pores. Energy storage can be maximized with greater surface area, which occurs with smaller, uniform pores. Liu's fibers bond PAN and PMMA, creating a block copolymer. One half of the compound polymer is PAN, and the other half is PMMA, with the two halves covalently bonded in the middle.

In a second article, published in *Nature Communications*, Liu shows how these fibers can enable high energy density and high electron/ion charging rates, typically mutually exclusive in electrochemical energy storage devices.

According to Liu, carbon fiber has been used for energy storage when coupled with pseudocapacitive materials such as manganese oxide (MnO_2), which enables the fiber to store a large amount of energy. Liu studied the use of MnO_2 and found that his porous carbon fibers reportedly have the ability to overcome the challenge others have faced of slow charge-discharge rates associated with soaking carbon fiber in MnO_2. Tests in his lab showed high loading of MnO_2 and sustained high charging and discharging rates.

AEROSPACE

Thermwood and Bell collaborate on 3D-printed helicopter blade mold


Source | Thermwood

Long-lead-time tooling is a common limiting factor in aerospace development. A joint venture program between Bell (Fort Worth, Texas, U.S.) and Thermwood Corp. (Dale, Ind., U.S.) recently explored a solution, resulting in what Thermwood claims may be "the largest 3D-printed autoclave-capable tool ever made."

Bell enlisted Thermwood to print a closed-cavity helicopter blade mold measuring approximately 20 feet long, 14 inches wide and 17 inches high. The tooling needed to meet several requirements: It must be printed in one continuous run for vacuum integrity, its surface finish must be 32 RMS or better and it must be able to withstand 90 psi at 360°F. Tight tolerances were also required to ensure proper mating of the two blade mold halves.

Thermwood employed its new 60-mm melt core technology, which was recently installed on the company's Large Scale Additive Manufacturing (LSAM) system at its Development/Demonstration Lab in Southern Indiana. The standard LSAM machine print head housing can be equipped with different capacity melt cores, each offering different minimum and maximum throughputs. According to Thermwood, the new 60-mm melt core has a measured maximum output of 480-570 pounds per hour, depending on the polymer being printed, and can print more than 100 feet of typical print bead (0.830 by 0.200 inches) per minute. This high print rate, even when processing high-temperature material, is said to allow the print bead to be oriented along the length of the tool.

During Thermwood's room-temperature print process, the cycle time for each layer is determined by how long it takes the printed polymer to cool to the proper temperature to accept the next layer. According to Thermwood, only by printing at the proper temperature is it possible to achieve a completely fused, void-free structure capable of maintaining a vacuum in an autoclave without a coating. The print head output determines how much material can be printed during the time it takes for the layer to cool. As the company explains, "bigger print heads mean larger parts, not necessarily faster layer-to-layer print time."

Thermwood printed Bell's tool in one continuous run using Techmer PM's (Clinton, Tenn., U.S.) 25 percent carbon fiber-reinforced PESU (polyethersulfone), a material specifically formulated for LSAM additive printing. The material has a glass transition temperature (T_g) of more than 400°F and reportedly can survive common aerospace component cure cycles. Thermwood technicians claim Techmer PESU prints as easily as ABS, but at a much higher temperature. The resulting print time for one tool half was 3 hours 8 minutes. The part had an "as printed" weight of 542 pounds.

The internal printed structure of the tool supports the mold without touching the back side of the mold cavity, allowing air to flow freely under the entire formed part in the autoclave – which helps the part cure more consistently. According to Thermwood, the ability to incorporate a complex internal design is another advantage of using additive manufacturing for this type of tooling, and its LSAM Print 3D slicing software is designed to support programming of involved internal structures such as these.

In addition to printing, the LSAM is capable of supporting trim and drill processes. Once the tool half was printed, Thermwood machined it within 40 hours. Further, the completed bond tool was able to maintain Bell's vacuum standards required for autoclave processing right from the machine, without the need for a seal coating.

Soon Thermwood will print the second half of the blade mold, with the goal of having Bell cure a full molded blade within the final additively-manufactured bond tool. The two companies plan to conduct further testing on PESU printed molds.

Q&A: Wiener Mondesir, co-founder and chief technology officer, Arevo

Arevo is a California-based manufacturer of additive manufacturing systems that feature the use of continuous fiber reinforcement. In 2018, the company produced a 3D-printed commuter bike using the technology. In a recent podcast episode, Mondesir talks about continuous fiber use in additive manufacturing — where the technology is and where it's headed. You can listen to the full CW Talks podcast on iTunes or GooglePlay, or visit **www.compositesworld.com/podcast.**

***CW*: Can you tell us a little about Arevo's additive manufacturing technology, and how you see this fitting into the broader additive manufacturing and composites manufacturing landscape?**

WM: … We built a software that has the intelligence to look at a part, its complexity, and optimize for weight, optimize for strength. The second piece of technology is composite material. Traditionally, carbon fiber composites are using thermosets as the resin matrix, and carbon fiber. … The key to our building block is a thermoplastic and it contains carbon fiber. And there are a lot of benefits to that that we saw. One, the in-situ consolidation. We built a system that consolidates thermoplastic with the carbon fiber in-situ that doesn't require post-processing for consolidation … It allows us to take a part out of our machine and it's ready to go. The robotics platform that is building parts is another Arevo invention. … It opens up applications for complex geometries made out of carbon fiber that done any other way would be cost-prohibitive.

***CW*: What kind of thermoplastics have you used so far?**

WM: We started at the top of the pyramid with PEEK and PAEK as our resin systems. … Today, a lot of the demanding applications that we're seeing have a need for high-temperature or chemical resilience, so a lot of the applications have PEEK or PAEK as their resin system.

***CW*: You've said that Arevo wants to build a 'factory-in-a-box.' What does this look like?**

WM: Our 'factory-in-a-box' is the world's largest composite factory. It's a modular cell … that you can place close to the demand, it's very flexible, it has a robot and our deposition head built-in and a bunch of integrated processes built-in. … It has inspection built-in and subtractive built-in. … This is a different way of thinking about manufacturing or even additively manufacturing parts.

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**

Dassault and Airbus to collaborate on next-generation combat jet
The aim of the joint concept study is to conceptualize the different Future Combat Air System (FCAS) capabilities and to pave the way for future design and industrialization.
2/8/19 | short.compositesworld.com/FCAS

Siemens electric propulsion motor powers Sun Flyer 2 flight
Bye Aerospace's all-electric, composite material aircraft has successfully completed its first official flight test with a Siemens electric propulsion motor.
2/12/19 | short.compositesworld.com/SiemensSF2

MHI Vestas named as supplier for Iberdrola 476 MW offshore wind project in the Baltic Sea
MHI Vestas will supply up to 52 V174-9.5 MW turbines for Iberdrola's Baltic Eagle commercial offshore wind project in German waters of the Baltic Sea.
2/13/19 | short.compositesworld.com/MHI_Baltic

MC-21 airliner faces one-year delay due to U.S. sanctions
The Russian airliner schedule will reportedly be delayed until 2021 as U.S. sanctions have interrupted the supply of composite materials for the aircraft.
2/20/19 | short.compositesworld.com/MC21_delay

University of Houston researchers explore potential of silk fiber composites
A researcher at the University of Houston-Clear Lake is working to produce natural silk fiber composites with stronger resistance to impact than traditional glass and carbon fibers.
2/20/19 | short.compositesworld.com/UHCL_silk

Spirit AeroSystems chosen for Aerion AS2 Supersonic Business Jet
Aerion Corp. and Spirit AeroSystems have entered into a collaboration agreement for the preliminary design of the AS2's forward, pressurized fuselage.
2/21/19 | short.compositesworld.com/Spirit_AS2

Airbus holds opening ceremony for China-based UAM Innovation Centre
Airbus China Innovation Centre works to identify emerging innovations aimed at transforming the aerospace sector and Urban Air Mobility, leveraging local talent, technologies and partners.
2/22/19 | short.compositesworld.com/AirbusACIC

Hyosung plant expansion to double company's carbon fiber manufacturing capacity
The company is investing $41.5 million into an expansion to its JeonJu plant, said to double production capacity of carbon fiber to 4,000 metric tonnes annually.
2/22/19 | short.compositesworld.com/hyosungexp

NCC's new Large Scale Resin Infusion (LSRI) technology designed for aerospace, wind industry R&D
New Large Scale Resin Infusion (LSRI) technology is aimed at widening the applicability of Liquid Composite Molding (LCM) processes to a wider range of components.
2/25/19 | short.compositesworld.com/NCC_LSRI

Virgin Galactic reaches new heights, adds third passenger with second spaceflight
The flight marks the highest altitude and speed that the SpaceShipTwo has achieved to date, and included the addition of a third crew member for the first time.
2/25/19 | short.compositesworld.com/SS2flight2

Rolls-Royce tests Advanced Low Pressure system (ALPS) for UltraFan engine
Composite elements of the Advanced Low Pressure system (ALPS), including fan blades, a fan case and annulus fillers, were tested together on a donor engine.
2/25/19 | short.compositesworld.com/RR_NMA

AEROSPACE

Teijin to supply carbon fiber tapes to Boeing, acquires Renegade

Teijin Ltd. (Tokyo, Japan) has expanded its aerospace business with recent acquisitions and partnerships. The company announced in January that its Tenax carbon fiber and carbon fiber thermoplastic unidirectional prepregged tape (Tenax TPUD) have been qualified by Boeing and registered in its qualified products list. Teijin will supply Tenax TPUD as an intermediate advanced composite material for primary structural parts for Boeing (Chicago, Ill., U.S.).


Source | Teijin

Since Teijin and Boeing signed a qualification agreement in June 2016, the two companies have been working on material qualification testing and application study of carbon fiber-reinforced thermoplastics for primary structure parts. Tenax TPUD is a carbon fiber thermoplastic unidirectional prepregged tape made with thermoplastic resin. It is designed to provide high heat, impact and fatigue resistance, and help reduce production costs and improve component manufacturing efficiency because of its shortened molding process. Teijin plans to begin commercial shipments of Tenax TPUD to Boeing approved parts makers within the next two years.

Teijin also recently announced its acquisition of heat-resistant thermoset prepreg supplier Renegade Materials Corp. (Miamisburg, Ohio, U.S.), making Renegade a wholly-owned subsidiary of Teijin.

Teijin says it will benefit from Renegade's well-established proprietary technologies and solution capabilities in heat-resistant thermoset prepregs to expand its business in the aerospace field, including next-generation aircraft engine parts. According to Teijin, the acquisition also means that Renegade's products will reach wider markets thanks to Teijin's expertise in carbon fibers and intermediate materials, as well as its large product lineup and global sales network.


Source | Airbus

AEROSPACE

Airbus to halt A380 production after Emirates cuts orders

Airbus (Toulouse, France) announced in February that it will cease deliveries of the A380 in 2021 following a decision by Emirates (Dubai, United Arab Emirates) to reduce its orders for the aircraft from 162 to 123. Emirates will take delivery of 14 further A380s over the next two years.

"As a result of this decision we have no substantial A380 backlog and hence no basis to sustain production, despite all our sales efforts with other airlines in recent years. This leads to the end of A380 deliveries in 2021," says Airbus CEO Tom Enders. "The consequences of this decision are largely embedded in our 2018 full year results."

Enders adds, "The A380 is not only an outstanding engineering and industrial achievement. Passengers all over the world love to fly on this great aircraft. Hence today's announcement is painful for us and the A380 communities worldwide. But, keep in mind that A380s will still roam the skies for many years to come and Airbus will, of course, continue to fully support the A380 operators."

Emirates also announced that it is ordering 40 A330-900 and 30 A350-900 aircraft.

"The A380 is Emirates' flagship and has contributed to the airline's success for more than 10 years. As much as we regret the airline's position, selecting the A330neo and A350 for its future growth is a great endorsement of our very competitive widebody aircraft family," says Guillaume Faury, president of Airbus Commercial Aircraft and future Airbus CEO. "Going forward, we are fully committed to deliver on the longstanding confidence Emirates is placing in Airbus."

Proving viability of dry fabrics, infusion for large aerostructures

Danobat's ADMP is used to produce a wing demonstrator with non-crimp fabrics.

By Sara Black / Senior Contributing Writer

» *CW* has covered several new aerostructure fabrication innovations unheard of a decade ago (see Learn More). Joining those now is a demonstrator wing skin project, unveiled at JEC World 2018, that also breaks new ground. The project is a result of collaboration between Danobat (Elgoibar, Spain) and Airbus Defense and Space (Airbus DS, Cadiz, Spain) and comprises a composite wing skin fabricated using Danobat's high-speed Automated Dry Material Placement (ADMP) technology, which is well known for rapidly laying wide multiaxial and broad-goods preforms for infusion in wind blade and aerospace manufacturing (see Learn More). The wing skin development partners agreed to share some of this breakthrough project's details with *CW*.

Composites displacing metal wing skins

The C295 is a twin-turboprop tactical military transport aircraft currently manufactured in aluminum by Airbus Defense and Space in Spain. A recent collaborative project in Spain produced a composite version of the upper wing skin for the outer wing section of a C295. Source | Airbus

Swapping prepreg for NCF

Almost all aerostructures are made today with prepreg materials, which require autoclave cure. But a definite trend is emerging that aims to get aerostructures out of the autoclave. That's the premise behind the wing demonstrator, says Asier Gandarias Mintegi, Danobat's manager of composites business development: "Our goal is to show the feasibility of manufacturing aircraft components by means of fully automated, dry, multiaxial non-crimp fabric deposition, to achieve disruptive high production rates."

First, a bit of explanation and background on Danobat's trademarked and proprietary ADMP technology. The ADMP automated work cell, with its layup end effector, deposits dry multiaxial or woven material, or dry tape, in any type of tooling. Gandarias Mintegi says that, depending on the requirements of the final application, ADMP can lay down widths from

100 millimeters up to 2 meters or more at rates of up to 2 meters per second. Further, the system has the capability to lay a constant-width roll, or to follow a pattern previously cut to the final dimensions required by the application. Because of the high deposition speed, the system, says the company, provides preforms with improved quality for higher productivity and throughput, at reduced labor cost.

To test this technology in a practical way for aerostructure manufacturing, the Airbus DS and Danobat team employed ADMP to make the upper skin for the outer wing section of a C295 aircraft. The C295 is a twin-turboprop tactical military transport aircraft currently manufactured in aluminum by Airbus DS in Spain. The outer, upper wing skin was 5,700 millimeters long, 1,170 millimeters wide at the root, 650 millimeters wide at the tip; and 4-5.5 millimeters thick. Luis Rubio Garcia, senior expert in composite manufacturing engineering at Airbus DS, says that the wing skin, dimensioned according to the known operational loads of an integral composite wing box based on a multi-spar configuration, is just a first step in technology development: "While the design was dimensioned for prepreg, we adapted it for NCF fabrics. Our design tools are the standard software packages used by Airbus."

Fabrics chosen for the dry layup were a combination of 0/90, ±45 and 0 degrees non-crimp fabrics (NCF), supplied by Saertex GmbH & Co. KG (Saerbeck, Germany). Rubio Garcia explains that these multiaxial carbon fiber fabrics are made with a customized stitching pattern and areal weight. The fabrics included a Hexion Inc. (Columbus, Ohio, U.S.) Epikote powder binder as qualified under an Airbus Specification (Epikote 05311). Eight plies make up the majority of the skin, with a final thickness of 4 millimeters, while 12 plies were placed in the root area and wing tip, for a final thickness of 5.5 millimeters. Gandarias Mintegi explains that the ply drop-off ratio from the thicker root and tip areas to the middle part of the skin was 1:20, or a 1-millimeter drop over a 20-millimeter distance.

Tooling for the demonstrator wing skin was an existing metallic tool with an Invar face (Fig. 1) built for an earlier phase of C295 research to determine the feasibility of a multispar »

FIG. 1 Steel tooling

The tool used for the wing demonstrator was an almost flat steel tool with Invar face that had been used for an earlier phase of C295 research. Layup time using the ADMP technology was 48 minutes.

Source | Danobat

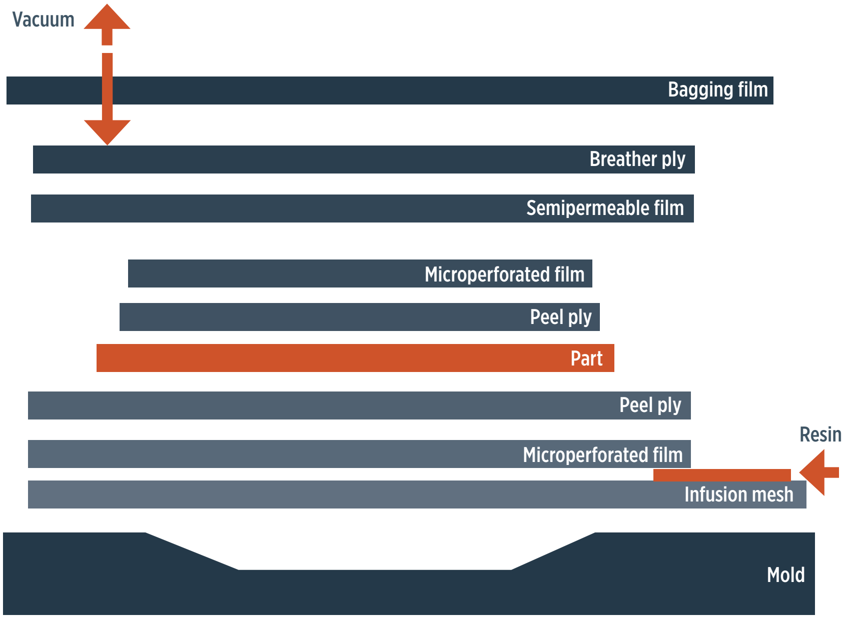


FIG. 2 Layers for infusion

The team employed the Airbus VAP technology for the infusion. The various consumable layers are shown, starting with (from the top down) bagging film over a breather ply, a semipermeable film, a microperforated film, peel ply, the part layup (in orange), with a second peel ply, microperforated film and an infusion mesh beneath the part layup in the metallic mold. Source | Danobat

The Danobat design team

The team that worked on the project is shown here. Automated lamination, infusion and curing of the component was carried out at Danobat facilities (Elgoibar, Spain), while component finishing operations and all testing was done at CBC (Airbus DS) facilities (El Puerto de Santa María, Spain). The design was based on the activities performed at Airbus DS Design Office (Getafe). All manufacturing processes were conducted in collaboration between Airbus DS and Danobat personnel. Source | Airbus

composite wing using prepreg. The ADMP, with its fabric-handling end effector, laid the entire laminate within 48 minutes in the shallow tool, which was prepped with a Loctite Frekote 700-NC mold release from Henkel (Dusseldorf, Germany), micro-perforated film and peel ply for the infusion, explains Gandarias Mintegi. The ADMP system was able to automatically adjust to each of the fabric types without the need for activating the binder on the fabrics (to keep them from slipping), and each ply was placed in the tool in one pass, because of the ADMP's width. He adds: "The time was measured to determine an order of magnitude for this development trial, under conservative conditions, and at 48 minutes we achieved the target proposed within the scope of the trial. This productivity corresponds to 90 kg/hr in a trial mode and can be extrapolated under current conditions up to 220 kg/hr for a mass production mode, once the technology is matured and tuned."

Infusing a fabric wing

While the laminating technology is well-developed, infusing the laminate took more time. The team employed the Airbus method, which is based on a semi-permeable membrane system to remove air from the fabric layups. As shown in Fig. 2 (p. 19), the layup was covered with another peel ply, followed by another micro-perforated film, a semi-permeable film and a breather layer, all enclosed within the bagging film. Consumables were manufactured by Airtech International Inc. (Huntington Beach, Calif., U.S. and Differdange, Luxembourg), except for the semi-permeable film, which came from Diatex SaS (Saint Genis Laval, Rhone Alpes, France), and were supplied to the team by Airbus DS.

The infusion resin was CYCOM 823 RTM epoxy from Solvay (Alpharetta, Ga., U.S.), a one-part room-temperature-injectable epoxy that had been previously qualified by Airbus in aerospace programs. "All of the materials and consumables were chosen to allow us to perform the infusion at room temperature and the cure at 120°C," says Gandarias Mintegi. The total time to bag, infuse and cure the part, including heating the tool and the layup with heating blankets, was approximately eight hours, he adds, under the conditions of the demonstration project.

The cured demonstrator wing skin has undergone a battery of tests so far, reports Rubio Garcia: "Airbus DS followed its standard test procedures for this demonstrator, including non-destructive inspection, geometrical tolerance tests, fiber volume percent and degree of cure. The results are equivalent to the current prepreg reference for the part." The team intends to continue developing dry fabric manufacturing methods for primary aerostructures.

Conclude Gandarias and Rubio Garcia, "So far, results have been very promising. Further development and demonstration activities are already being carried out towards the industrialization of the whole manufacturing process, including the integration of spar and stringers." They add that the plan is to manufacture a new, second dry fabric (NCF) demonstrator shortly, under the Project Airbus DS 2020 roadmap, and *CW* will continue to follow this disruptive technology. CW

LEARN MORE

Read about Irkut's out-of-autoclave composite wing box | short.compositesworld.com/infuseMS21

Read about MTorres' fuselage demonstrator | short.compositesworld.com/MTorr_fuse

Read *CW*'s special supplement on out-of-autoclave composites | short.compositesworld.com/OOA

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Reaping the benefits: Composites use grows in agricultural equipment

Multiple trends support composites advances in this huge but fragmented market.

By Peggy Malnati / Contributing Writer

» While it's not the first transportation segment most people think about as a growing market for composites, perhaps agricultural equipment should be and, in time, it will. After all, as human populations increase across the planet, more resources will be needed to grow the plants and livestock to feed us. Despite a century of horrific wars and some significant international plagues, human populations managed to grow 400 percent during the 20th century. Today's world population is 7.6 billion, and the United Nations (New York, N.Y., U.S.) projects that another billion will be added by 2030, still another by 2050, and that by 2100, the world population will be 11.2 billion. As agriculture grows, the equipment market will grow, too.

Currently the agricultural equipment industry is geographically fragmented, with only a few global OEMs building at the industry's highest production volumes — and these are generally lower volumes than even the heavy truck industry. However, a constellation of trends — including land consolidation in the Americas, tougher fuel efficiency and emissions standards for diesel-powered vehicles in many geographies, the complex issue of weight reduction, greater interest in the use of design differentiation as a marketing tool, and changes in how backward-integrated

A growing market

Projected increases in human populations over the next few centuries will require more food and livestock, and a corresponding increase in the amount of agricultural equipment needed to tend crops and animals. A giant but fragmented industry, agricultural equipment is a growing market for composites and, at some point, could consume a significant amount of these materials.

Source | CNH Industrial N.V.

machinery OEMs still are in metals — has led to more and larger components being converted to composites using a broader array of materials and processes. As those trends gain traction, it's not hard to envision a time when agricultural equipment could become a major market for composites.

Transportation — but different

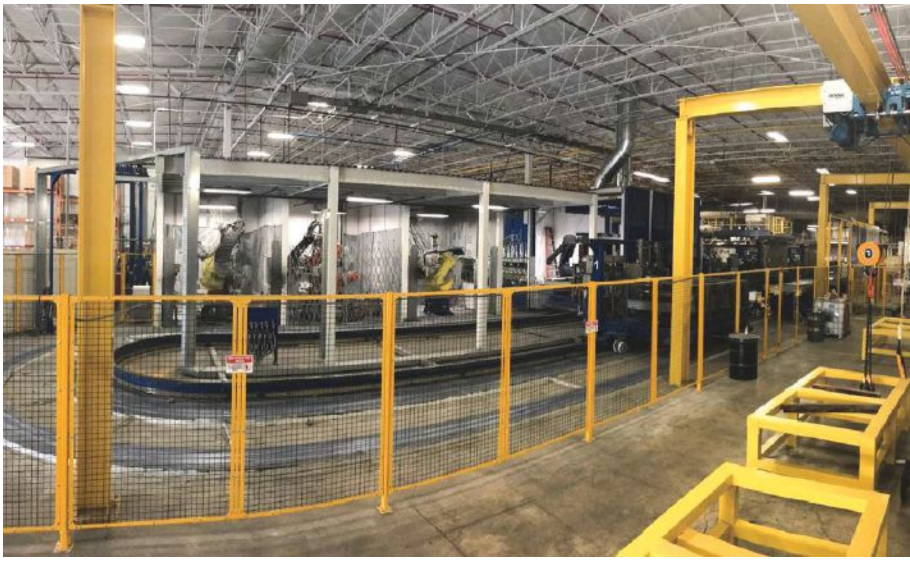
One of the first things to understand about the agricultural equipment market is how big but fragmented it is, and how that affects the kind of equipment produced and used in each region.

"Regionality is an interesting factor in this market," explains Deavron Farmer, global key account manager/agriculture market manager, LyondellBasell Engineered Composites (Houston, Texas, U.S.). "Thanks to consolidation over the last five decades, the biggest farms in the Americas [particularly in the U.S., Canada, Argentina and Brazil] tend to be tens of thousands, if not hundreds of thousands, of acres in size, often with contiguous fields. Given the size of these fields and the tendency toward monocropping [planting single crops under huge acreage], equipment has gotten larger and more modular so farmers can service increasingly large tracts of land efficiently." He adds that that's not necessarily the case in Europe, where farms have remained smaller and equipment is appropriately sized.

On the other hand, in developing countries, other drivers are at play. "Cost — which is an issue everywhere — is an especially sensitive issue in developing regions, where equipment like a tractor might also serve as family transportation into town," adds Farmer. "Although farmers there may use older-style equipment, change is escalating so rapidly that farmers in developing nations may well leapfrog entire generations of equipment that took decades to evolve in other regions — as happened with consumer electronics." Given how geographically fragmented the agricultural equipment market is, there are fewer opportunities for global OEMs like John Deere (Deere & Co., Moline, Ill., U.S.), Case New Holland (CNH Global NV, Amsterdam, Netherlands) and AGCO (AGCO Corp., Duluth, Ga., U.S.) to create world models of their vehicles that permit sharing of parts and reduction of costs as is done in other transportation segments. This means that global purchasing agreements are less common, so »

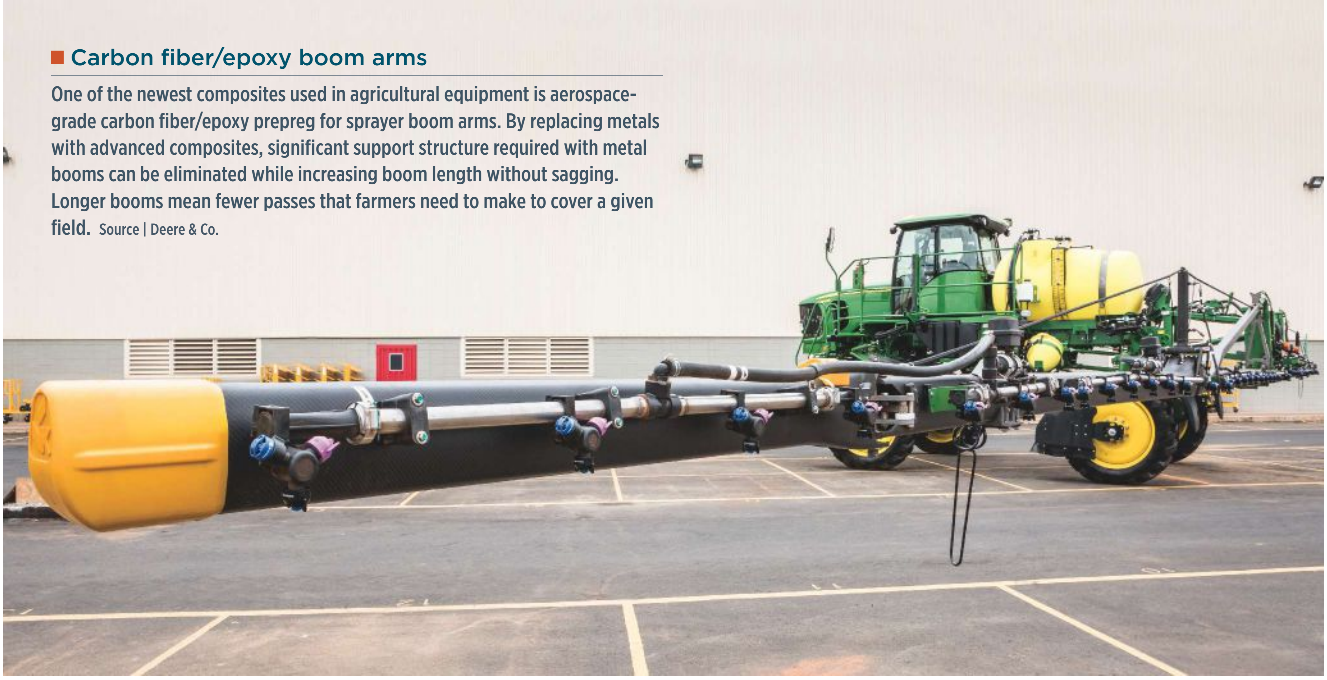
Greater interest in composites

A constellation of trends over the past few decades — including the advent of biotech and seed genetics, the evolution of chemical inputs, farm consolidation and the move to industrial farming, autonomy, vision systems and the huge increase in onboard electronics — has led to greater interest in and use of composite materials in the agricultural equipment segment. Source | Deere & Co.



More cost-effective molding

Much effort is focused on making composite materials for agricultural equipment more cost-effective. Romeo RIM (Romeo, Mich., U.S.) recently installed North America's largest rotary long-fiber injection (LFI) press for reaction-injection molded (RIM) polyurethane parts. The system can simultaneously mold up to seven different parts in six different colors per molding cycle, reducing the effective cycle time from 10 minutes/part to less than 2 minutes, while also eliminating the need for post-mold painting. It's being used to produce parts like tractor roof panels and knotter shields. Source | Romeo RIM



Carbon fiber/epoxy boom arms

One of the newest composites used in agricultural equipment is aerospace-grade carbon fiber/epoxy prepreg for sprayer boom arms. By replacing metals with advanced composites, significant support structure required with metal booms can be eliminated while increasing boom length without sagging. Longer booms mean fewer passes that farmers need to make to cover a given field. Source | Deere & Co.

manufacturers, molders and materials suppliers must qualify in each region where they wish to make sales.

Another difference in this market is that farm equipment is designed to have a long life. Carmakers these days target a use-life of a decade. Commercial truck manufacturers test and warranty for 482,803 kilometers for severe service vehicles and 1.9 million kilometers for long-haul trucks — with the latter target being achieved in as little as five years — although dump trucks, concrete mixers and the like may operate for several decades.

However, even in North America, it's nothing to see farm equipment still in use that's 40, 50 or 60 years old. The used-equipment market is very active and, as a consequence, farm machines are designed to operate for a long time. That's complicated by the fact that most farm equipment spends its entire life outside, constantly exposed to heat, cold, wind, moisture and UV radiation while being subjected to stone, gravel and dust impingement during operation. Not only must materials used on such equipment be corrosion- and dent-resistant and have good weathering characteristics, but they also must provide chemical and thermal stability.

These machines are routinely exposed to everything from hydrocarbon fuels and lubes to fertilizers and pesticides, many of which are chlorinated or dispersed in lipid bases. And like cars and trucks, heat around the engine compartment is increasing due to new tailpipe-emissions regulations. Add to that the fact that farmers spend long days cooped up in tractor cabs, which increases demand to reduce noise, vibration and harshness (NVH) and to increase operator comfort. All in all, that's a tall order for any group of materials.

Lower production volumes, though, can make composites less cost-effective than traditional materials. With the exception of small riding lawnmowers, which can be produced in car-like volumes of 350,000 annually, most equipment is produced on the order of a few hundred to the low tens-of-thousands annually. That's partly because there are a lot of customization options available in the new machinery segment and partly because some of the newest equipment is being designed in larger sizes and with new features that add cost and complexity. Depending on the type of equipment and model, it can be as expensive as purchasing a new car or even a new house. In fact, the high capital investment required to enter and stay in farming has become one of the largest barriers preventing new farmers from getting into the industry.

Composite knotter shield

This knotter shield was produced via Romeo RIM's LFI press. Source | Romeo RIM

Additionally, the lightweighting that composites offer over traditional materials can be a benefit — but weight reduction in agricultural equipment is a complex issue. On the one hand, high vehicle weight can lead to soil compaction, which stunts plant growth. In certain applications, like sprayer boom arms used to apply water and chemicals to fields, lightweighting is a real benefit. To efficiently service increasingly large fields, boom arms have been getting longer and longer, reducing the number

Testing greener, bio-based resins

A new generation of greener SMC composites was recently introduced for agricultural equipment. Based on an unsaturated polyester (UP) resin that uses a bio-based monomer from corn or soy, two grades — Premi-Glas 7001 for Class A parts and Premi-Glas 3501 for non-appearance critical parts — are said to offer comparable properties to conventional UP-based SMC with petroleum-based monomers. The 3501 grade also incorporates PIR PET resin. Although no commercial applications are ready yet, the 7001 grade is reportedly being sampled for tractor hoods, combine doors and body panels.

Source | LyondellBasell

of passes needed to cover a field. However, that, in turn, means that larger support structures are required to keep the arms from sagging over such long spans — which can exceed 15 meters on each side of the vehicle. Efforts to reduce weight — by switching from aluminum to composites — can provide real benefit to OEMs and farmers.

On the other hand, lightweighting is not always beneficial — especially if it impacts vehicle stability. Front-heavy combines, for example, need weight at the back of the vehicle to keep the rear wheels on the ground during operation. Hence, *distribution* of weight is key to ensuring safety and efficiency. All these factors mean weight is complicated when it comes to agricultural equipment, and its reduction doesn't have nearly the buzz that it does in truck, bus and passenger vehicles.

SMC for tractor panels

UV-stable, molded-in-color black SMC originally developed for automotive is now being used on after-treatment diesel (ATD) panels on John Deere 8000 tractors. The unsaturated polyester resin was jointly developed by Ashland and Chromaflo Technologies LLC and the panels are compression molded by Ashley Industrial Molding. The material eliminates the cost and environmental burden of paint.

Source | Deere & Co.

Many materials, many processes

Given the range of size and production volumes seen in agricultural equipment — from riding lawnmowers and compact-utility tractors (CUTs) to bailers and combines — a variety of open- and closed-mold processes are used to produce mostly thermoset composite parts in this segment, although reinforced thermoplastics are beginning to gain ground in specific applications. Surprisingly, one of the newest materials being used in agricultural equipment is aerospace-grade, autoclave-cured carbon fiber-reinforced epoxy prepreg for sprayer boom arms. In aluminum or steel, these arms require so much support structure that there are practical limits to how long they can be. However, by converting to high-performance, lightweight carbon fiber composites, not only can support structure be reduced or eliminated but booms can be made longer. 3D printing also is gaining ground in this segment — mostly for tools and assembly fixtures but also to produce some parts on production vehicles. »

Composite grain-extender doors

The composite grain-extender doors for John Deere combines (above and right) were produced via a process called tooless engineered composites (TEC) from Plastics Unlimited. Source | Deere & Co. (above) and Plastics Unlimited (right)

As appearance fit and finish, as well as part consistency, become more important to OEMs and customers, both for product differentiation and visual branding, equipment manufacturers are exploring the well-known benefits of plastics and composites to facilitate design freedom, parts consolidation and high aesthetics. Color is another well-used aspect of visual branding in this segment via paint, gel coat and pigmented polymer. In fact, some OEMs combine different paint textures on the same body panel (for example, light stipple plus gloss) to hide scuff marks in wear areas while still achieving a pleasing look. Ongoing work among the supply base is searching for ways to extend the durability of paints and coatings and to eliminate both technologies in favor of films and molded-in-color (MIC) materials with higher UV-stability.

Greening ag composites

Sustainability — from improvements in fuel efficiency to the use of recycled and plant-derived polymers — is just as important and desirable in farming as it is in other transportation segments. Interestingly, bio-based monomers turned out to be a much easier sell here than in automotive. “It just makes sense to our customers in the farming community,” explains Jay Olson, materials engineering and technology manager at John Deere, as well as brand owner/council chair and officer on the board of the PLASTICS Industry Association (Washington, DC, U.S.). “They use our equipment to grow corn and soy and then those commodities are used to make polymers that are molded into components for new equipment that we produce for those same customers.”

Currently the most common plant products used in thermoset agricultural composites include corn and soy that go into unsaturated polyester (UP) resins for sheet molding compound (SMC) and bulk molding compound (BMC). Around 2000, Ashland LLC (Columbus, Ohio, U.S.) introduced Envirez 1807 bio-based unsaturated polyester resin to compounders who, in turn, convert it into SMC and sell it to molders for parts that go into the agricultural equipment market — primarily for use in large combine sidewall panels. The company claims that Envirez was the first commercially available UP resin containing a significant portion (18 percent) of grain-derived monomer from corn or soy. The polymer is supplied uncatalyzed and is said to offer uniform thickening response, good paintability and good surface characteristics at low cure temperatures in SMC. It’s also less prone to price fluctuations than polymers derived from petroleum feedstocks.

Another green SMC product that eliminates the cost and environmental burden of paint is a weatherable, structural UP resin first used for visible surfaces on pickup boxes and now featured on

Tooless engineered composites

The ability to maintain stiffness, strength, dimensional stability and toughness while looking good for a long time under loads as large as 9,072 kilograms led to the development of the patented TEC (tooless engineered composites) process by Plastics Unlimited. The technology combines a thermoformed thermoplastic A surface and a pigmented, smooth composite B surface to produce a structure with a high stiffness and strength to weight ratio and exceptional damage tolerance.

Source | Plastics Unlimited

after-treatment diesel (ATD) panels on John Deere 8000 tractors. Arotran 805 is a UV-stable, MIC black grade that was jointly developed by Ashland and additive supplier Chromaflo Technologies LLC (Ashtabula, Ohio, U.S.) and is compression molded by Ashley Industrial Molding (Ashley, Ind., U.S.). When compounded into SMC and used in applications like the ATD panels, it helps maintain aesthetics long-term, which helps support higher resale values for tractors.

A new-generation SMC targeted at agricultural equipment as well as building/construction and the electrical/electronics markets was introduced at the 2018 CAMX show by LyondellBasell Engineered Composites. “As an industry, we know that thermoset composites have limitations with respect to end-of-life recycling,” explains Mike Gruskiewicz, director of technology for the U.S. region, LyondellBasell Engineered Composites. “As we continue to work on recycling, we see many benefits to incorporating renewable and recycled content in the manufacture of SMC, thus contributing to the circular economy on the front end »

Autonomous tractors

Autonomy is an exciting new direction for ag equipment and could prove a boon for farmers in many parts of the world who struggle to find skilled labor during peak use seasons. CNH showcased the industry's first fully autonomous tractor concepts in 2016. The fully autonomous and cabless drone tractor (left) and hybrid cabbed autonomous tractor with traditional driving capabilities (right) can plant, spray and harvest without humans on board. The equipment is controlled and monitored remotely via an operator with a tablet.

Source | CNH Industrial N.V.

of the life cycle. As we started looking for green solutions, we set a goal of zero compromise in terms of performance, moldability and aesthetics compared to petroleum-based SMCs."

The company offers two new sustainable SMC products, both of which offer fire-retardant performance. "Premi-Glas 7001 grade produces Class A paintable surface profiles, allowing tractor hoods to achieve aesthetics comparable to fine automobiles, and adding the fire-retardant aspect for the severe ag environment, and Premi-Glas 3501 offers molded-in color and is intended for parts such as electrical enclosures, brackets and housings, and cab components," Gruskiewicz explains. Additionally, 3501 incorporates recycled thermoplastic content to bolster its sustainability footprint. In both cases, the resin's propylene glycol monomer is produced using either corn or soy and is said to yield properties identical to monomers created from traditional petroleum products. The 3501 grade includes post-industrial recyclate (PIR) polyethylene terephthalate (rPET), which has been chemically digested to yield terephthalic acid and then reacted back into the polyester resin. Although no commercial applications have yet been announced, Gruskiewicz says the 7001 grade is already being sampled for tractor hoods, combine doors and body panels. "Another exciting area for SMC involves valve covers for large diesel engines as well as oil sumps [pans]," he adds. "Compared with similar parts on passenger vehicles that have converted from SMC to thermoplastics, we see much more severe operating conditions in ag. For example, on larger engines, stiffer materials are required owing to the large spans across those bigger units."

Meeting crushing loads

One challenge in the agricultural equipment industry is that composites must maintain mechanical performance under loads that can top 9,000 kilograms. For example, Tier-1 molder Plastics Unlimited (Preston, Iowa, U.S.) has developed a molding technology called tooless engineered composites (TEC), which has been used to produce 1.5-by 2.1-meter door flaps/grain-extension doors that can carry loads up to 9,072 kilograms, for large combines with nominal walls that are 6.4 to 12.7 millimeters thick. TEC blends the high aesthetics and durability of thermoplastics with the strength, toughness and dimensional stability of composites to produce a structure with a Class A surface and a B-side contributing a high stiffness and strength to weight ratio. The appearance A-side is produced by thermoforming a sheet of MIC acrylonitrile butadiene styrene (ABS), which subsequently becomes tooling for half of the B-side of the part, although for these larger, more complex structures, a second composite tool is used during the forming process. The latter is a vacuum-bagged composite produced using UP resin infused into stitched layers of chopped glass fiber cores. Both metal bracketry as well as large ribs (produced in rigid polyurethane foam) can be inserted into the composite during layup.

> One challenge is maintaining mechanical performance under loads that can top 9,000 kg.

The result is a UV-stabilized, corrosion-resistant part offering design flexibility and high impact strength that resists chipping and cracking at a reasonable cost. The A side (thermoplastic layer) can provide a grained or shiny surface (the latter in solid colors or clear over patterns, which include metallic, chrome, wood, camouflage and even a carbon-mesh). This thermoplastic layer is said to offer excellent depth of image and is much more durable than painted or gel-coated SMC, permitting minor surface scratches to be buffed out. The non-appearance B-side (composite layer) is pigmented and smooth. Aside from the high-performance grain-extension doors on combines, the TEC process also is used to mold fenders, side shields, hoods and front and rear enclosures for a variety of smaller recreational vehicles and farm-type equipment.

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Read about UP resin on a Honda pickup box | short.compositesworld.com/HondaR-G2

What's the future of agricultural equipment? In 2016 at the Farm Progress Show in Boone, Iowa, U.S., Case New Holland (CNH) showcased the industry's first fully autonomous tractor concepts that can plant, spray and harvest, and where humans no longer operate vehicles from onboard, but rather control and monitor the driverless equipment remotely via tablet as the tractor travels pre-mapped guidance routes. Equipped with onboard cameras providing real-time views and advanced obstacle detection, these drone tractors can alert operators of obstacles and other issues, allowing the operator to select the best route to avoid or fix problems. The system's software is said to automatically plot the most efficient in-field pass to help farmers make the most of narrow weather windows or work around the clock when needed to increase productivity, all while collecting data to monitor current crops and better plan future ones. CNH says this technology will help farmers in many parts of the world who struggle to find skilled labor during peak use seasons. Intermediate equipment likely will combine cabbed machines with traditional driving capabilities and some level of automation.

"Agriculture hasn't changed from its foundational goals to feed, fuel and clothe the world," adds Olson. "However, technology — including all aspects of biotechnology and the materials needed for intelligent systems solutions — has accelerated to meet the productivity challenges of feeding a rapidly growing population. Farmers have always been stewards of the land, so sustainability of natural resources is key to our success as an industry, a community and a world." CW

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Spar forming simplified

Adapting its Automated Stiffener Forming (ASF) technology to build spars directly in female molds, Northrop Grumman Innovation Systems anticipates dramatic drops in cycle time and manufacturing cost.

By Karen Mason / Contributing Writer

» "Innovation Systems" seems an apt moniker for Northrop Grumman's (Falls Church, Va., U.S.) newest business sector. Formerly Orbital ATK, the business claims a rich history of new technologies for aerospace composites manufacturing — technologies that have increased part consistency and accelerated production speeds by automating fabrication processes. One of the most recent innovations developed by Northrop Grumman Innovation Systems' (NGIS) Aerospace Structures Division extends an existing manufacturing method for aerospace stiffeners to the fabrication of spars and other wider, thicker components with more complex geometries.

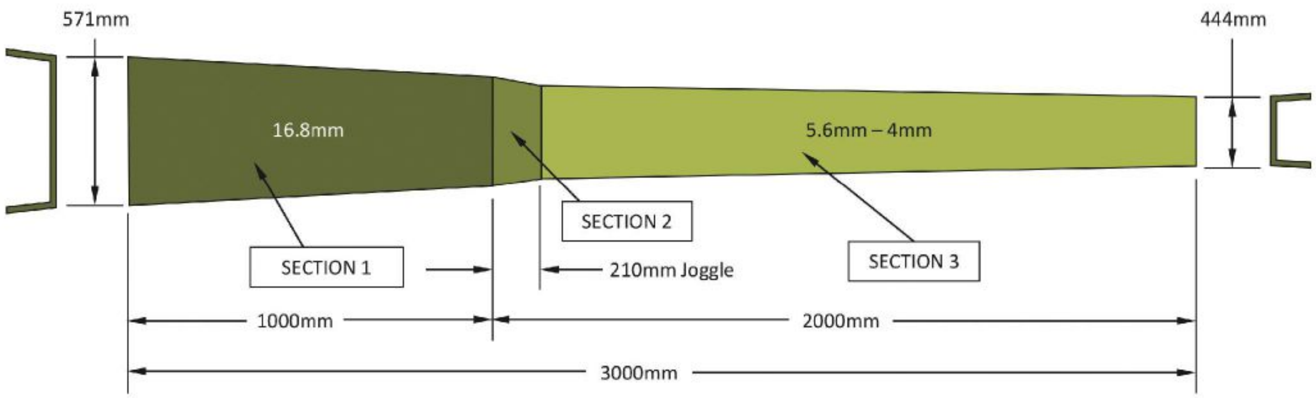
Starting with stiffeners

When one of NGIS's predecessor companies (Alliant Techsystems) developed the patented Automated Stiffener Forming Machine (ASFM) back in the early 2000s, the technology easily raised the bar for both quality and cycle time; it was the first automated composite stiffener fabrication process to replace hand layup. The Automated Stiffener Forming (ASF) process, which makes both linear and radial airframe structures, achieves superior compaction and repeatability at production rates nearly 10 times that of the traditional hand-layup process. The advantages ASFM offered were quickly recognized, and the company landed multiple contracts with aerospace OEMs, including Airbus, to which the company shipped its first ASFM-built components in mid-2010. Using ASF and automated material preparation production lines, NGIS currently produces approximately 33 kilometers of A350 XWB composite components per month based on a build rate of 10 aircraft, and has the capacity to produce more than 40 kilometers per month. As of January 2019, the company has completed more than 250,000 composite parts in support of the A350 XWB program.

A companion technology to ASF, aptly named the Material

■ **Automated spar forming**

For spar fabrication, NGIS uses a linear Automated Spar Forming Machine (ASFM). For radial components, the ASFM is oriented around a donut-shaped steel rotary table that rests horizontally on the shop floor. Source | NGIS



Challenging demonstrator

The 3-meter-long spar demonstrator that NGIS built using the new ASF process deliberately includes the most challenging geometric features, including a variety of flange angles, radii, thicknesses and fiber angles. Source | NGIS

Preparation Machine (MPM), converts unidirectional (UD) tape — currently HexPly carbon fiber prepreg tape from Hexcel (Stamford, Conn., U.S.) — to the material form the ASF machines use (Step 1, p. 32). One MPM supplies material to multiple ASFMs. The MPM unrolls prepreg tape, up to 600 millimeters wide, from rolls up to 600 meters long, and passes it through a proprietary collation system, which creates *flags* — the term for job-specified lengths — of prepreg at bias angle cuts from 10 to 90 degrees. The system then re-orients each flag to a pre-programmed angle, puts it back in line with the other flags onto a continuous carrier, and re-spools the re-oriented material. The new prepreg roll comprises a series of UD flags oriented at a specified angle and width needed to meet specific design requirements of the stringer or frame to be produced. The MPM also has slitting capability to make multiple narrower rolls during one material preparation run. The slit spool widths can be optimized for part geometry, helping to keep material waste reportedly under 15 percent.

After it leaves the MPM, each roll is delivered to a cleanroom, where it is loaded onto an ASFM. Parts are laid up on the ASFM in a relatively simple and rapid process: the mold passes under a material placement station and a series of compaction stations, which accurately place the material onto the tool surface and conform/compact it into the shapes, angles and dimensions needed for the particular stiffener being formed (Step 2). During this process, ASFM dispenses carbon fiber prepreg tapes or dry fiber formats into the female spar tool from a selected supply head with the proper angle orientation(s) and width. As tapes are laid, a series of rollers and forming devices pass over the material/tool, simultaneously compacting and debulking the material tightly against the tool/underlying laminate, so that separate debulk cycles are not required. The rollers work all surfaces of the part: horizontal, vertical, radii, etc. "It is a progressive roll forming process on one forming head," summarizes Vern Benson, technical fellow in composites automation at NGIS.

For radial components, the ASFM is oriented around a donut-shaped steel rotary table that rests horizontally on the shop floor. The appropriate mold is secured to the table, which then rotates to the machine's tape-laying station. A robot — currently one from Kuka Robotics Corp. (Shelby Township, Mich., U.S.) — is used to choose tapes of varying widths and orientations from several NGIS feed heads docked alongside the ASFM. When the material placement is complete, the table indexes to the forming station, where tapes are formed and compacted by a series of rollers and forming devices similar to the linear stiffener machine.

From the start, ASF technology has been capable of fabricating parts that vary in shape (primarily omega-, C- or T-shaped), that may be straight or curved and twisted, and that may be relatively thin or thick for a stiffener. The machines have built stiffeners up to 66 plies thick and 18 meters long without intermediate vacuum debulks. Extending the technology to spars meant scaling up significantly. "We have already been making long stringers, curved frames and engine cases, but scaling up to the cross-sectional size of the spars is the difference," Benson explains. Thickness of most stiffeners, he says, is less than 0.25 inch, but spars can have thicknesses of 1 inch or more. The ASF process allows for short ply adds and drops within the structure to manage thickness changes down the length. "Managing consolidation of something that thick — making sure there are no wrinkles — isn't easy," Benson declares.

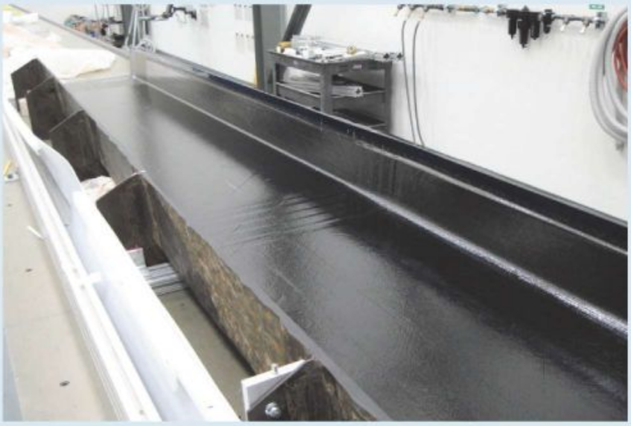
> Extending the ASF technology from stiffeners to spars meant scaling up significantly.

Adapting from stiffeners to spars

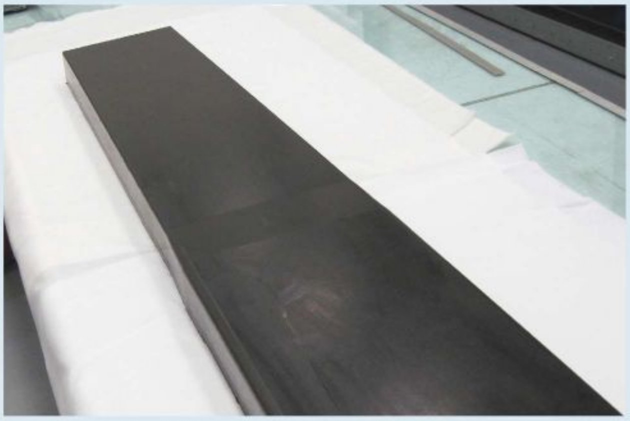
Motivation for adapting Automated Stiffener Forming to Automated Spar Forming (still designated ASF) arose in 2012 as an NGIS customer recognized an opportunity for improvements in the manufacture of a particular airframe spar. "The existing process required male to female mold transfer," explains Ron Zipprich, director of business development for NGIS's commercial segment. "It was costly; it required the spar to be made in three parts instead of one; and there were quality issues. Our team »

1 Material is prepared for Automated Spar Forming on a Material Preparation Machine, which unrolls, collates, re-orients and re-rolls prepreg.
Source for all step photos | NGIS

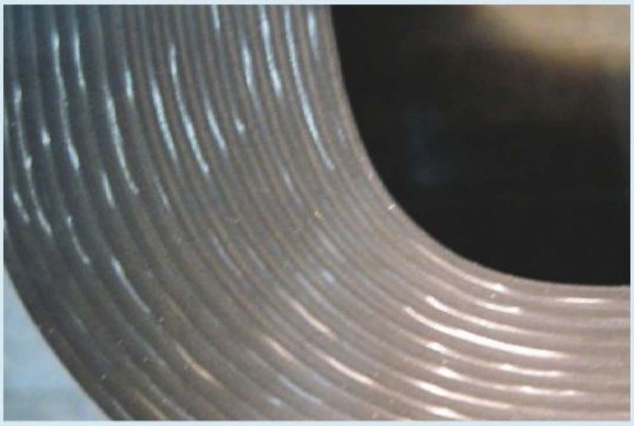
2 As it lays down material, the linear Automated Spar Forming Machine (ASFM) passes a series of rollers and forming devices over the material, simultaneously compacting and debulking it tightly against the tool and underlying laminate, so that separate debulk cycles are not required.



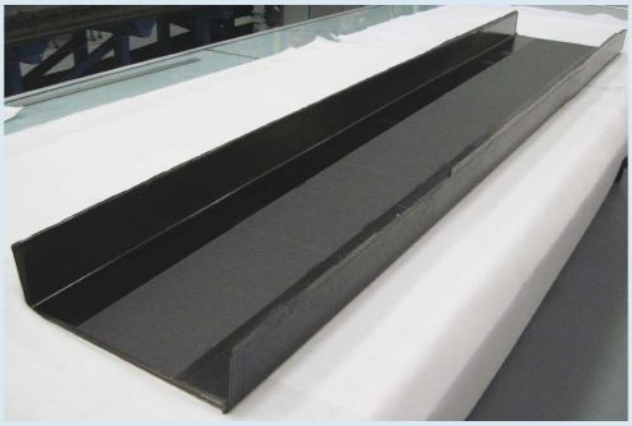
3 ASFM rollers and forming devices work effectively on all part surfaces, including vertical and horizontal features as well as radii. The demonstrator spar's joggle is visible in the center of the image.



4 A view of the spar OML (outside mold line) shows the joggle region, where ply drop-offs were required to create the structure properly.



5 ASF rollers and forming devices maneuver effectively through radii in female molds. Images show consistent compaction in a cross-section of the spar web flange radius.



6 The finished demonstrator spar proved ASF to be a viable and cost-efficient alternative to automated fiber placement. NGIS is working toward its adoption in next-generation aircraft programs.

reviewed the issues and said, 'Hey, we can solve that.'"

That conventional approach is automated fiber placement (AFP). While it has been successfully applied and handles contoured surfaces well, AFP entails multiple challenges that hinder high-speed, high-quality spar production. Specifically, laying down off-angle plies (±45 degrees, 90 degrees) is difficult and time-consuming on a male tool — and impossible on a female tool. Additionally, Benson notes, "To lay up off-angle plies on a male spar mold, the AFP machine has to negotiate tight corners, which reduces the material placement rate. Effectively, the machine seldom gets up to full speed before it has to slow down for another corner or an end cut/restart." Also, band widths that are placed must be kept narrow for the AFP to effectively negotiate and compact corners. ASF, on the other hand, is able to handle these female mold geometries because the MPM'd tape already provides the off-angle fiber orientations, and rollers and forming devices can be oriented according to the tool geometry rather than the fiber orientation.

The other significant challenge with forming spars on a male tool is that most spars need to be cured in a female mold to tightly control the outer mold line surfaces for later integration into the wing box structure. This then requires the male formed part to be transferred into a female cure mold. The natural bulk factor (resulting from the fact that the laminate is not yet fully consolidated) makes it difficult to fit the part into the female mold, hence adding some risks to the transfer process. This approach also doubles the cost of the tooling: a male layup tool, a female cure mold and an associated transfer station/tooling. Male-formed AFP parts have been cured on the male tool, but then caul plates and secondary surface machining in areas of critical interface are required.

Several features of NGIS's stiffener-forming technology suggested that forming spars in a similar manner would not only eliminate the difficulties of AFP spar manufacture, but also introduce opportunities for cost savings, risk reduction and quality improvements. Not least among these, as seen in the test case presented by the NGIS customer, is the anticipated ability of ASF to form what was a three-piece spar in one single piece. NGIS's lengthy experience with stiffener production demonstrates this technology's exceptional quality, especially in terms of thickness control and accurate fiber alignments in corners. Also, instead of narrow material, ASF lends itself to wide UD tapes (which the MPM modifies so that wider layup and compaction devices can be used), a significantly lower-cost material form versus AFP narrow slit tapes.

To scale up from stiffeners to spars, NGIS mainly needed to prepare the technology for wider material formats by scaling up the supply and forming heads which dispense the carbon fiber prepreg tapes or dry fiber formats into the female spar tool. »

The spar forming system can accommodate thickness changes down the length of a spar with partial length plies. It can also accommodate thickness changes across a spar with placement of narrower width plies (used in particular to add extra plies to the flanges). The system accommodates tapered joggles in the tool or part. It also handles complex geometries seen in both stiffeners and spars, including roll (twist), pitch (bending) and yaw (lateral translation).

Paralleling ASF development, NGIS has rolled out a next-generation Material Preparation Machine, designated MPM2. NGIS partnered with MTorres (Pamplona, Spain) on this new machine, which provides two new features: production of material up to 1.5 meters wide; and tapering of flag width to optimize material use especially in spar fabrication. The new machine was initially added to supply material to aircraft engine case fabrication (in a process aptly called automated case forming, ACF), but it was developed with capabilities to serve spar formation effectively as well. The MPM process typically produces formats 1 to 3 plies thick. Benson reports that the team is investigating whether ASF can be used to form up to three plies of large-width formats to accelerate spar production. "The pounds per hour that we could lay down would be significant," he notes.

Benefits of ASF are substantial, and include reduced handling risk, good fiber alignment, consistent and tight radii, low void content, elimination of intermediate debulks, increased design flexibility and reduced buy-to-fly ratio. Capital cost is lower for ASF technology compared to AFP machines. Of course, tooling costs are drastically reduced since only one mold is needed compared to two for AFP.

Demonstrator success

The 3-meter-long spar demonstrator that NGIS built using the new ASF process was designed to prove the system's capabilities to meet a variety of flange angles, radii, thicknesses and fiber angles. "The most challenging spar geometric features are condensed in the demonstrator," Benson reports.

NGIS built three of the demonstrators using MPM'd prepreg material approximately 800 millimeters in width. The demonstrator design includes significant joggles, thickness ranges from 18 millimeters (more than 60 plies) to 5 millimeters (less than 20 plies), web height change, flange-web angle varying from 2 to 5 degrees, and radius changes between 8 and 30 millimeters. All three demonstrator spars passed NGIS's ultrasonic non-destructive testing (NDI), the company's standard post-forming inspection method.

With stiffener forming technology successfully migrating to spar forming, NGIS also performed a business case study in which the company compared conventional AFP to ASF spar manufacturing. Highlights include a nearly 50 percent drop in capital investment required (tooling, capital assets, footprint), more than 10 percent savings in raw material costs and more than 50 percent potential savings in labor.

Lead time leads to next-gen adoption

With aircraft development cycles such as they are, although NGIS demonstrated ASF technology based on spar designs for a current program, it will not be adopted by the program for which it was demonstrated. "Had we presented ASF five years earlier," Zipprich says, "for sure this would have been onboard several aircraft programs, I believe." Instead ASF technology demonstration has opened the door to adoption on next-generation aircraft, and NGIS is working with its customers toward this end, Zipprich reports. Importantly, requalification should be straightforward, since ASF represents only a process change, not a design change.

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As next-gen aircraft programs continue to unfold, the NGIS team is developing new capabilities and capacities for ASF. Currently, for example, the team is working on advances in approaches to heating the material, with the goal of more closely controlling heat application to promote improved forming and consolidation. Additionally, Zipprich reports, the team is refining ASF to migrate more toward fabrication with dry material formats, which may enable forming of larger integrated structures that reduce assembly and fastening work. Currently, ASF's sister MPM technology is used on prepreg material, and dry fiber is purchased in stitched, non-crimp fabric forms; so one part of advancing dry-fiber spar forming may be to adapt MPM to create dry ASF fiber forms in-house.

ASF so far has been used with thermoset resins, but "we think it has the capability to be used with thermoplastics," Benson says. Although it is not specific to the spar-forming effort, Zipprich also mentions an NGIS production program using similar technology (Automated Case Forming) to form an aircraft engine rear fan case with integral flanges, using a carbon fiber/bismaleimide (BMI) resin material system.

Benson characterizes ASF of spars and other similar products as evolutionary. "We started with stiffeners, forming small profiles, then engine casings, and now we're branching out to larger components such as wing spars." He expresses confidence that the technology will continue to find broadening success. "They are unique parts," he admits, "but it's one common process." CW

ABOUT THE AUTHOR

CW contributing writer Karen Mason focused academically on materials science and has been researching and writing about composites technology for more than 25 years.
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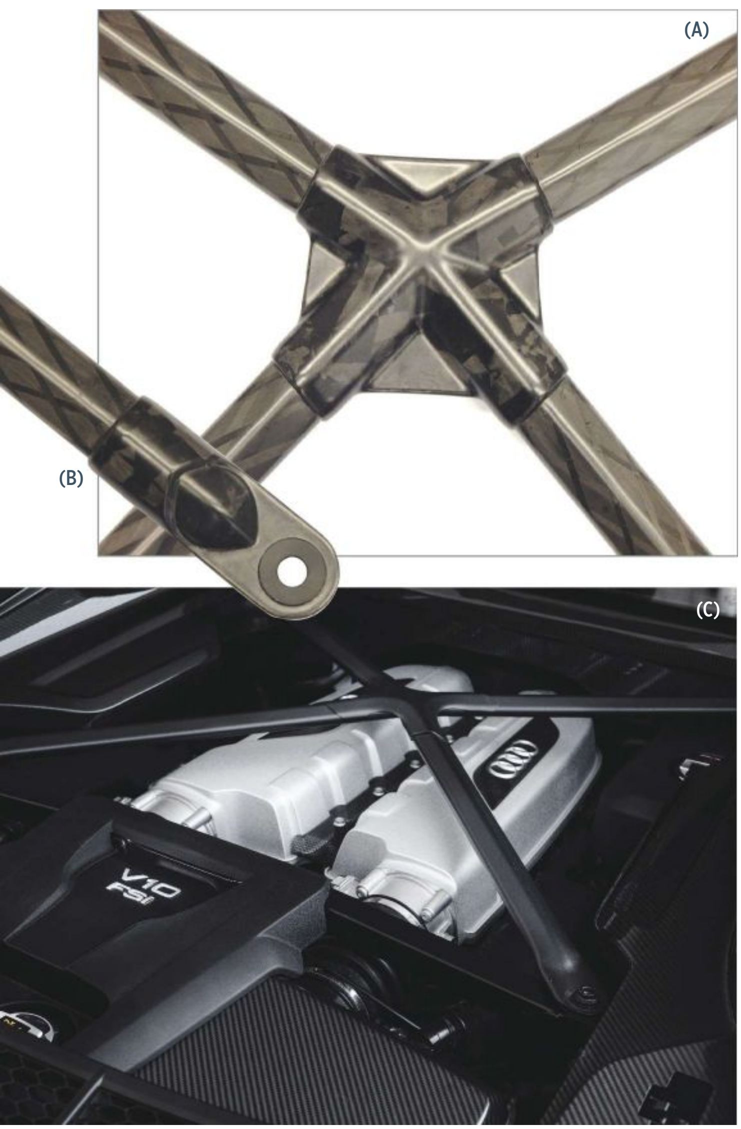
MULTIMATERIAL CARBON FIBER COMPOSITE ENGINE BRACE

The project's aim was to produce a lighter, composite version of an aluminum engine brace, with a more aesthetic molded shape.



The central node of the x-shaped Audi *R8* carbon fiber engine bay brace (A) and the tube terminations (B) are formed via compression overmolding. The current aluminum brace is shown here (C).

› HexMC from Hexcel (Stamford, Conn., U.S.), developed more than a decade ago, is a high-performance molding material that comprises chopped, randomly-oriented high-strength carbon fiber prepreg "chips" assembled into a mat-like material. The industrial version, trademarked HexMC-i 2000, is made with snap-curing HexPly M77 resin in a 2,000-gsm format for compression molding. According to the company, HexMC-i 2000 can produce complex 3D geometries and parts with varying thicknesses and is intended to bridge the price/performance gap between lower-cost sheet molding compound (SMC) and pricier, high-performance autoclave prepreg.

Hexcel's automotive business unit was looking for a project that could demonstrate HexMC-i 2000's performance, says Achim Fischereder, Hexcel's director of sales and marketing for automotive. With a history of previous joint projects with Audi (Ingolstadt, Germany), Hexcel's automotive business unit approached the OEM's composites development team in early 2016 with the aim of qualifying the material into a production-ready manufacturing process. Audi was already evaluating carbon fiber SMC materials at the time and decided to assess HexMC-i 2000 as well. For the project, Audi selected the *R8* engine bay brace, a cross-shaped component that braces the *R8*'s mid-mounted V10 engine, providing torsional stiffness to enhance driving dynamics. The project's aim was to produce a lighter composite version of the existing aluminum part, with a more aesthetic molded shape.

Carbon fiber specialist Secar Technologie GmbH (Hönigsberg, Austria) joined the project, bringing its trademarked PulWinding process that effectively combines pultrusion with filament winding to produce high-torsion-strength, foam-cored carbon fiber profiles — the core is typically Rohacell PMI foam from Evonik Industries (Darmstadt, Germany). For the *R8* brace, Secar produced shaped, foam-filled carbon fiber/epoxy tubes, which were then arranged in an X pattern and compression overmolded with HexMC-i 2000 to form the central "node" portion of the part. The opposite ends of the tubes were also overmolded to create attachment points to the car, with the metallic inserts molded in during the production process.

One of the toughest challenges was to achieve a good bond between the HexMC-i 2000 and the thin-walled (less than 1 millimeter wall thickness) carbon fiber tubes, without crushing the tubes. Ultimately the bond strength of the HexPly M77 resin system produced adhesion with no over-compression of the tubes; no adhesive film or additional bonding material was required between the tubes and the overmolded compound. The composite brace is reportedly 15 percent lighter than the aluminum version, and the random prepreg chips create an attractive surface, a key requirement of Audi's development engineers. Following production of the first prototype parts at Secar, Audi subjected the component to static and dynamic load testing under room temperature as well as hot/wet conditions, and all test requirements were satisfied.

"We see a lot of applications where we can combine the impressive characteristics of HexMC-i with our innovative and high-performance Pulwinding and Pulbraiding technologies. This is a unique combination and a good answer to increased performance requirements in the automotive market," says Werner Stoeger, sales and marketing director, Secar Technologie GmbH. CW

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TRFA Annual Meeting
trfa.org/meeting

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s1.goeshow.com/acma/2017PultrusionConference/ereg419088.cfm

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spacesymposium.org

April 9-11, 2019 — Detroit, Mich., U.S.
SAE 2019 World Congress & Exhibition
10times.com/sae-world-congress

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compositesinconstruction.com

April 23-25, 2019 — Moscow, Russia
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composite-expo.com

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Sept. 4-6, 2019 — Novi, Mich., U.S.
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New Products

Source | Sabic

» GLASS FIBER

Glass fiber-reinforced panels save weight on scaffolding

Sabic (Riyadh, Saudi Arabia) introduces its STADECK heavy-duty panels for scaffolding and other applications. The high-strength, lightweight panels for the building and construction industry were launched in Europe in 2018.

STADECK panels are made from glass fiber-reinforced thermoplastic resin and are up to 60% lighter than wooden planks. The weight savings have an important influence on energy consumption during transport, where Sabic estimates the total savings cost can be more than 30%. Recyclability and long expected lifetime of STADECK panels are said to make them more sustainable and efficient than standard wooden planks. The panels are corrosion-resistant, and resistant to weathering, UV radiation and chemicals commonly used in the construction industry. They are also said to have good flame-retardant properties.

STADECK panels conform to NEN-EN 12811-1, the European standard that specifies performance requirements and methods of structural and general design for access and working scaffolds. They also have anti-slip properties.

According to Sabic, in addition to scaffolding, the panels offer significant advantages in applications where weight savings and high strength are important. STADECK panels are well suited for decking, fencing, floodwalls, jetties, sheathing, wheelchair ramps and numerous other purposes.

The panels, which can be produced in different colors, come in standard dimensions — gauge 2.165", width 9.06"; and lengths of 118" and 236" — with custom lengths available on request. **sabic.com**

» THERMOSET RESINS & ADHESIVE SYSTEMS

Fast-curing toughened epoxy

Source | Epoxies, Etc.

Epoxies Etc. (Cranston, R.I., U.S.) has launched its new 10-3041 Toughened Epoxy Adhesive, which reportedly develops a 3,000 psi lap shear strength within four hours. Within minutes the material is dry to the touch.

The 10-3041 high-performance epoxy adhesive bonds to a variety of plastics and metals. It is also said to act as a good electrical insulator, making it suitable for many electronic bonding applications. For ease of application, the 10-3041 is packaged in the company's TriggerBond dispensing system which eliminates the weighing and mixing of a two-part epoxy. **epoxies.com**

» PART REPAIR

Composite repair technology for aircraft parts

Heatcon Composite Systems Inc. (Seattle, Wash., U.S.) has unveiled a new technology for the aircraft composite repair market. The HCS9400-02 Smart Susceptor has the ability to repair unique and complex aircraft parts.

Source | Heatcon Composite Systems Inc.

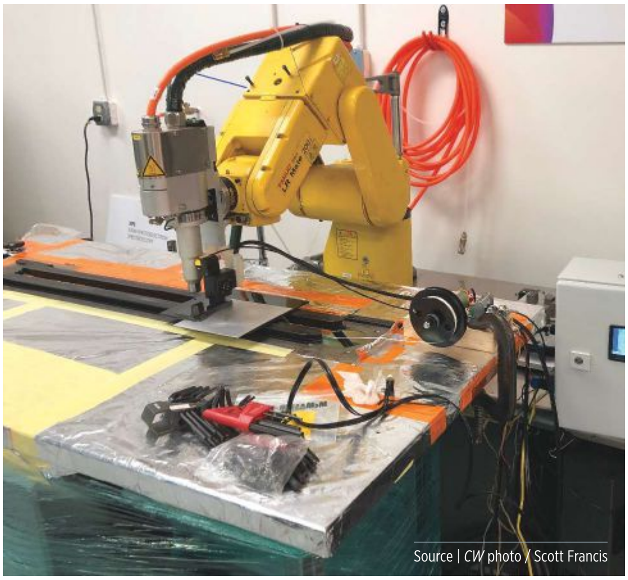
The Smart Susceptor employs the use of a high-frequency inductive power supply combined with temperature-limiting heating wire to transform heat blankets into an active mechanism to improve thermal uniformity and to ensure that composite materials are properly cured and repaired. **heatcon.com**

» TESTING, MEASUREMENT & INSPECTION SYSTEMS

Automated material surface inspection

BTG Labs (Cincinnati, Ohio, U.S.) has introduced the Surface Analyst XA, an automated solution for evaluating material surfaces for bonding, coating, sealing, painting or printing. The XA reportedly delivers real-time surface condition feedback to manufacturers to ensure the success of adhesion processes.

The XA applies the same technology employed by the original handheld Surface Analyst unit. The process works by depositing a highly purified drop of water on a surface and then measuring



Source | *CW* photo / Scott Francis

the contact angle. By automating this process, the XA is said to increase evaluation speed and efficiency by completing inspections on multiple surface points on a material surface at rates of up to 5,000 inspections per hour. As a result, the XA maps a surface across multiple points to ensure the consistency and uniformity of surface quality.

The measurement process is non-destructive. The XA unit uses highly-purified high-performance liquid chromatography (HPLC)-grade water to prevent contamination of inspected material surfaces. Measurements are touchless, eliminating the potential transfer of contaminants from point to point on a surface. Automation limits operator error or variation between inspections. Archer software automates data capture and transfer to a manufacturing execution system (MES), reportedly providing statistical process control as well as long-term trend analysis that monitors process drift.

BTG Labs says the XA unit can be integrated into a production line using either a robot or linear actuator to move it from point to point, or it can be fixed in place on the line. Off-line cell inspections can be conducted robotically or with a linear actuator. The company says self-implementing or full-line integration options are available. **btglabs.com**

Source | Thermwood Corp.

Source | Kent Pultrusion

» PULTRUSION TECHNOLOGY

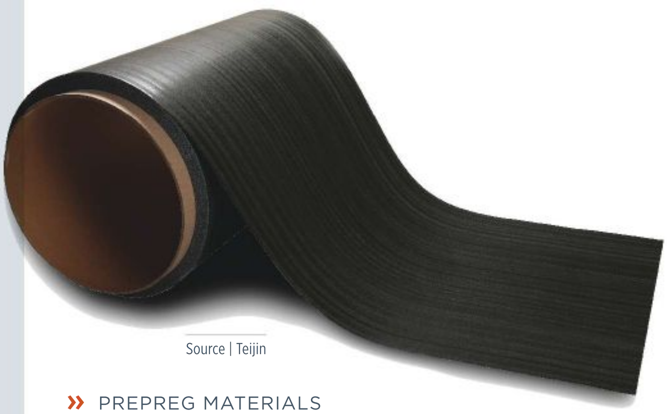
Fully electric pultruder installed at composite provider

Kent Pultrusion (Kent, Ohio, U.S.), a subsidiary of Kent Automation Inc., has announced the installation of a ServoPul 3012 fully electric pultrusion line at a North American leading provider of composites. The company's ServoPul Machines introduce servomotor and drive technology to control pulling and clamping forces and register monitored feedback to the operating system.

According to Kent Pultrusion, the ServoPul 3012 line processes sheets up to 30″ wide as well as shapes 12″ high. It reportedly has a 40,000-lb pull and clamp force. A touchscreen pendant system allows access to operation of the line. All functions of the line can be monitored and stored from the touchscreen — including heaters, pull force, clamping force and product storage. The line can be contacted via remote access for maintenance and troubleshooting as well as monitoring the process.

The ServoPul Pultruder includes a flying cut-off in-line saw solution for 30″ wide by 3′ to 10′ long sheets at thickness up to 0.43″ cutting at a line speed up to 80″ per minute. The saw is said to cut shapes up to 8″ high.

The line incorporates a pulling winch system that facilitates access for product setup. The 40,000-lb rated winch automatically raises into position where the operator can attach the 0.75″ round cable to the glass as it is pulled through the first set of clamps to initiate the startup of new product runs. **kentautomation.com**



Source | Teijin

» PREPREG MATERIALS

Carbon fiber/BMI UD prepreg for aerospace engines

Teijin Ltd. (Tokyo, Japan) has introduced a new prepreg composed of unidirectional carbon fiber tape with a bismaleimide (BMI) matrix resin, targeted toward aerospace engine components. This carbon fiber/BMI prepreg offers a T_g of 280°C and compression after impact (CAI) of 220 MPa, a combination, says Teijin, that previously was difficult to provide. Teijin also says the new prepreg maintains its coefficient of linear thermal expansion and high dimensional stability at low and high temperatures. Moreover, by adjusting resin viscosity, Teijin says it has improved moldability; it also reports that it has reduced cure time compared to conventional BMI-based prepregs.

Teijin reports that it will build on its carbon fiber/BMI work with the support of Renegade Materials Corp. (Miamisburg, Ohio, U.S.), a provider of high-temperature composites, that Teijin recently acquired. **renegadematerials.com, teijin.co.jp**

» RESIN SYSTEMS

CIPP resin system simplifies with single initiator

Interplastic Corp. (St. Paul, Minn., U.S.) recently launched its ONESTEP CIPP resin system, which is designed to be a simpler, safer process for initiating a cured-in-place pipe (CIPP) resin.

Using a single liquid initiator, the system is said to provide mechanical properties, cure, pot life and corrosion resistance comparable to currently available CIPP resins. ONESTEP is available with several resin formulations, both neat and enhanced. The product has been used in CIPP liners ranging from 8" to 36" in diameter.

Additional benefits are said to include easier introduction of the initiator to the resin, fewer mixing problems and reduced initiator use, energy cost savings, labor savings and improved safety.

interplastic.com

» PROCESS CONTROL SYSTEMS & SOFTWARE

Software streamlines design-to-3D printing process

Stratasys (Eden Prairie, Minn., U.S.) has launched an Advanced FDM feature for its GrabCAD Print 3D printing software. The feature has been designed to eliminate CAD-to-STL file conversion, simplifying the overall process and resulting in quicker delivery of lightweight, strong and purpose-built parts. By avoiding CAD-to-STL conversion, users are reportedly able to work in high fidelity to quickly advance the design-to-3D print process without losing design intent, boosting both time to market and time to revenue.

Source | Business Wire

The software automatically calculates 3D print tool paths after engineers select areas on native design geometry and specify design attributes directly to CAD models. No manual generation of complex tool paths is required. Users pinpoint areas of strength and rigidity, control infills, ensure sufficient material around holes with inserts and avoid seams. Since tool paths are automatically generated from model assignments, the user spends less time on part setup.

According to the company, the software also streamlines part processing by eliminating the use of multiple programs, helping to control the structure of end-use parts for markets such as automotive.

Advanced FDM is available for download with GrabCAD Print (versions 1.24 and later) and is supported on a variety of Stratasys 3D printing systems: F370, Fortus 380mc, Fortus 380mc Carbon Fiber Edition, Fortus 450mc, Fortus 400mc, Fortus 900mc and F900. **stratasys.com**

Source | Business Wire

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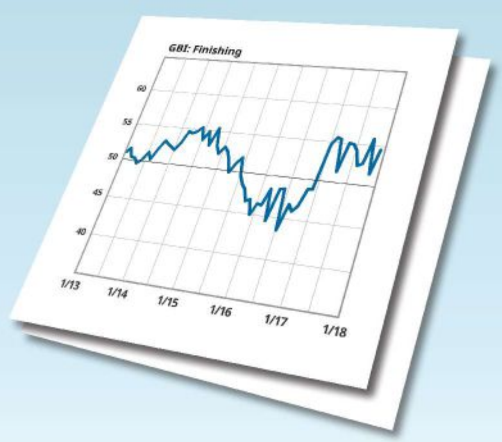

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SHOWCASE

Skeleton design enables more competitive composite autostructures

New approach combines thermoplastic pultrusions with injection overmolding in a two-step, 75-second process.

By Ginger Gardiner / Senior Editor

» As manufacturers seek to reduce the cost of composite components, designers strive to use constituent materials as efficiently as possible while enabling automated production and integration of multiple functions. For automotive applications, this challenge is exacerbated by the need for cycle times as short as 1-2 minutes.

Overmolding — injection molding thermoplastic composite features on top of continuous fiber preforms — has been pursued as a possible solution for years. For example, the CAMISMA project demonstrated an overmolded composite seat back in 2014 (see Learn More). "But this approach has been taken to the next level, now achieving fully automated production of thermoplastic composite BIW [body-in-white] structures," explains Dr. Christoph Ebel, head of SGL Carbon's (Wiesbaden, Germany) Lightweight & Application Center (LAC, Meitingen, Germany).

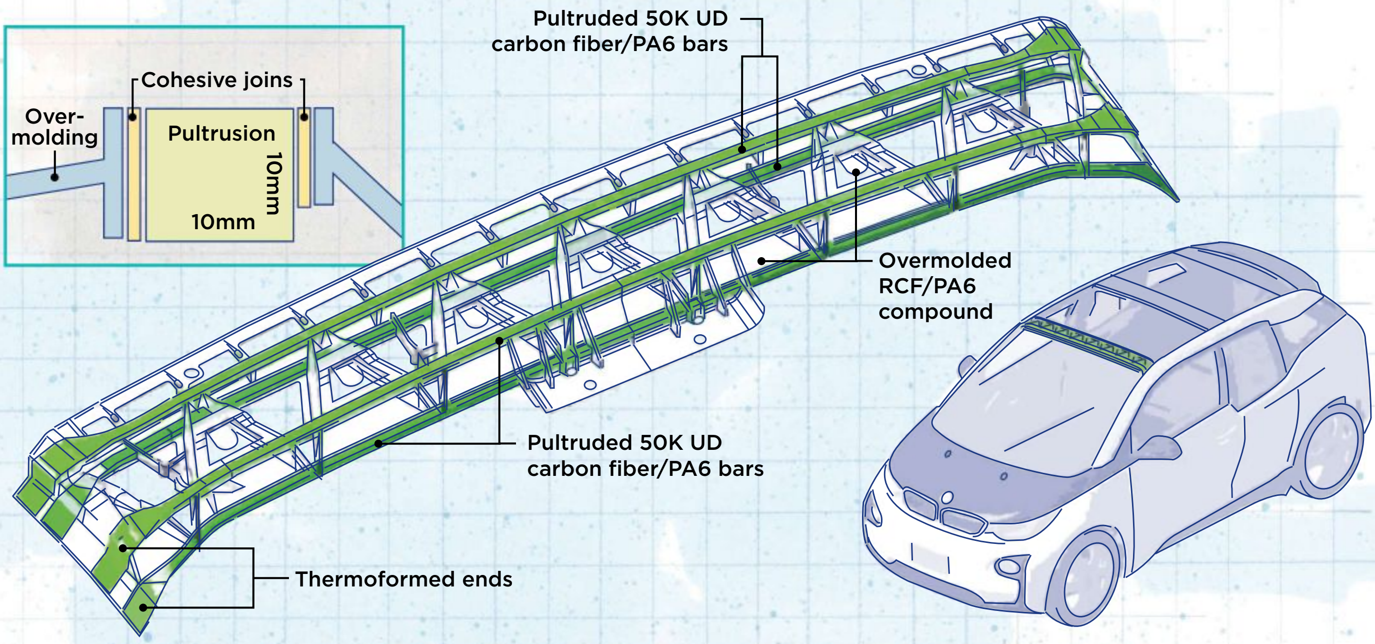
This advancement is thanks to a "skeleton" design approach that has been in development for several years. As first demonstrated in the MAI Skelett project in 2015, the process involves use of unidirectional (UD) carbon fiber *thermoplastic* pultrusions that are thermoformed and overmolded in a two-step, 75-second process to produce a structural roof member that exceeds all previous version requirements. It also integrates clips for attachments and changes crash behavior from brittle to ductile failure mode for increased BIW residual strength (see Learn More).

Pultruded skeleton

Pultruded profiles serve as the load-carrying skeleton for the overmolded, fiber-reinforced PA6 muscle of this next-generation windshield frame that outperforms the current BMW *i3* structure. Source | SGL Carbon

MAI Skelett demonstrator

The 17-month MAI Skelett project was supported by the German Federal Ministry of Education and Research (BMBF) and completed by MAI Carbon, a regional division of the Carbon Composites e.V. (Augsburg) network. Led by BMW (Munich, Germany), the project's focus was to realize a specific demonstrator: the windshield frame, located between the two A pillars above the glass windscreen. Its design was based on the current



DESIGN RESULTS — "Skeleton" CFRTP windshield frame demonstrator

- Maximize carbon fiber efficiency and minimize cost via 50K unidirectional (UD) CF/thermoplastic pultrusions.
- Fiber-reinforced PA6 overmolding joins pultrusions into the frame component, boosts torsional rigidity and provides functional attachments.
- Thermoplastic pultrusions enable thermoformed ends to achieve frame shape and introduction of attachment loads.

Illustration / **Karl Reque**

BMW *i3* structure, including all functional and space requirements. The windshield frame serves not only as a transverse structural member for the roof, but also provides other functions: rigidity, which also reduces noise, vibration and harshness (NVH); strength (roof pressing test) to help meet crash requirements; a fixture for interior components (for example, visor, interior trim, wiring harness for lighting, etc.), as well as support for connections with the windshield, sun roof and exterior roof panel.

The skeleton design windshield frame comprised four UD fiber-reinforced pultruded bars in the corners of the part, encapsulated in an overmolded frame to provide torsional rigidity and complex-shaped functional attachments. The pultruded profiles are not all in one plane, but instead are arranged at different heights: two are near the bottom of the 60-millimeter-tall part, and two are near the top.

Pultrusions as part of TP toolbox

For the MAI Skelett windshield frame, a 10-by-10-millimeter square cross section was finalized for the design. The goal was to use less expensive, heavy-tow carbon fibers. However, the 50K tow fiber chosen has a tight packing of myriad filaments that makes resin impregnation more difficult. "In general, this challenge can be overcome by optimized fiber guidance and spreading to reach optimum impregnation and high fiber volume content around 50 percent by volume," says SGL product manager for thermoplastics Veronika Bühler. SGL has mastered this technology and now offers pultrusions as part of its thermoplastic toolbox. "We already had a broad knowledge of semi-finished products because of our thermoplastic tapes, which are also pultrusion-based. So we were able to quickly adapt our currently used pultrusion technologies to create our own profiles." The process includes quality tests for fiber volume, porosity and dimensional accuracy. "The latter is very important due to automation and robot handling," she continues. "There can be no curvature, for example, due to residual stress in the pultruded profiles."

Beyond pultrusion reinforcements, thermoplastic resins were also investigated in MAI Skelett. Various types of polyamide 6 (PA6 or nylon 6) were tested to determine the required viscosity and rheology for optimized pultrusion quality and speed. SGL »

FIG. 1 Thermoformed ends

Three different shapes were trialed for thermoforming the ends of the pultruded bars. Those stretched in the direction of the matrix flow maintained the best fiber alignment to meet load requirements.

Source | MAI Skelett final report, BMW Group

offered a range of materials for the project via its thermoplastic toolbox, which comprises UD tapes, organosheets, chopped fiber for short and long fiber-reinforced compounds, and now UD-reinforced pultrusions, all based on SIGRAFIL 50K carbon fibers with sizing suitable for a matrix of polypropylene (PP) and polyamides, including PA6 or in-situ PA6. “It is essential to harmonize fibers, sizing and matrix in order to achieve optimum performance of composite structures,” says Bühler.

She also explains in-situ PA6: “This is when you react caprolactam monomers, or a single monomer with a catalyst and an activator, which then polymerize [form long polymer chains] during molding of the composite part.” In other words, the caprolactam polymerizes *in situ* into a polyamide. Bühler notes that polyamides as a polymer group include PA66 and PA12, as well as certain types of PPA as additional matrix choices.

Another important aspect of the windshield frame’s manufacture is the ability of thermoplastic semi-finished products to be thermoformed during and after molding. This enables further functionalization of the shape as well as fusion bonding during overmolding. Both were important factors in the MAI Skelett demonstrator design.

Thermoforming and overmolding

Production of the MAI Skelett windshield frame began with carbon fiber/PA6 pultruded profiles. These then had to be modified to accommodate the shape of the component as well as load introduction at different points. Thermoforming was chosen to do this, with the primary concern that the high strength and stiffness of the carbon fiber could only be realized by keeping it as straight as possible. This was achieved when the pultruded bars were stretched in the direction of matrix flow, and then flattened and bent at the ends of the bars (Fig. 1).

The second step of the process was to place the thermoformed pultruded profiles under an infrared heater to bring them up to temperature in less than 50 seconds, followed by transfer into an injection mold using an automated handling system developed for the purpose. All parts within the project were produced on existing injection molding machines. Fiber-reinforced compound was then overmolded onto and around the profiles. Precision was required in both the mold and the process during overmolding in order to hold the four thermoformed, pultruded bars in position.

The total cycle time for the two-step process (thermoforming and overmolding of premade pultrusions) was roughly 75 seconds. “Because the thermoplastic matrix is remelted prior to overmolding, it allows for forming and bonding the premade and thermoformed bars into the finished part in very short cycle times,” Ebel explains. “Generally, the fusibility of thermoplastics also enables joining with even metallic components,” adds Bühler, noting that thermoplastic thermoforming and injection molding processes offer excellent reproducibility and process control, which are critical factors for high-volume production.

Ductile failure

PPA and PA6 profiles with compatible molding compounds using glass and carbon fiber were evaluated to explore a more ductile failure mode for the component. Although a more ductile failure mode decreased the amount of load the windshield frame could transfer, it improved the structural integrity of the BIW as a whole.

Analysis methods included solid modeling, rebar modeling (geometry modeling where the pultrusions act as rebar reinforcing the overmolding) and modeling using shell elements, as well as various combinations of these. Software included the FE solver ABAQUS (Dassault Systèmes, Paris, France) and Dakota parameter solver developed by Sandia National Laboratories (Albuquerque, N.M., U.S.). OptiStruct (Altair Engineering, Troy, Mich., U.S.) was used for topology optimization.

Although BMW did not specify a preferred material combination in its final project report, it did conclude that final simulation and test results showed that the skeleton components exceeded all requirements for the current carbon fiber-reinforced plastic (CFRP) part except for torsional stiffness, which was determined not to be a key design driver for the windshield frame. The skeleton design exceeded both load level and energy absorption in crash load cases vs. the current CFRP part It also succeeded in achieving a more ductile failure mode, which further advances not only composite structure crash performance but also the understanding of that crash performance and how it relates to the BIW structure as a whole.

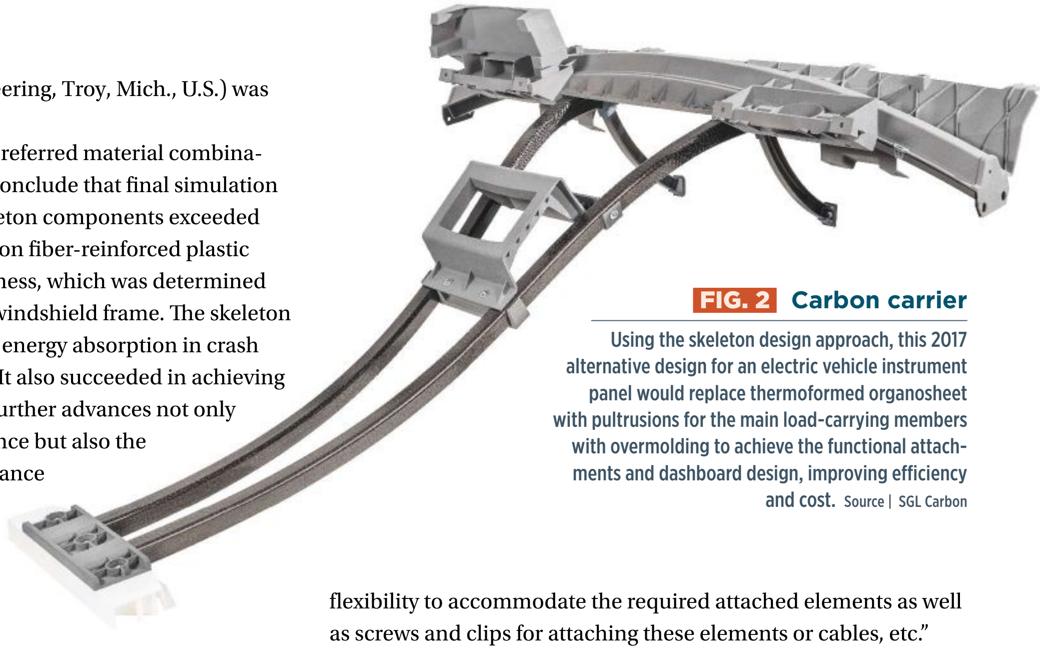


FIG. 2 Carbon carrier

Using the skeleton design approach, this 2017 alternative design for an electric vehicle instrument panel would replace thermoformed organosheet with pultrusions for the main load-carrying members with overmolding to achieve the functional attachments and dashboard design, improving efficiency and cost. Source | SGL Carbon

Future skeleton design applications

In the MAI Skelett final report, BMW noted that it had identified six other vehicle components that could benefit from the significant reduction in manufacturing, material and tooling costs provided by using the skeleton design approach. SGL Carbon suggests applications in both automotive and aerospace seat structures, dashboards, robot arms, X-ray benches and more.

However, the skeleton design approach was developed even further, extending to *multiaxially* stressed components in the follow-on project MAI Multiskelett (which was conducted from September 2015 to June 2017). It looked at areas where bearing components and pultruded profiles intersect, and also at high-load introduction areas, particularly for large structural components where several main load paths cross. As in the previous Skelett project, component designs and cost-efficient serial production lines were investigated.

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

Read more details on the MAI Skelett process | short.gardnerweb.com/MAISkelett

Read about CAMISMA's hybrid car seat back | short.compositesworld.com/Hybridseat

An example of how skeleton design can further optimize existing composite components is the Carbon Carrier front interior for an electric vehicle (Fig. 2) developed by SGL and automotive technology specialist Bertrandt (Ehningen, Germany) in 2017. Integrating all major function and trim components of a conventional instrument panel, the Carbon Carrier was based on a thermoformed organosheet as the load-bearing "backbone" to add stiffness. "In the future, this part could be replaced by a design with overmolded thermoplastic profiles," says Ebel. "This would omit cutting, layup and trimming operations for the organosheet. Also, the cross member would be obsolete because we would integrate it as pultruded profiles and overmold them to achieve the dashboard design. This overmolded part would also provide more space and flexibility to accommodate the required attached elements as well as screws and clips for attaching these elements or cables, etc."

Ebel concedes this would be a huge design change, "but it reduces cost and makes the whole component more efficient." He points out that it is possible to design a process with almost no waste because profiles are cut exactly to length as needed and no carbon fiber reinforcement is lost in these steps or in the thermoforming prior to overmolding. Bühler points out that seats are also prime candidates for skeleton design. "In composites, they are typically made with fabrics or tapes and are still sheet-like structures. But we could decrease thickness in the plane area by integrating profiles at the bottom and increasing stiffness." She notes that pultruded profiles are not the only efficient UD product possible to build around. "It could also be tape, which is easily adapted to the load paths for each part."

"We are touring a lot of companies at the Lightweight & Application Center," says Ebel. "The skeleton design as an additional innovative concept has inspired a lot of interest and is seen to be very promising by our visitors." He explains that the center has built up its design capabilities and can help companies integrate innovative ideas such as the skeleton concept to open up a new design space for future material-efficient components.

"There are a lot of applications where we can use designs similar to the windshield frame," says Bühler. "It is important for the industry to advance from quasi-isotropic layup, which leaves much of carbon fiber's strength and stiffness on the table. Instead, we must exploit more efficient material forms, putting each material only where it is needed. This is what the industry needs for the future." CW

ABOUT THE AUTHOR

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