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3D-printed molds: COMPOSITES ACCELERATE FACADE FABRICATION

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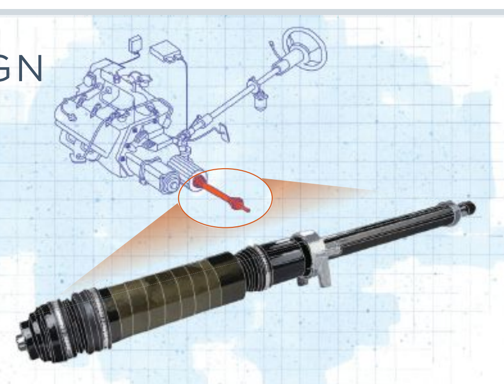
» ON THE COVER

The One South First building, part of Domino Park in Brooklyn, N.Y., features a concrete facade fabricated, in part, with composite molds produced using a large-format additive manufacturing machine. See p. 22.

Source / Max Touhy

FOCUS ON DESIGN



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» The coronavirus crisis we face has engendered its own language, comprising everyday words as well as not-so-common abbreviations. For example, over the last two-plus months (it's May 13 as I write this) words and phrases like "social distancing," "Zoom," "peak," "SIP," "virtual," "community spread," "PPE," "curve," "supply chain security," "WFH," and "remote learning" are now deployed so readily and frequently that we immediately and intuitively understand what each of them means. Moreover, we can use this coronavirus vocabulary as a sort of shorthand to quickly convey ideas and concepts, and to do so in a way that might have seemed unimaginable just a few months ago. Think back to late 2019 and imagine yourself in a conversation with a colleague or friend who says to you: "If we don't practice good social distancing, community spread is highly likely. As a result, flattening the curve becomes nearly impossible, which puts tremendous pressure on PPE supply chain capacity." Today, you know exactly what this statement means. In late 2019, not so much.

> The only question is *when* we will pivot, not *if* we will pivot.

In the business and manufacturing world that *CW* operates in, we have heard one particular coronavirus vocabulary word very frequently: pivot. In fact, we have heard it so frequently that I don't feel like I need to explain what it means. But, just in case: "Pivot" is used to describe a business or manufacturing operation that has been compelled to reorient itself in the market to meet new or expanding demand for products or services associated with response to the coronavirus pandemic.

Pivot is a useful word because it conveys constancy (the pivot point) and the ability/willingness to adapt to a changing environment. It implies allegiance and fidelity to a core technology or operation, coupled with operational flexibility.

We hear "pivot" a lot in two contexts. In the first, a composites-related manufacturer that possesses some expertise primarily serves a market that has ground to a halt because of the pandemic; the company has pivoted to apply its expertise in another market that stands to benefit from that expertise. For example, an aerospace composites fabricator good at cutting and kitting carbon fiber fabrics starts cutting and kitting PPE supplies.

In the second context, a composites-related manufacturer is pressed to increase capacity to an existing market because the traditional supply chain to that market has been cut. For example, a domestic moldmaker sees orders increase as competitors in other countries become inaccessible because of pandemic-caused disruptions.

We are also seeing that it's easier for small businesses to pivot than it is for large businesses. Which makes sense. A small business typically has just one or a few decision-makers and can more readily redeploy people, material and equipment as it pivots to the new opportunity.

The use of "pivot" also implies some choice — that in this unprecedented environment a composites business (whether supplier, fabricator or end-use customer) has the option of rethinking its place in the market and thus can either stay the course or change.

In truth, staying the course is not a viable option for survival. The pandemic's long course, global reach and disruptive nature guarantee that there are no parts of our professional and personal lives that will not be affected. Further, a return to pre-pandemic life is now so distant in the future that it is hardly worth contemplating. Pivoting, therefore, is mandatory. The decisions left, then, are when and how.

Business leaders, companies and organizations that recognize this and develop a strategy now will be best positioned for success in the short-term and in a post-pandemic world. And this is true not just for you, the *CW* reader, but for *CW* itself. We are also looking at how the composites manufacturing world is evolving and trying to position (pivot) ourselves to be a continuing and vital part of it.

So, a big part of our job in the coming months will be to change and adapt in such a way that we can see your pivots. And we want to share those pivot strategies with our audience, because right now knowledge distributed to the entire composites industry will have a vast and compounding benefit — and is necessary to all of our success.

So, get pivoting. And let me know how it goes.

JEFF SLOAN — Editor-In-Chief

■ Improved efficiency and sustainability

Fiberglass composite windowframes offer energy-saving benefits such as stiffness, resistance to thermal expansion and greater insulation than traditional windowframe materials.

A window to a greener world

» As part of the 10th annual World Green Building Week, which took place in September 2019, the World Green Building Council (WorldGBC) issued a bold vision for how buildings around the world can reach 40% less embodied carbon emissions by 2030. To meet this goal, changes need to be implemented throughout a building's infrastructure.

According to WorldGBC, buildings and construction are responsible for 39% of global energy-related carbon emissions. Out of this, 28% come from the operational "in use" phase to heat, power and cool buildings, while 11% of these emissions are attributed to embodied carbons, the carbon released during construction and material manufacturing. But no matter where these carbon emissions come from, the sector must tackle energy inefficiency across the entire building lifecycle. A way of improving building efficiency is to evaluate where energy is wasted. One area that contributes to a large portion of wasted energy is through a building's entry and exit points — its windows and doors.

Fiberglass offers several benefits over traditional materials used in door and window frames.

Keep heat in

On average, around 30% of a building's heat escapes through its windows alone. During colder months, the efforts of a building's heating system can be in vain, as much of the expense and energy to keep the building at a desirable temperature goes to waste.

Unlike metal, fiberglass composite materials are effective thermal insulators, making them the ideal candidate for window and door frames. Typically, insulation in an aluminum window frame is referred to as a thermal break — the continuous barrier between the inside and outside window frames that prevents thermal energy loss. While effective, this insulation method requires thicker frames, which can alter the desired appearance of windows. The insulating properties of composite materials such as fiberglass mean that there is no need for a thermal break, as the material is capable of ensuring thermal efficiency alone.

Built to last

When a wooden frame faces change in moisture and humidity, it risks warping, swelling or contracting. This can impact the condition and operation of the window or door and create draft space for warm air to escape and cold air to leak out. Repeated exposure to moisture may even cause rot. Unlike wood, fiberglass does not expand or contract when exposed to wet or humid conditions, and it does not rot, meaning it can last longer and work effectively in any environmental conditions.

While another common window frame and door material, polyvinyl chloride (PVC), does not swell or warp like wood, it presents its own challenges. PVC can be easily misshapen, so metal inserts are sandwiched between the exterior and interior frames of the window to match wood's structural stiffness. However, a problem arises when the seal binding these elements together isn't maintained — stopping it from keeping the elements out and the heat in. These inserts create complexity, and complexity can create costs. Fiberglass window frames do not require structural inserts, as the stiff material is manufactured in a single profile.

Combining forces

From a materials performance perspective, fiberglass offers several benefits over traditional materials. First, it has inherent stiffness and strength that obviates the need for adding stiffeners, and this simplifies the manufacturing process. Secondly, fiberglass is resistant to thermal expansion, corrosion and rot. This means less maintenance over the lifespan of the window or door frame. Thirdly, fiberglass frames are a great insulator, helping to retain heat or cooling to help save energy.

No matter where you use composites, the benefits of the material will greatly impact the efficiency of windows and doors. In order to improve sustainability, homeowners and construction companies will have to take a number of measures to reduce unnecessary energy loss. Windows and doors may be a necessary feature in any home, but the wasted energy that escapes through them is anything but needed. To tackle lost energy and improve efficiency, composite materials for windows and doors are an advantageous option. CW

ABOUT THE AUTHOR

Gert De Roover has 15 years of experience in the composite materials sector. Coming from the Hilti construction company, he began his career at Exel Composites as a sales representative before becoming sales manager. After this success, he continued his journey by achieving the position of head of the building, construction and infrastructure segment at Exel Composites. He believes in the potential of composite materials for their versatile, resistant and durable properties. He has a passion for architecture, design, classic cars and sports.

Innovate globally, fabricate locally

» Last month, I wrote about the frustration of spending three weeks working from home due to protective measures necessitated by the coronavirus pandemic. Now, 30 days later, most of us, including me, are still doing the same, although there appears to be signs of "flattening the curve" and some promise of treatment and eventual prevention of infection. Here in the U.S. Midwest, spring weather is allowing us to spend time outdoors, albeit while maintaining social distancing. Some countries and U.S. states, after two months or more of partial lockdown, are starting to allow businesses and factories to reopen, although it will still take a while for manufacturing to return to robust levels. Similarly, it may still be some months before we are able to congregate as a composites community in something other than a virtual environment. I hope to be able to attend September events like the SPE Automotive Composites Conference (ACCE) in Detroit and CAMX in Orlando.

> Innovation can happen anywhere, and much of the time, not in our backyard.

The world has changed as a result of COVID-19, and the implications are far-reaching. Two of the largest markets for composites, commercial aviation and automotive, have been hit severely, with production numbers for 2020 shrinking to levels not seen in many years. As the economy — and employment — recovers, one hopes that there will be significant pent-up demand for automobiles such that assembly plants, and those factories supplying them, will start humming again. The travel and hospitality industry, which includes aviation, is in for a longer period of recovery, especially given the wild card of how virtual meetings may change business travel. Social distancing is difficult on airplanes, so it will be some time before the flying public develops enough confidence for airlines to justify taking deliveries of new aircraft from Boeing (Chicago, Ill., U.S.) and Airbus (Toulouse, France). The marine industry is also likely to see some contraction until employment strengthens. While the wind industry may suffer a temporary setback, it is still poised to keep expanding, which is positive for composites. And if part of government stimulus worldwide includes infrastructure investment, composites should benefit.

I believe the mindset of humanity is changing as a result of COVID-19. After years of increasingly nationalistic trends, the global pandemic has quickly reminded us that we all share a relatively small sphere, and our fates are intertwined, even if we are forced to temporarily close borders to fight an invisible, insidious enemy. Overcoming this coronavirus requires a global effort, be that developing therapeutic treatments for those infected, or conducting clinical trials of promising vaccines in multiple locations around the world. The results of these treatments and trials will be shared across borders and, as supply chains are being restructured to reduce distance, scaling production of these solutions will occur simultaneously in many countries, as is now happening for personal protective equipment (PPE).

This mindset change will accelerate underlying trends that were already underway prior to the rise of COVID-19, including a transition from fossil fuels to renewable energy, battery storage and electrification of vehicles, despite historically depressed oil prices. These trends are positive for composites. I am reminded of the term "think globally, act locally," coined decades ago and originally used in the context of the environment and sustainability, which applies here. The pandemic is also forcing OEMs to look hard at supply chains. While automotive suppliers have long set up factories close to assembly plants for just-in-time delivery, aerospace has developed increasingly longer-distance supply chains, partly driven by foreign government manufacturing offset demands. It is inevitable that some of these supply chains will become much shorter. To increase competitiveness of local manufacturing in all industries, other trends that will be accelerated include increased automation in manufacturing and faster deployment of machine learning, artificial intelligence and Industry 4.0. I suggest, following the example of the medical community, that we, as a composites industry, invigorate our efforts to "innovate globally, fabricate locally."

What do I mean by this? Innovation can happen anywhere, and much of the time, not in our backyard. It is essential that we, as an international community of composites scientists and engineers, work together to address critical manufacturing competitiveness needs, and share those technologies with colleagues globally, preferably via physical interaction, but also in virtual environments. While some of this collaboration has started happening on an organic basis, ideally, industry and governments should actively fund global collaborative research in composites that address these evolving trends, led through national institutes, consortia and technology clusters. Commercializing these innovations around the globe will benefit the composites industry, and mankind, for the long term. 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.


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Composites Index contracts faster in second month of COVID-19 lockdown

April 2020 — 35.1

The Composites Index fell sharply for a second month in April to 35.1, setting consecutive all-time lows. Production and new orders in recent months have moved into territory that was formerly unthinkable with readings in the low 20s. The latest readings are approximately 15 points below previous historic low readings. Gardner Intelligence would like to clarify for our readers that the Index's readings represent the breadth of change occurring within the industry and are not to be confused with any rate of decline taking place. These low readings indicate only that a relatively large number of fabricators reported a decreased level of business activity in the current month as compared to the prior month, without quantifying the actual magnitude of the downward change.

Although much of April's data was challenging to digest, when segmented by end market, certain critical composites markets reported a slowing decline in overall activity relative to March. Fabricators serving aerospace, automotive and machinery manufacturing all reported a *slowing* decline in April. Conversely, fabricators serving the electronics market reported an *accelerating* decline in overall activity.

As of the end of April, data that tracks expected capital spending over the next 12 months had been significantly impacted by the coronavirus pandemic. Between January and April, larger fabricators have indicated that they plan to reduce their per-plant capital spending on average by more than 50%. Smaller firms, in contrast, reported only negligible changes to their forward-looking capital spending plans. CW

ABOUT THE AUTHOR

Michael Guckes is the Chief Economist/Director of Analytics 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.
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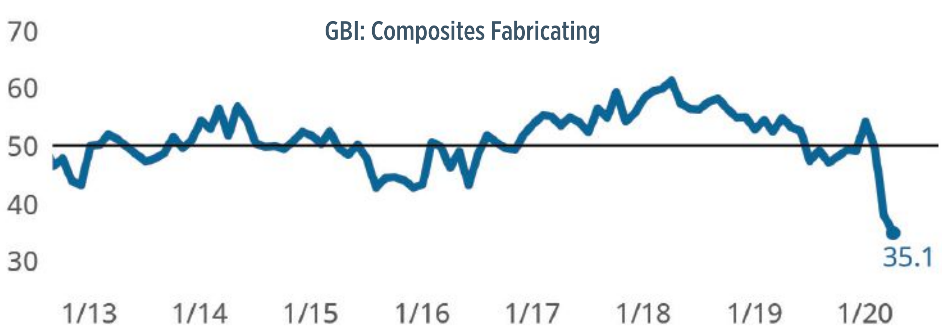
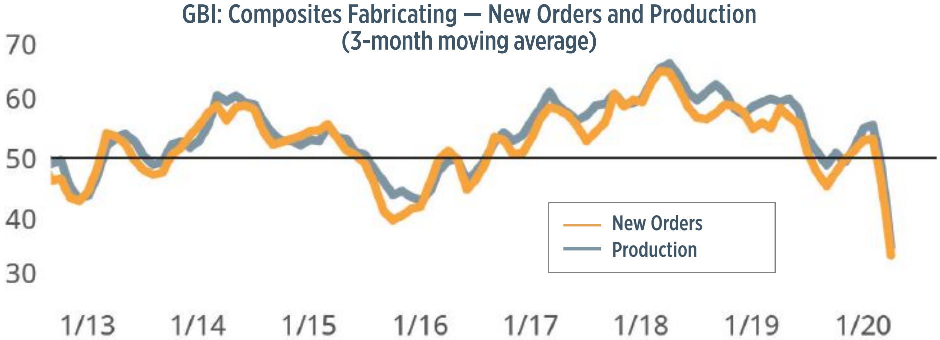


Second month of contraction

The Index fell sharply in April for a second consecutive month. All measures of business activity reported worsening conditions. In certain end-markets readings moved higher while remaining below 50; such results indicate slowing contraction in business conditions for these markets.



Backlog sinks as new orders and production activity levels collapse

New orders and production activity indicators set new lows that were substantially worse than past low activity readings. New orders and production serve as leading indicators to the movement of backlog and employment activity, suggesting that several months of challenging readings lie ahead.

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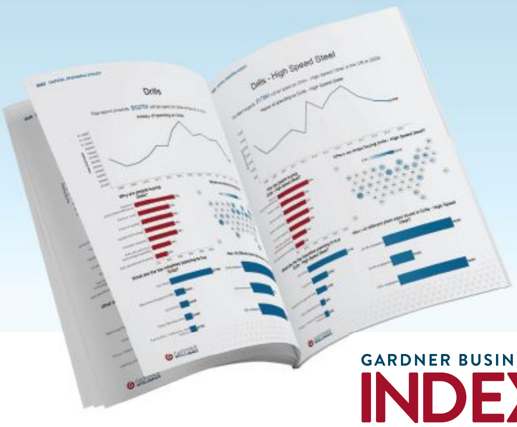
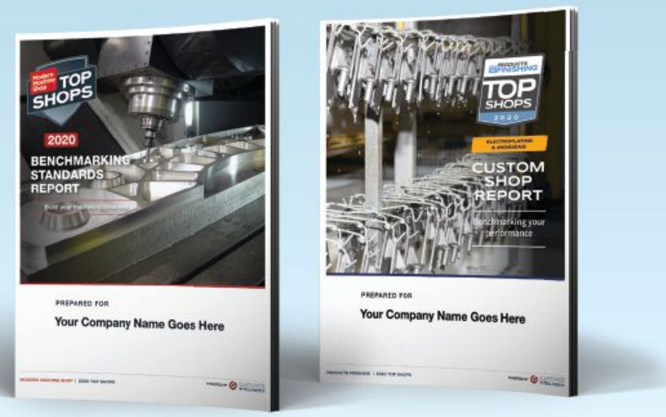


GARDNER BUSINESS INDEX

GARDNER BUSINESS INDEX

A business trends index measuring monthly changes in new orders, production, backlog, employment and other critical measures.



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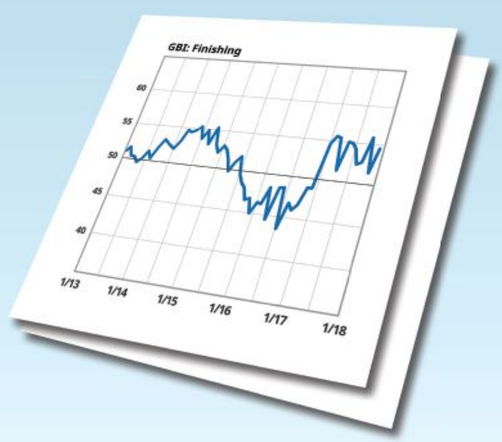

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This month's composites industry trends include composites innovations featured at this year's automotive PACE awards, new developments in dismantlable joints, graphene additives for PAN precursor and more.

AEROSPACE

Airbus CEO outlines short- and long-term goals

Source | Airbus

Airbus (Toulouse, France) CEO Guillaume Faury, during an April 29 earnings call, assessed the company's current situation and prospects for long-term growth in the wake of the nearly total global shutdown of commercial passenger air travel, caused by the coronavirus pandemic.

Faury said first that "our industry is now facing its gravest crisis in history," and noted that the dramatic decline in commercial passenger air travel — and the reduced demand for new aircraft that followed — has compelled the company to take "prudent steps to insure the future of Airbus."

The company, he said, is in the midst of trying "to match production with our best understanding of this new demand, and trying to meet our customers' expectations." The first step in that process occurred on April 8 when Airbus announced across-the-board production rate cuts of about one-third. The company will reduce narrow-body production from 60 per month to 40 per month. It will also manufacture two A330s and six A350s per month.

Through early June, Faury said, Airbus will continue to work with airlines and aircraft lessors to understand their aircraft needs, their financial status and how those two variables will affect Airbus's order books. For the most part, Faury said, Airbus has managed to avoid outright order cancellations, in favor of order deferments. That said, Faury admitted that the company has "limited visibility" about how passenger air travel will return. "We are very carefully managing our ability to understand all of the implications," he said.

Faury said he expects Airbus delivery of new aircraft, which began a downward trend in Q1 2020, will continue to be low in Q2 and Q3 2020. Following the summer, however, he expects the company will be on firmer footing and begin on a path to a more "normal" delivery pace.

However Airbus's recovery coalesces, Faury said he expects the company's narrowbodies — the A220, A320, A321 XLR — will lead the way as the return of domestic air travel is expected to precede the return of international air travel. For that reason, Airbus anticipates a 3-5-year recovery window for global passenger air travel, with A330 and A350 recovery expected closer to the 5-year end of that range. "Our product range is the right one for growing out of the crisis," he said.

Regarding the Airbus supply chain, Faury noted that it is a complex and interdependent ecosystem vital to the company's health and that "we need and will navigate this crisis together with them [suppliers]."

Looking ahead, Faury expects, by June, to have a clearer sense of the company's customers' positions and requirements; he hopes, at that time, to be able to offer more substantive guidance about how Airbus will adapt its delivery schedule. Another production rate cut is possible, he said. Other projects and efforts have also been put on hold, including expansion of the A320 final assembly line (FAL) in Toulouse and decarbonization efforts.

Ultimately, however, Faury said Airbus remains convinced that passenger air travel will return. The question, he said, is when and how. In the short term, he said, Airbus will be cautious and prudent, but long term he wants to position the company to act quickly to support the return of commercial air passenger travel. "There will be a ramp-up again," he stated. "The question is when and at what pace. After the crisis, I am convinced people want and will still need to fly."

AUTOMOTIVE

Composite parts fare well at 2020 PACE Awards

For 26 years, *Automotive News* magazine (AN, Detroit, Mich., U.S.) has presented its prestigious PACE (Premier Automotive suppliers' Contributions to Excellence) awards to honor commercial innovations in the global transportation supplier community. In the months leading up to the awards, a team of independent industry experts travels the world to visit each supplier submitting a nomination to hear in detail its benefits and see how it works. Then judges confer to pick competition finalists (30 made the cut this year) and winners, which normally are announced at a black-tie event in the Detroit area in April.

This year's announcement was delayed as COVID-19 shut down not only the automotive industry, but most of the planet. However, on April 28, 2020, *AN* held a virtual awards ceremony via webinar and announced two Innovation Partnership and 13 Product/Process awards. Composites applications fared well in the competition, which this year was dominated by technology focused on vehicle lightweighting, advanced communications and enhanced visibility.

One PACE Innovation Partnership Award went to the team of General Motors Co. (GM, Detroit, Mich., U.S.) and tier one Shape Corp. (Grand Haven, Mich., U.S.) for their innovative work developing the industry's first curved pultruded automotive part — the rear bumper beam on the 2020 model year (MY) Chevrolet *Corvette Stingray* sports car. Weighing just 1.3 kilograms, the hollow, two-chambered carbon fiber composite part contributes to vehicle stiffness and rear-crash performance, while its curved geometry better matches rear styling and fits in limited package space. Shape produces the beam via the radius pultrusion process and equipment (both developed by Thomas GmbH + Co. Technik + Innovation KG, Bremervörde, Germany) using carbon fiber rovings as well as non-crimp fabrics with a polyurethane-acrylate matrix.

In the Process/Innovation category, two additional composite parts were winners. The first is the structural liftgate reinforcement produced by Magna Exteriors (Troy, Mich. U.S.) for the 2020 MY Toyota *Supra* sports car from Toyota Motor Corp. (Toyota City, Aichi, Japan). The lightweight, integral spaceframe replaced steel at 10% lower mass while boosting stiffness-to-weight ratios, reducing the coefficient of linear thermal expansion (CLTE) and noise/vibration/harshness (NVH), improving dimensional stability, and reducing tooling costs. The filament wound structure — comprising fiberglass rovings wound around a reaction injection molded (RIM) polyurethane foam core, then impregnated with a polyurethane resin and formed via high-pressure resin transfer molding (HP-RTM) — also provides a continuous load path between hinges and latches. The technology is said to be ideal for meeting the needs of difficult packaging situations and challenging load cases.

The third composite part is the CarbonPro pickup box produced by Continental Structural Plastics, a Teijin Group co. (Auburn Hills, Mich., U.S.) for the GMC *Sierra Denali* 1500 and *Sierra AT4* 1500 pickups from GM. As the industry's first thermoplastic composite pickup box (compression molded from Sereebo chopped carbon fiber/polyamide supplied by Teijin Ltd., Tokyo, Japan), it reduced mass 40% (28 kilograms) and increased cargo carrying capacity (thanks to deep-draw molding capabilities) while offering significantly higher impact performance than a steel box. The UV-stable material (with molded-in-color black) is corrosion and damage resistant, and eliminated the need for paint as well as an 18-kilogram bedliner, yet provides numerous customer features, including functional compartment dividers and motorcycle tire pockets.

The auto industry's first curved pultruded composite part — produced by Shape Corp. for the 2020 Chevrolet *Corvette Stingray* by General Motors Co.— was honored with an Automotive News 2020 PACE Innovation Partnership Award. The carbon fiber composite rear bumper beam reduced mass 2.2 kilograms vs. the outgoing aluminum beam, was durable enough to travel with the body-in-white through the electrophoretic rust-coat process, and was produced via the radius pultrusion process, which is fast enough to meet high-volume automotive production requirements. Source, both images | SPE Automotive Div.

The filament wound composite liftgate reinforcement structure developed by Magna Exteriors for Toyota Motor Corp. and first used on the 2020 Toyota *Supra* won a 2020 PACE Process / Innovation award. The fiberglass/polyurethane composite technology is said to be fast enough to support higher production volumes and provides automakers with new styling features to create more complex and bolder shapes thanks to the ability to vary frame diameter, shape and wall thickness.

CARBON FIBER

4M demonstrates large-diameter carbon fiber production

4M Carbon Fiber Corp. (Knoxville, Tenn., U.S.) announced in April that it has produced a carbon fiber of filaments with relatively large diameter using its patented plasma oxidation technology with a textile-grade polyacrylonitrile (PAN) precursor supplied by one of its partners, Dralon GmbH (Dormagen, Germany).

4M large-diameter carbon fiber made with Dralon textile-grade precursor. Source | 4M Carbon Fiber

4M and Dralon co-developed the low-cost, textile-grade PAN precursor capable of producing a 10K tow carbon fiber with filaments about 9.6 μm in diameter (compared to 6-7 μm in typical fibers). In preliminary work with the precursor, 4M says it has achieved a residence time for the oxidation phase during carbon fiber manufacture of only 52 minutes. 4M says this is considerably faster than conventional oxidation of commercial (smaller diameter) PAN precursors. 4M says work is continuing with the textile-grade PAN to further improve material properties and optimize the process.

4M notes that until now, large-diameter carbon fibers have not been produced at scale, mainly due to challenges related to the oxidation stage. 4M says that using conventional oxidation technology, the larger filaments require long residence times and additional energy, which creates a carbon fiber that is not economically viable. Additionally, says 4M, large-diameter carbon fibers tend to yield subpar performance as a result of defects introduced during conventional oxidation. For these reasons, says 4M, carbon fiber manufacturers do not offer a large-diameter commercial carbon fiber.

The advantages of a large-diameter carbon fiber are lower cost and better performance, says 4M. A larger diameter filament introduces cost savings throughout the manufacturing process, from precursor production to carbon fiber conversion, most readily seen in increased mass throughput, the company asserts. Combine this savings with the low-cost precursor Dralon normally produces, and the total cost savings becomes significant.

Carbon fibers are known for their high tensile strength, but they are not particularly strong in compression, especially compared to glass fibers. However, says 4M, larger-diameter carbon fibers can have significantly higher compressive strength. Advances in this aspect could enable new applications as well as growth in existing markets, such as wind turbine blades.

AUTOMOTIVE

Polypropylene honeycomb lightens, strengthens automotive panels

Source | DPA Moldados

Honeycomb cores are not new to the composites industry, but they are relatively new to the automotive composites market, where composite materials are only just starting to migrate into parts and structures for high-volume vehicles.

Recognizing this, ThermHex Waben GmbH (Halle, Germany) has developed a polypropylene honeycomb core material for composite sandwich structures in automotive panels. The standard volume weight of this core is 80 kilograms per cubic meter. Also available, for applications that require less compressive strength, is a core with a density of 60 kilograms per cubic meter. Core thickness ranges from 3 to 28 millimeters, with cell sizes of 3 to 9.6 millimeters. The ThermHex honeycombs have a half-opened surface that, in combination with various surface finishes, enables what is said to be an optimal connection between core and skin layer in the subsequent sandwich element. Small cells also enable an almost perfect surface finish.

ThermHex produces its honeycomb cores by extrusion of thermoplastic polymers into a film, rotational vacuum-forming, a folding process and in-line lamination of the surface finish to allow a better bonding of skin layers. This patented, continuous, inline process, in which various skin layers can be applied to the honeycomb core, produces panels that ThermHex customers turn into finished components by applying additional surface layers, forming and cutting to size. By contrast, ThermHex says, other processes require each layer of honeycomb to be individually cut from a block and then laminated.

Automotive supplier DPA Moldados (Itupeva, São Paulo, Brazil), which fabricates interior trim components, air ducts and thermal and acoustic insulation for various automotive OEMs, has recognized that car manufacturers need alternatives for various monolithic components that are lighter but have similar or better mechanical properties.

Since 2017, DPA Moldados has used the black version of the ThermHex polypropylene honeycomb core, replacing core materials of other producers. The honeycombs are used by DPA Moldados to fabricate, for example, the trunk floor in the Hyundai *Creta* ix25.

In this application, glass fiber mats are preheated, stacked on the top and bottom side of the ThermHex honeycomb core and then press-molded with a polypropylene resin matrix (granules) into a sandwich structure. According to DPA Moldados, the company is one of the few manufacturers in the world that is technically capable of producing this type of sandwich molded part for mass production. Furthermore, the materials used are 100% recyclable and require less energy to produce than competitive materials.

ThermHex says its honeycomb core helps reduce the weight of automotive components compared to solid materials, with similar or better strength properties.

In addition to the production of automotive components, ThermHex says its honeycomb cores can be found in truck box bodies, marine interiors, swimming pools and furniture. The ThermHex production process is offered worldwide under license by parent company EconCore (Leuven, Belgium) and is used, for example, by Renolit under the name Gorcell for the trunk floors of the Maserati *Gihbli* and the Jaguar *F-Type*. In Japan, the technology is marketed by Gifu Plastics under the name Teccell and used there to fabricate the trunk lid of the Toyota *Prius*.

BIZ BRIEF

The **Society of the Advancement of Material and Process Engineering**'s (SAMPE, Diamond Bar, Calif., U.S.) new CEO Zane Clark assumes his new role effective June 15. According to SAMPE, Clark brings to his new position 20 years of success as an association and operations leader, and as an individual contributor directing large and complex program solutions and driving strategy in a constantly evolving environment. Clark is a California association executive with experience in volunteer engagement, membership benefit development, association foundation program direction and committee management. He most recently served in a senior position at the Specialty Equipment Market Association (SEMA, Diamond Bar).

CARBON FIBER

CSIRO: Developing higher-quality, higher-strength, lower-cost carbon fibers

The Commonwealth Scientific and Industrial Research Organisation (CSIRO), Australia's national science agency, says it is developing the next generation of carbon fiber. Specifically, its researchers aim to control both the molecular structure of polyacrylonitrile (PAN) precursor and its processing to produce carbon fiber that is higher quality, more affordable and higher performance.

In 2017, CSIRO launched its own wet-spinning line to manufacture PAN precursor, working in collaboration with Deakin University's Carbon Nexus facility (which launched its carbonization line in 2013). CSIRO and Carbon Nexus are part of Deakin University's Waurn Ponds campus in Geelong, roughly 75 kilometers southwest of Melbourne. These groups are working with the local composites industry as part of the Advanced Fibre Cluster Geelong, which includes well-known composites manufacturers such as Carbon Revolution and Quickstep — also located on the Waurn Ponds campus — as well as GMS Composites, Sykes Racing, ACS Composites and others.

"CSIRO's work is centered around the first steps in carbon fiber production, including the polymerization of acrylonitrile into polyacrylonitrile and then spinning and further processing PAN to produce a higher-quality and cheaper precursor fiber," explains Andrew Abbott, CSIRO team leader carbon fiber. PAN production accounts for 50% of carbon fiber's cost but 70-90% of its properties. "Deakin University's technology involves the final steps in carbon fiber production, including oxidation and carbonization," he continues. "The technology they have licensed to LeMond Composites [Oak Ridge, Tenn., U.S.] is for rapid oxidation aimed at lowering the cost of these final steps."

To achieve its goals for next-generation carbon fiber, CSIRO is using a set of strategic tools: RAFT polymerization, FLOW chemistry processes and CarbonSpec metrology. "Our aim is to produce an aerospace-grade carbon fiber with 20% higher strength," says Abbott, noting the team hopes to have some initial results by the end of 2020.

Wet spinning pilot line

In order to complete the necessary research in carbon fiber precursors, CSIRO first had to establish its own wet spinning line. The pilot line was custom built by MAE (Fiorenzuola d'Arda, Italy), a machine manufacturer which specializes in polymer and fiber process equipment. "It is designed like a commercial line but at a smaller scale," explains Abbott.

RAFT polymerization

Another tool CSIRO is applying is its patented and commercialized RAFT (Reversible Addition-Fragmentation chain Transfer) technology. RAFT is a sophisticated form of controlled free-radical polymerization that enables the synthesis of tailored polymers with unprecedented control of composition and architecture. Though applications for RAFT range from novel drug delivery systems to industrial lubricants and coatings, CSIRO's carbon fiber team uses it to exert control over the PAN polymerization process.

CSIRO's wet spinning line, including rollers for controlled stretching.

Source | CSIRO

"Conventional polymerization from monomer to polymer produces a broad polydispersity — in other words, a lot of different lengths for the polymer chains," explains Melissa Skidmore, CSIRO team leader polymer chemistry. "If we add a RAFT agent, however, we now get polymer chains of almost the same length, and thus a much narrower molecular weight distribution. We are still using the same initiators, monomers and solvents but just adding RAFT."

"Molecular weight affects the viscosity of the spinning solution," says Skidmore. "Traditionally, higher molecular weight in dope solutions has led to grooved surfaces on the precursor fibers. Adding RAFT decreases viscosity of the dope solutions, leading to a higher solids loading. Removing the very high molecular-weight polymer of the polymer may result in better molecular alignment in the fiber and improved properties." She adds that low molecular weight has a plasticizing effect on fibers. "RAFT produces PAN polymers which could produce denser, more uniform precursor fibers with fewer structural defects. This could also help speed carbonization and lower cost."

"This also gives us access to complex polymer architectures," notes Skidmore. "RAFT allows for further chemical manipulation of the polymer group." An example of where that comes in handy is when the dope solution is manipulated to coagulate into fibers. "There is a delicate balance between the ideal characteristics of the dope polymer solution and coagulation conditions," she adds. "The polymer is 95% PAN and 5% additives. Because RAFT polymers behave differently, we think we can lower some of the traditional additives and convert a higher percentage to high-solids fiber, which leads to less defects. We are testing this now."

Continuous FLOW process

"With RAFT, we gain control over polymerization," Abbott says. "With FLOW, we have more control over the fiber formation." FLOW converts polymerization to a continuous rather than a batch process. Abbott and Skidmore explain that the batch reactors used currently are well-established, easy to set up and efficient in mixing and monitoring the reaction kinetics, but they also require a larger volume than continuous process reactors, meaning industrial-scale set up is expensive. These larger-volume batch reactors are also inefficient in regards to space and energy consumption. Continuous process reactors are smaller and less expensive, easy to scale, more energy-efficient and offer better process control and reproducibility vs. batch processing. However, because they are a dedicated, continuous line, they are less flexible in switching between different parameters and products.

CarbonSpec – measure to manage

The final tool in CSIRO's carbon fiber approach is CarbonSpec. "It's basically metrology we have developed to test the fibers we produce and better understand the property/material relationship," explains Tony Pierlot, CSIRO project leader fiber metrology. "We are also better able to predict carbon fiber properties from a minimum amount of measurements."

Using synchrotron X-ray computed tomography (CT), standard for determining carbon fiber microstructure, a new dedicated characterization protocol has been developed for scanning the microstructure of individual PAN precursor and carbon fibers. "A microstructure map of individual fibers as small as 5 microns in diameter is achieved in a matter of minutes," Pierlot says. Using both the SAXS and WAXS signals at the Australia Synchrotron beamline simultaneously, he notes, "we can monitor and optimize the mechanical strength and stiffness along each phase of the production process from PAN dope to carbon fiber."

20% increase in strength

"We have improved our understanding of how to convert polymer into fiber and are now making commercial fiber," Abbott says. "We are applying these technology tools to other precursor polymers to make SIROPAN, which is the CSIRO version of PAN using RAFT. We can make kilograms of that fiber now."

"The next step is to assess the benefits of using RAFT polymers," he continues. "We are still making PAN, but we're better controlling the molecular weight and increasing it while lowering the viscosity, which can produce stronger carbon fiber." How much stronger? "We're not sure yet, but our aim is 20% stronger," Abbott says.

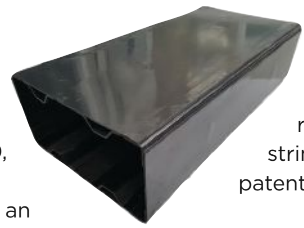
AEROSPACE

Welded thermoplastic composite keel beam demonstrator completed

Funded by the European Commission in the framework of the Clean Sky 2 Public-Private Partnership within the EU Horizon 2020 program, the goal of the KEELBEMAN project, which successfully concluded in February 2020, was to complete design and manufacture of a thermoplastic composite keel beam section for an Airbus A320-type aircraft to validate the technology at technology readiness level TRL3.

The KEELBEMAN project addressed the design and manufacture of a full component via a keel beam section demonstrator, using thermoplastic matrix resin reinforced with carbon fiber. The use of manufacturing technologies with significant potential for automation were explored and selected combinations were demonstrated at TRL3.

Under the technical lead of CETMA (Brindisi, Italy), an R&D center highly specialized in composite processing and characterization, a novel continuous compression molding (CCM) process was used to manufacture the skins and the stringers of the keel beam section. CCM is a very fast process, one of the most promising for manufacturing very long thermoplastic composite parts, and CETMA is one of the leading providers of this technology in Europe.



Source | EURECAT

Stiffening ribs were produced using more conventional non-isothermal compression molding by the project coordinator EURECAT, a leading research center located in Barcelona, Spain. Skins, stringers and ribs were assembled using CETMA's patented induction welding technology.

These manufacturing technologies were complemented by the contributions from two additional KEELBEMAN project partners:

CT Ingenierie, a French engineering company, carried out the keel beam re-design from metal to composite with no rivets, starting from the metallic baseline defined by Clean Sky 2 topic manager Airbus (Toulouse, France) and defined the architecture and thickness according to calculations from structural and manufacturing process analysis.

SOFITEC, a leading Spanish Tier 2 supplier for aerostructures, focused on the detailed definition and implementation of ultrasonic nondestructive inspection (NDI) of coupons, subcomponents and the final demonstrator, based on Airbus standards and the particularities of welded thermoplastic composite structures.

CARBON FIBER

Graphene-reinforced carbon fibers may offer path to stronger, cheaper composites

As published by the Graphene Council, researchers at Oak Ridge National Laboratory (ORNL, Oak Ridge, Tenn., U.S.), the University of Virginia (UVA, Charlottesville, Va., U.S.) and Pennsylvania State University (University Park, Pa., U.S.) have published research in the April 2020 issue of *Science Advances*, evaluating the use of pristine graphene as an additive to polyacrylonitrile (PAN) solution for carbon fiber precursor fibers based on previous research using carbon nanotubes (CNTs) and graphene oxide (GO) liquid.

The authors explain how adding CNTs can not only optimize PAN spinning dope and coagulation parameters, but also serve as both the template for the alignment and orientation of polymer chains and the nucleating agent for the polymer crystallization. They cite research by Chae *et al.* which reported a 49% increase in carbon fiber modulus and a 64% increase in strength with the addition of 1.0 wt % carbon nanotubes. The addition of CNTs have also been shown to reduce the carbonization temperature, which can significantly reduce the energy consumption during carbon fiber (CF) manufacturing.

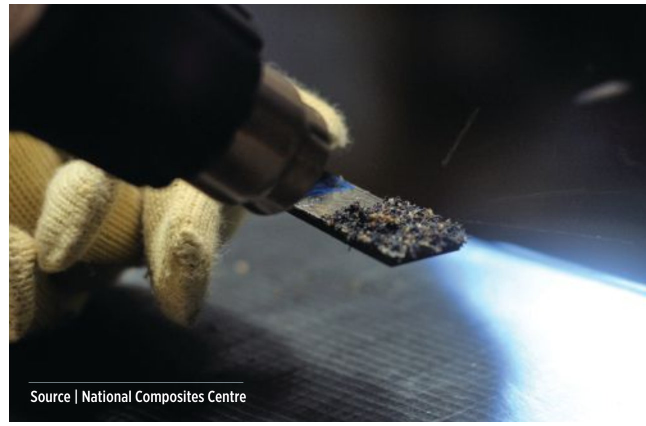
As a single-layered, two-dimensional carbon allotrope, graphene demonstrates superior properties to CNTs, including larger surface area, superior electron mobility and higher tensile strength and Young's modulus. However, recent experiments using graphene oxide (GO) liquid crystal in the fabrication of carbon fiber resulted in fibers with subpar tensile strength because of their poor intrinsic alignment and crystallinity.

Theorizing that pristine graphene may be a better additive than CNTs and GO for PAN-based carbon fibers, the ORNL, UVA and Penn State researchers added a small amount of shear-exfoliated pristine graphene (0.01 to 1.0 wt %) to a PAN/dimethyl sulfoxide (PAN/DMSO) solution to fine-tune the properties of the PAN spinning dope. The PAN/graphene-based carbon fibers with 0.075 wt % graphene exhibited a tensile strength of 1916 MPa and a Young's modulus of 233 GPa — a 225% increase in strength and 184% increase in modulus compared to PAN fibers without graphene.

In addition, large-scale molecular dynamics simulation results show that adding graphene introduces favorable edge chemistry, promotes carbon content, enhances polymer chain alignment and increases crystallinity.

The authors claim these results not only expand the understanding of PAN-based carbon fiber production but also provide a foundation for developing low-cost alternative precursor fibers enhanced by graphene, which may yield carbon fibers that offer superior performance and lower cost to current PAN-based products.

Dismantlable joints research demonstrates adhesive additive technology


Source | National Composites Centre

The National Composites Centre (NCC, Bristol, U.K.) and Oxford Brookes University have developed a new technology that enables composite structures to be separated (or disbonded) quickly and cheaply using a simple heat source. With a goal of making it easy to work with, repair and disassemble composite parts, the researchers intend for this technology to significantly impact the design, use and end-of-life recycling of a wide range of products, including cars, aircraft and wind turbines.

Researchers at Oxford Brookes University demonstrated that by adding low-cost additives to off-the-shelf structural adhesives, composite parts could be separated in as little time as six seconds by raising the temperature of the joint to approximately 160°C. The National Composites Centre reports that it has now proved that the new approach works at an industrial scale as part of its Technology Pull-Through Programme, which exists to transition new ideas from the lab to the marketplace.

Small quantities of expandable graphite (widely used for fire protection) or thermal expandable microspheres are added to adhesives routinely used to bond composite parts. According to the NCC, these additives have minimal impact on the performance of components in normal operation, but when heated to the required temperature exert a force causing components to “pop apart.” This means, NCC says, that in the near future, composite components may be easily repositioned and reused during manufacturing (reducing waste), repaired in operation and recycled more efficiently at the end of their working life.

“Historically, when a part is damaged or reaches the end of its life, it would be classed as waste and discarded,” says Lucy Eggleston, research engineer at the NCC “With this technology, we can take these structures apart to be repaired, reconfigured, or used in different ways. This could increase available end-of-life strategies for components, ultimately reducing their impact on the environment.”

For example, the automotive sector, NCC. says, is looking to increase its use of composites and bonded parts in order to reduce vehicle weight. Vehicles also have to be 85% recyclable to comply with end-of-life directives. The new technology would reportedly enable mechanics to swap damaged parts using a simple heat gun. Recyclers could put whole cars through low-temperature ovens and watch them dissemble in seconds.

The researchers also hope to extend this technology to recycling of the large amounts of carbon fiber and glass fiber composites on scrapped aircraft and wind turbine blades.

“We’ve been looking at ways to disbond structural adhesives for about 10 years, and working with the NCC through the Technology Pull-Through programme has enabled us to prove the technology readiness of our research,” says Professor James Broughton, head of the Joining Technology Research Centre at Oxford Brookes University. “We can now work with industry to fully optimize the technology for specific applications and tailor it for them as required.”

INFRASTRUCTURE

Composite Advantage ships FRP camels to U.S. Naval base in Guam

Infrastructure maintenance posed challenges for U.S. Naval Base Guam (NBG) due to lack of services and support on the tiny western Pacific island. NBG handles submarine deployment for the 7th fleet and is home port to four Los Angeles-class attack submarines. External flotation structures called camels prevent damage to vessels and port structures when submersibles are berthed or moored, but conventional materials make them prone to high maintenance and frequent replacement. NBG found a solution with Composite Advantage's (Dayton, Ohio, U.S.) corrosion-resistant, fiber-reinforced polymer (FRP) composite universal submarine camels.

"Metal and wood camels require removal every two years for inspection and repair which can be costly if corrosion has set in," says Scott Reeve, marketing director for Composite Advantage, which is now part of the Creative Composites Group. "Poor durability was another problem. The FRP universal composite camel is corrosion-resistant to salt water and chemicals, requires no maintenance, reduces life cycle costs and can accommodate any class of submarine."


Source | Composite Advantage

A set of two FRP camels — 36 feet long, 18 feet high and 17 feet deep, weighing 70,000 pounds — each were fabricated in Composite Advantage's Dayton, Ohio factory and shipped to Whittier, California in December 2019. The camels traveled 6,111 miles by ship to Guam, arriving January 13, 2020. Assembled at a Guam shipyard, the two camels were set in the water and tugged to the naval base where they were moored to the pier ready for use. Composite Advantage has been designing and fabricating FRP universal camels for the Navy since 2013.

Composites speed concrete facade fabrication

The 45-story One South First building, on the 11-acre Domino Park campus in Brooklyn, N.Y., features a geometrically complex concrete facade made, in part, with composite molds fabricated using large-format additive manufacturing.

By Jeff Sloan / Editor-in-Chief

» Every multi-story building constructed today requires a facade. Derived from the French word *façade*, which in turn came from the Italian *facciata*, it means "face." In short, the facade is the exterior, public-facing structure that gives the building its character, color and shape. For architects, the facade sets the tone for the rest of the building and says much about the designer's architectural intent.

A facade is also functional. It provides the structure that surrounds windows and doors, protects the building from weather and impacts, and affects the building's energy efficiency. A facade can be constructed from a variety of materials, including composites, stone, steel, glass or concrete. Concrete in a facade, by virtue of its formability, can be used to give a building a highly dimensional and visually impactful appearance, particularly if the concrete shapes are varied.

Built with composites

The One South First building, part of Domino Park in Brooklyn, N.Y., features a concrete facade fabricated, in part, with composite molds produced using a large-format additive manufacturing machine.

Source | Max Touhy

Sugar is king

This was the case at Domino Park, an 11-acre redevelopment project along the Williamsburg waterfront in Brooklyn, N.Y., U.S. At the heart of Domino Park is the 138-year-old

Domino Sugar Refinery, which closed in 2004 and is now being renovated as office and retail space. Part of Domino Park includes several new buildings, including the 45-story One South First and the conjoined 10 Grand. For these buildings, the architect, COOKFOX (New York, N.Y.), decided to use a concrete facade that features multiple surface angles, multiple window frame shapes and multiple window frame widths to, from a distance, loosely convey a sense of sugar crystallinity, in keeping with the site's history.

Gate Precast Co. (Jacksonville, Fla., U.S.) won the contract to construct the concrete facade — a series of window frames — for the One South First project. The company would, as is typical for a concrete facade, fabricate the frames at its own facility and then ship them to the work site where they would be hoisted into place for installation via crane. If Gate had followed tradition, it would have built wooden molds with which to shape all of the concrete frames. Gate, however, decided not to follow tradition.

To understand, go back to 2017, when Gate partnered with the Precast/Prestressed Concrete Institute (PCI, Chicago, Ill., U.S.) and Oak Ridge National Laboratory (ORNL, Oak Ridge, Tenn., U.S.) to conduct a preliminary assessment of the use of large-format additive manufacturing to build composite molds for in-plant precast concrete forming. This assessment was done using a BAAM (Big Area Additive Manufacturing) machine at ORNL. BAAM is a large-format additive manufacturing machine with a 25-square-meter build envelope, co-developed by ORNL and Cincinnati Inc. (Harrison, Ohio, U.S.). Gate committed to build composite molds for the One South First facade. The project required 80 molds total, 37 of which would be printed. The remaining 43 would be made from wood. By the time this decision was made, timelines for mold delivery was tight.

Meanwhile, in 2016, Additive Engineering Solutions (AES, Akron, Ohio, U.S.) had acquired its first BAAM machine from Cincinnati Inc. Because of that, ORNL and Gate Precast turned to AES for help. Andrew Bader, VP and co-founder of AES, says his company and ORNL split the work package, with AES producing 18 of the 37 molds. Bader says each window frame mold measures about 5-6 feet wide, 9-10 feet tall and 16 inches deep and weighs about 500 pounds.

Bader says the interior geometry of the molds, because they are designed to produce frames that »

Designing the facade

The 45-story One South First building (far left) in Domino Park features a facade designed to emulate the crystallinity of sugar, a nod to the 138-year-old Domino Sugar refinery (with smokestack) that is the centerpiece of the site. Source | COOKFOX

CFRP mold

One of the AES composite molds being finished via CNC after it was built in a BAAM machine. Material, supplied by SABIC, is an ABS with 20% chopped carbon fiber reinforcement. Source | AES

Side-by-side

Two of the AES-built composite molds (background) are ganged with a traditional wood mold (foreground) in a three-window frame at Gate Precast in Winchester, Ky., U.S. Source | AES

Finished frames

Finished concrete frames fabricated by Gate Precast await transport to the One South First site in Brooklyn. Source | AES

Installation

A concrete frame, with windows, is hoisted up for installation on the One South First building. Source | COOKFOX

surround rectangular windows, was relatively simple. However, the design of the *exterior* surfaces of the frames was more complex, with varied depths and angles in each mold. "The geometry was simple, but complicated," Bader says. "The project required several unique frame designs, depending on frame location."

For part of its production, AES chose an LNP THERMOCOMP AM compound, a high-modulus, low-warp material based on ABS with 20% chopped carbon fiber reinforcement supplied by SABIC (Houston, Tex., U.S.). Bader says it took the BAAM machine 8-10 hours to build each monolithic mold, followed by 4-8 hours of machining and finishing in a Quintax CNC machine. He reports that the molds were sanded to the required dimensions, but they were not sealed as is typically done with large printed parts.

Fabricating window frames

The molds were delivered to Gate's Winchester, Ky., U.S., facility where they were used alongside the traditional wood molds that Gate built for the project. The wood molds were hand-assembled by Gate employees, then a fiberglass mat and resin coat were applied, with form oil sprayed on to facilitate release of formed concrete frames. Form oil was also sprayed on the composite molds to facilitate release.

To perform a concrete pour, multiple molds were placed on a wood casting table 40-50 feet long. Molds were ganged to produce a single frame, a double frame or a triple frame. Concrete was poured into each mold and then the casting table was vibrated to consolidate the concrete. After 14-20 hours of cure, the window frames were demolded, acid washed and polished, windows were installed and then all was shipped by truck to Brooklyn.

Bader says the AES composite molds, working alongside the traditional wood molds, quickly revealed their advantages. First, he says, a wood mold only allows 15-20 concrete pours before it must be removed from service and refurbished or replaced. The AES molds, conversely, allowed 200 concrete pours with minimal refurbishment or out-of-service time. And the 200 pours, says Bader, represented the end of the project, not the end of the mold's service life. "That's just where they stopped," he says. "If our molds are taken care of properly, we think they can be used hundreds and hundreds of times."

Further, for 150 pours or more, Gate calculates that it would have taken up to 10 wood molds to meet the performance of one AES mold. Further, given that it takes Gate 40 man-hours to produce a wood mold, without the 37 composite molds the company would not have met the schedule requirements of the One South First project.

Bader concedes that an AES composite mold costs four times as much as a wood mold, but its durability is unbeatable. "The way precast forms have been built has remained relatively unchanged for decades," Bader asserts. "All of a sudden, one day, we're making 500-lb 3D forms and everyone was shocked." That said, he acknowledges that additive manufacturing such molds is most cost effective in applications where concrete forms have complicated geometry or high repetition.

AES, Bader reports, now owns and operates four BAAM machines and can produce parts up to 8 feet tall. Much larger parts have been constructed by joining multiple pieces. CW

LEARN MORE

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

ABOUT THE AUTHOR

Jeff Sloan is editor-in-chief of *CompositesWorld*, and has been engaged in plastics- and composites-industry journalism for 24 years. jeff@compositesworld.com

Thank you, IACMI members

COVID-19 has impacted the U.S. health care system in unprecedented ways and has highlighted the need to strengthen the U.S. manufacturing base. Many of our 160+ IACMI members have transitioned and adopted their operations to meet the health and safety needs of their local communities as well as the nation. We are proud of the innovation, creativity, and resilience that our IACMI members have shown during the COVID-19 crisis. We are thankful to support our community and continue to bring together the innovation and workforce necessary to meet U.S. manufacturing needs. Learn more about our industry's COVID-19 response at **iacmi.org**.

Plant tour: Hexcel, Salt Lake City, Utah, U.S.

The scale, precision, speed and quality of carbon fiber manufacture has evolved substantially since the material's modern introduction in the late 1960s. Hexcel offers a glimpse of the state of the art today.

By **Jeff Sloan** / Editor-in-Chief

The Salt Lake City campus

This aerial view of Hexcel's Salt Lake City campus features the company's newest carbon fiber lines in the foreground, including lines 13 and 14, located in the building second from the right. Carbon fiber manufacture in this building began in 2016. Source | Hexcel

» The apparently simplistic nature of the chemical composition of carbon fiber — carbon atoms organized in chains of hexagonal graphitic structures — might give one the impression that its manufacture is similarly simple. The production of carbon fiber is, after all, a chemical process that uses heat, tension and time to transform an organic precursor fiber (usually polyacrylonitrile) into carbon fiber that is then organized into multi-filament tows and wound onto a spool for delivery to customers — weavers, prepreggers and composites fabricators.

The resulting product is one that — pound for pound — offers strength, stiffness and durability unlike any other manufacturing material the world has to offer. It's a critical component of commercial and defense aircraft structures, car and truck structures, wind turbine blades, marine vessels, sporting goods and much more. It has, over the last 40 years, evolved from being an obscure, rarely used and difficult-to-process advanced material, to become a staple of the modern manufacturing material palette. The global supply of carbon fiber — and its attendant demand — are watched closely as barometers of the health of the global composites manufacturing industry.

In truth, however, the "simple" chemical transformation that is the manufacture of carbon fiber, even if it has progressed tremendously since its modern inception in the late 1960s, is a complex, capital-intensive and daunting process only practiced well by a handful of companies throughout the world. Each of these producers has a long history of manufacturing carbon fiber and relies on a carefully cultivated and closely held formula that provides a much-valued competitive advantage. (This story is not a full accounting of the carbon fiber manufacturing process; for that, see Learn More.)

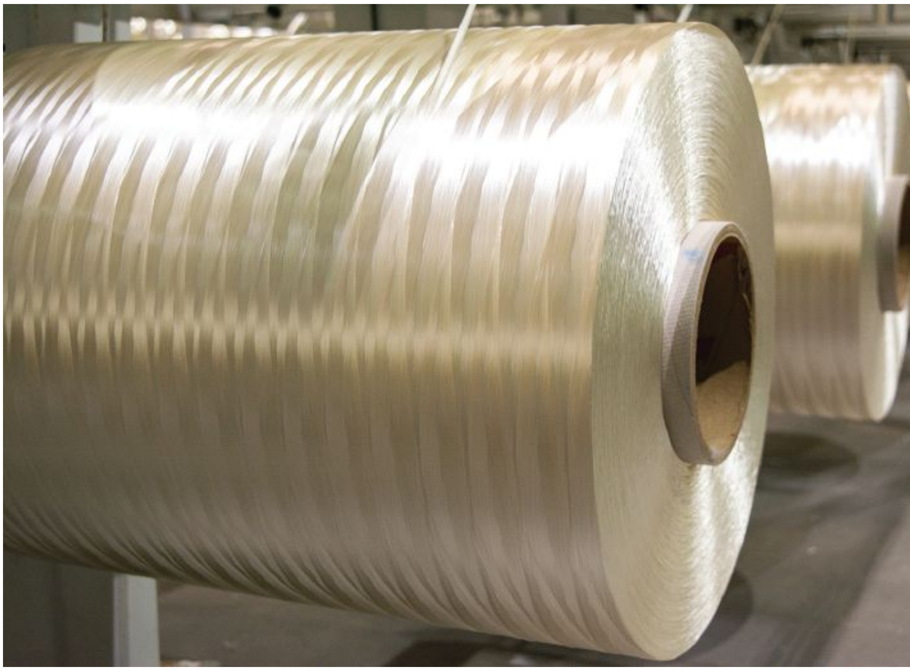
It is for these reasons that gaining access to a modern carbon fiber manufacturing line is difficult to achieve. However, Hexcel (Stamford, Conn., U.S.), one of the world's largest suppliers of carbon fiber, opened its doors to *Composites-World* and offered a glimpse of the scale, precision, speed and quality that are hallmarks of a world-class carbon fiber production process.

What Hexcel is

The carbon fiber line *CW* was allowed to visit is located on the company's sprawling carbon fiber manufacturing campus in West Valley City, Utah, U.S., just southwest of Salt Lake City. This location is home to 14 carbon fiber lines, including the company's oldest and newest. Hexcel also has carbon fiber manufacturing in Illescas, Spain, and Roussillon, France, as well as polyacrylonitrile (PAN) precursor production in Decatur, Ala., U.S., and Roussillon. All told, the company has annual, global and nameplate capacity of more than 16,000 metric tonnes of carbon fiber, with 95% of that coming from the Salt Lake City campus, which produces 45,000 *miles* of carbon fiber tows each day. Hexcel is second only to Toray (Tokyo, Japan) in total carbon fiber production capacity, and is the world's largest producer of aerospace intermediate modulus carbon fiber.

Of course, like most carbon fiber manufacturers, Hexcel produces other products as well, including resin systems, prepregs, tapes, fabrics, adhesives, honeycomb cores, tooling materials and some finished parts and structures. Most of this business, however, revolves around the company's HexTow carbon fiber brand, which includes well-known products like AS4 and AS7 (high strength); IM7, IM8, IM10 and IMA (intermediate modulus); and HM50, HM54 and HM63 (high modulus).

Most of the carbon fibers Hexcel manufactures are available in tow counts of 3K, 6K and 12K, which are targeted primarily toward aerospace, defense and other high-performance applications. Hexcel is the primary supplier of carbon fiber prepreg to Airbus for the A350 XWB aircraft and delivers total product content valued at approximately $4.8 million for each aircraft. The company had 2019 sales of approximately $2.5 billion and is in a good position to compete with Toray, Teijin, Solvay and others for placement of carbon fiber on next-generation aircraft expected from Boeing and Airbus over the next decade, as well as emerging automotive, urban mobility and energy segments. »



Starting with "cheeses"

Carbon fiber manufacture at Hexcel starts with hundreds of creels, like this one, of PAN precursor. Hexcel calls these creels "cheeses," which is a textile term derived from the fact that the material at this stage looks like a cheese wheel. Tows of PAN are unwound, tensioned and then delivered to the first stage of carbon fiber manufacture: oxidation. Source | Hexcel

Unwinding before oxidation

As the PAN is unwound from the cheeses, each tow passes over a winder near the ceiling where they are collimated. These tows, which span about 2 meters wide, then pass under another winder near the floor of the plant and then horizontally through a gap in the wall to enter the oxidation oven.

Source | Hexcel

How it got here

All of this might have seemed unlikely when Hexcel was founded in 1948, near San Francisco, as California Reinforced Plastics, producing honeycomb core. The founders, Roger Steele and Bud Hughes, attended the University of California at Berkeley and focused on development of honeycomb core/glass fiber sandwich structures for use in aerospace manufacturing. The company, started in Hughes' basement, managed to win a few defense contracts before, in 1954, changing its name to Hexcel Products Inc. Along the way, as production operations matured, Hexcel moved into a true manufacturing facility in Berkeley.

In 1962, Hexcel's materials were applied to the *Friendship II* capsule, which carried U.S. astronaut John Glenn into Earth orbit. Throughout the 1960s and 1970s the company grew, acquiring ancillary businesses, and expanded outside the U.S. Hexcel saw its products applied on NASA's Space Shuttle and, in 1986, the company built a production facility in Arizona to support its involvement in the B-2 bomber program.

By 1993, however, Hexcel had spread itself too thin, began to struggle financially and filed for Chapter 11 bankruptcy, emerging two years later after restructuring and reorganizing. Soon after, in possibly the most important strategic move in the company's history, Hexcel in 1996 acquired Ciba-Geigy's composites business, as well as the composites operations of Hercules, based in Salt Lake City. In the process, the company moved its global/corporate headquarters from California to Connecticut.

Up until this point, Hexcel's products for composites manufacturing included prepregs, fabrics, core materials and adhesives. With the acquisition of Hercules, Hexcel for the first time entered the business of carbon fiber manufacturing. Hercules, for its part, began carbon fiber production in Salt Lake City in 1971, using precursor and production technology developed by and licensed from textiles and chemistry giant Courtaulds (Coventry, U.K.), and then Sumitomo (Tokyo, Japan). Hercules, a supplier of parts for defense and weapons systems, was compelled to sell its carbon fiber business in 1996 following a series of program cancellations that created excess capacity in the carbon fiber market.

What followed for Hexcel, after the acquisition of the Hercules business, was two decades of substantial growth that very much mirrored the expansion of the composites industry itself, driven by carbon fiber application in several high-profile defense and aerospace programs. These included the Airbus A380, the Boeing 787, the Airbus A350, the Airbus A400M, the GEnx engine, the LEAP engine, the Airbus A220 and a variety of business jets, helicopters and space launch vehicles. Carbon fiber also began to make inroads into other markets, including automotive, wind energy, medical, marine and personal electronics.

Riding this wave, Hexcel continued to expand its operations in Salt Lake City and through the 2000s built new weaving and prepregging facilities throughout the world, including in France, Germany, Spain, Morocco and China. Since acquiring Hercules in 1996, Hexcel has more than tripled its carbon fiber production capacity.

Carbon fiber manufacturing is a notoriously capital- and energy-intensive business, with a single, world-class, 2,000-metric-tonne line requiring as much as $60 million worth of equipment alone. Further, construction of a single line typically takes two to three years to complete. Because of this, it is difficult for carbon fiber producers to quickly respond to demand increases. The result is a de facto business model that requires developed and known technology, patience, deep pockets and a willingness to play a very long ROI game. This also creates a significant barrier to entry for firms not already making carbon fiber, thus the list of the world's carbon fiber manufacturers is a relatively short one, and not growing quickly.

Historically, many carbon fiber producers have devoted a single line to manufacturing a single fiber type, with the goal of taking advantage of economies of scale and the efficiencies that come from no or minimal product variation. The vulnerability of this strategy is that demand reduction for a given line's fiber type can cause a producer to slow or cease line production, causing a drag on profitability. Conversely, demand increase for a given fiber can be difficult to meet if production capacity is already maximized or if customers require a different fiber in new designs.

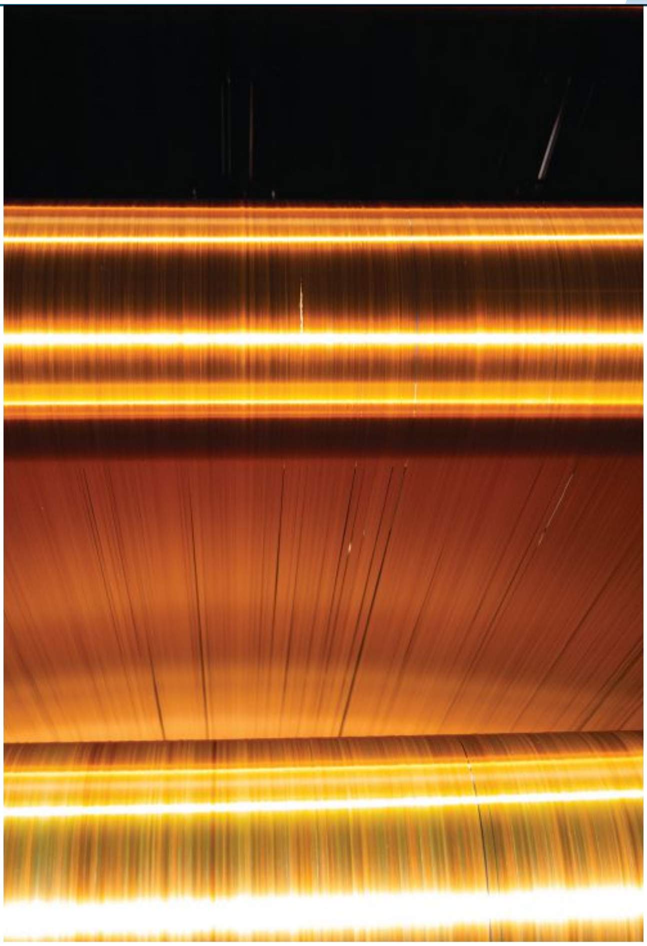
One strategy for coping with the onerous capital requirements of carbon fiber production is to build lines that offer flexibility — the ability to manufacture more than one fiber type, depending on customer and market demands. This is the strategy Hexcel has successfully adopted in its Salt Lake City and other plants.

Hexcel's carbon fiber line

Hexcel's carbon fiber manufacturing campus in West Valley City is located on a high plateau just east of Highway 85 and a 20-minute drive southwest of downtown Salt Lake City. The property is about a mile long and a quarter mile wide at its widest point, a collection of old and new buildings that tell the story of the site's evolution from the late 1960s to today. Some of the original Hercules carbon fiber lines are housed in relatively small buildings; the newest lines are hard to miss — massive, quarter-mile long behemoths that belie the scale and intensity that are hallmarks of carbon fiber manufacturing today. *CW's* tour at Hexcel took place in one of the newer buildings at the west end of the campus, which houses two carbon fiber lines. *CW* was shown line 13 which, on the day of our visit, was producing IMA fiber for the Airbus A350.

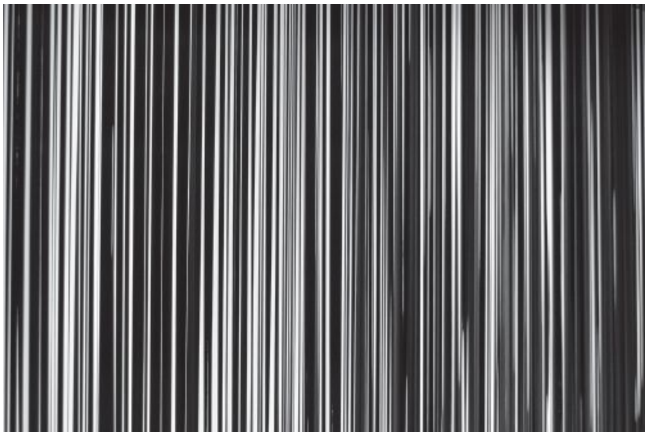
Our guide was LaRhea McBee, senior carbon fibers technical support engineer and a veteran of carbon fiber manufacturing operations in West Valley City — her first paycheck was from Hercules, in 1985. McBee led us into line 13 at the east end of the building, explaining that line 13, although it was running IMA fiber at the moment, can be configured to produce any Hexcel intermediate or standard modulus carbon fiber.

Our first stop was a large bank of creels holding the white PAN fiber tows that feed the carbon fiber production line. These PAN creels, also called "cheeses" (a textile term, because wound »



The colors of carbon fiber

As the PAN fibers pass through the oxidation ovens, they gradually change color, from white to gold, to dark brass, to brown and then black. Temperatures here are 200-300°C; this is a highly exothermic process and temperature and air flow must be carefully controlled. Source | Hexcel



Carbonization

Carbon fiber, here in front of a lightboard, assumes its characteristic black color following oxidation. The next step is the all-important carbonization, accomplished via passes through two furnaces. The first (400-900°C) and the second (1000-1500°C) furnaces burn off about half the mass of the fiber and establish final fiber properties. For its high-modulus fibers, Hexcel uses a third furnace (2000+°C) to achieve graphitization. Source | Hexcel

SIDE STORY

Carbon fiber standardization

Since the Boeing 787 and the Airbus A350 entered the commercial aerospace market in 2011 and 2015 respectively, observers of the aircraft manufacturing industry have marveled at the ability of the carbon fiber supply chain to maintain sole-source contracts for these large programs. That is, Hexcel's HexPly M21E/IMA carbon fiber prepreg is the only prepreg qualified for composite structures on the A350. Similarly, Toray's Torayca 3900/T800S carbon fiber prepreg is the only prepreg qualified for composite structures on the 787. Conversely, aircraft aluminum is qualified by type and can be sourced from multiple suppliers. The question is this: Is the day coming when carbon fiber and/or carbon fiber prepreg will be qualified by type, with multiple suppliers producing fiber that meets the specifications of the qualification?

The short answer, says Brett Schneider, president – global fibers at Hexcel, is not yet. The challenge lies in how composite materials are qualified for aerostructures and other high-performance applications. As matters stand, Schneider notes, aerospace designers must have a specific material database to reference when developing composite structures. That material — a carbon fiber prepreg, for example — must be qualified by the airframer, which means it's been through the coupon, elements, details, subcomponent and component testing required to prove its viability as an aerostructures material.

Carbon fiber supply, nameplate, metric tonnes

Manufacturer	Headquarters	2019
Toray	Japan	57,000
Hexcel	U.S.	16,000
Mitsubishi Chemical Carbon Fiber & Composites	U.S.	16,000
Teijin	Japan	14,000
SGL Carbon	Germany	13,000
Formosa Plastics	Taiwan	9,000
Solvay Composite Materials	U.S.	4,400
DowAksa	U.S.	3,000
Hyosung	South Korea	2,000
Various	China	21,800
Various	Rest of World	5,000
	Total	**161,200**

Source: Anthony Roberts/AJR Consultancy

Qualifying a composite material, particularly for aerospace use, takes about seven years and can cost millions of dollars, so aerostructures designers are more apt to reference already qualified materials when designing new structures. And, even if a new material is qualified, that qualification is tied to the specific material, which is tied to a specific manufacturer, which is tied to specific resin and fiber chemistry, which leads us back to sole-sourcing.

Virtual material qualification — which depends on use of data-based material testing — has been discussed for the last few years, but remains an idea only. Still, as composites manufacturing integrates more Industry 4.0 technologies, finished parts and structures will be tracked from digital design through receipt of fiber and resin, molding and finishing, potentially increasing the pace toward virtual qualification.

In the meantime, Schneider says carbon fiber standardization — a la aluminum standardization — has been discussed for years, but the complexity of composites in general (multiple resins, fibers and processes) does not support such a system. One of the strengths of composites, he notes, is that they can be specifically engineered to meet specific mechanical loads in specific applications. Such specialization is the opposite of standardization. Schneider then adds, "If you want to see standards in composites, look to the high-volume products we have been building for over 40 years that are used in many different applications. AS4 and IM7 are great examples."

fibers look like a cheese wheel), are organized into four sections, with two sections on each side of the racks. Each cheese creel is numbered and barcoded to provide full traceability.

PAN, in this form, is somewhat fragile, so the primary goal is to get the PAN tows off of each creel and fed into the carbon fiber line as carefully as possible. "We are trying to deliver that fiber off that spool with as little damage as possible to provide a high-quality finished product," McBee says. "This is an important first step." All of the tows are pulled in the same direction, toward a wall that separates the feed creel room from the rest of the carbon fiber line. As they approach the wall, the tows are collimated, creating a 2-meter-wide band of side-by-side fibers, which descends vertically over a roller near the ceiling, toward the floor, under another roller, and then horizontally toward a gap in the wall.

It's at this point that the PAN fibers begin the oxidation process, the most time-consuming step in the manufacturing process. Here, the fibers are wound through a series of oxidation ovens at 200-300°C and gradually stretched and stabilized. The time, temperature and tension of the fibers in this stage affect the density, tensile strength and tensile modulus of the finished product. Oxidation is an exothermic process, so temperature and air flow must be closely controlled. The PAN fibers, which were white when they exited the creel racks in the previous room, gradually turn a brassy gold color, then dark brown and then black as they wind up and through the ovens during oxidation.

Following oxidation, the fiber then moves into the pyrolysis/carbonization stage, passing first through a low-temperature (400-900°C) furnace, and then a very high-temperature furnace, where temperatures range from 1,000-1,500°C. This is the most important step in the manufacturing process, with as much as 50% of the mass of the fiber burned off as the fibers assume the pure black color for which they are so well known. Ultimate density, tensile strength and tensile modulus of the fibers are set during pyrolysis/carbonization.

Regardless of fiber type, what was once PAN fiber is now carbon fiber, and it emerges from the final carbonization furnace in a chemically inert state; primary fiber properties are now set. The next step in the process is surface treatment, where the fiber tows are passed through a bath that provides additional oxidation and prepares the fiber surface for sizing application. However, before that happens, operators working the line extract fiber samples from the tows for statistical process control (SPC) and quality control assessment. Following this, the fiber is sized to improve the physical handling attributes of the material. McBee says Hexcel has developed six types of sizing, designed to accommodate different fiber formats and resin use. Sizing levels range from 0.2-1.6%. McBee also notes that Hexcel has the option to leave the carbon fiber unsized for use with thermoplastic resin matrices.

Finally, a full 200 meters from where we started, the carbon fiber tows pass through another wall and into the winding and packing room. They enter from a height of about 15 feet and pass through widely spaced guides that direct the fibers down toward the production floor where banks of winders, each about 30 meters long, receive the tows. Each tow — and there are hundreds of them — is wound onto one spool, and that spool has the same number and same barcode as the original cheese of PAN we encountered at the start of the tour. A digital counter overhead tells operators how many meters of fiber have been delivered. McBee says fiber winding is the most complex part of fiber production as fiber must be under constant and correct tension to build a good spool.

The size of a finished spool varies, but can range up to 4.5 kilograms of carbon fiber, and when full is manually doffed from the winder and placed in one of several shipping containers throughout the winding area. "This is the finished product," McBee says. "How it looks is important to our customers."

Following winding, finished spools are moved to the final stop at the back of the production line where a six-axis robot automatically vision inspects each one for flaws. Spools that fail inspection are set aside; those that pass are re-boxed and prepared for shipment to either another Hexcel facility for prepregging or weaving, or to an outside customer.

The business of carbon fiber

Spending even a short time at Hexcel's Salt Lake City campus, it's quickly apparent how substantially industrialization of carbon fiber production has grown. The mix of older, smaller facilities cheek-by-jowl with larger, newer facilities (like line 13) tells the stark story of how quickly this industry has matured. Brett Schneider, president – global fibers at Hexcel, and the person most responsible for managing the company's carbon fiber manufacturing strategy, says the scale and efficiency of carbon fiber production over the last decade has helped drive costs down and quality up. »

Quality monitoring

After carbonization, surface treatment and sizing application, each tow is separated and wound onto one of hundreds of spools arrayed at the end of the carbon fiber manufacturing line. Here, Hexcel employees carefully monitor the quantity of carbon fiber on each spool and doff (remove) the full ones to a storage container for inspection. Each spool is barcoded to match the barcode on the PAN creel from which the fiber started the manufacturing process. Source | Hexcel

Ready for shipment

After it's wound, each spool is automatically scanned and assessed for quality. Those that pass inspection are poly-wrapped and then boxed for shipment to prepreggers or fabricators. Hexcel produces 45,000 miles of carbon fiber tows each day at its Salt Lake City campus.

Source | Hexcel

■ **Exterior view**

Hexcel Salt Lake City carbon fiber lines 13 and 14, exterior. Source | Hexcel

"Lines are long, wide, fast and dense," Schneider says, adding that technical and chemical knowledge, combined with enabling data, have given all carbon fiber producers greater visibility into the manufacturing process. "Statistics have brought us knowledge, AI [artificial intelligence] has brought us knowledge, scale has brought us knowledge."

Ten years ago, he says, "there were things — subatomic things — we thought we knew about carbon fiber manufacturing but could not measure. We can measure them now, and that has helped us see that there is even more that we would like to measure and control today, but we are not there yet." For example, he says, fiber surface characteristics used to be measured using microscopy, with inferences and conclusions drawn from photographic evidence. Today, that's done by directly measuring fiber atomic level data.

Looking to the future, Schneider believes the product flexibility Hexcel has built into its carbon fiber lines positions the company to meet market demands that are becoming more complex, not less. "There are three variables in the process: Time, temperature and tension," he notes, adding that in just a few hours Hexcel can convert a line from one carbon fiber product to another. "We've built assets that can manipulate time, temperature and tension that allow us to produce different products repeatably, quickly and efficiently."

The carbon fiber market, as it entered 2020 (pre-coronavirus pandemic), Schneider says, was generally in balance between supply and demand for multiple fibers, depending on fiber type, tow count and application. That balance, however, is "tight," meaning that a demand surge from a market or customer could tip the supply chain into a fiber type shortage. Schneider points in particular to end segments that are poised for growth and being watched closely, including urban air mobility (UAM), space, aerospace, defense, automotive, wind energy, pressure vessels and oil and gas.

LEARN MORE

Learn about how carbon fiber is made | short.compositesworld.com/makingofCF

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

All of this matters because carbon fiber producers like Hexcel are disproportionately affected by over-the-horizon events, primarily because of the long lead time — three years — required to set up a new production line. "We don't necessarily know what our customers will do next for consumption or technology selection," Schneider says, "but when they make choices, we have to be ready with products and assets that can do the job." Hence the product-flexible lines.

Coping with the uncertainty of the future is a full-time job at Hexcel, Schneider reports. The company tracks trends and events that are likely to influence the uptake of composite materials in general, and carbon fiber in particular. These include a wide variety of macro commentary on GDP growth, aerospace traffic miles, space and defense objectives and light-weighting expectations in many segments.

"We look at all of these things through our strategic planning process," he says, "we work closely with industry to be prepared to support the growth our customer's want with a just-in-time asset readiness and material delivery model. We develop new technology in line with our customer's goals and then build assets that can provide a flexible and secure supply chain to help them achieve those goals during adoption and production."

The bottom line is that even if the world's supply of carbon fiber is currently adequate, it certainly must grow to meet future demand as the world needs more lightweighting performance — regardless of the short-term impact of the coronavirus pandemic.

Hexcel, says Schneider, is land-locked at its Salt Lake City campus, which limits capacity expansion there. Hexcel's facilities in Decatur, Ala., U.S., Illescas, Spain and Roussillon, France, however, each have room to grow. "When we need to expand, we have a plan for that and are prepared to do so," he says. "We have great technology and the financial wherewithal to support the growth our customers and the industry need in the future." CW

ABOUT THE AUTHOR

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3D printing large composite molds with a 5-axis CNC machine

Hungarian manufacturer uses CEAD Robot Extruder to cut composite tooling time and cost.

"We were building molds using CNC-machined polyurethane foam and hand layup GRP [glass fiber-reinforced plastic], but that approach involved too much labor and waste," explains György Juhász, owner of Rapid Prototyping (Budapest, Hungary), which bought a Robot Extruder from CEAD (Delft, Netherlands) in December 2019. "We are now 3D printing molds using 30% short glass fiber-reinforced polypropylene and cutting our labor time by 50%."

Juhász began working with composites as a boatbuilder. His projects include Como Yachts and the Narke Electrojet, which claims to be the world's first all-electric personal watercraft in series production. "In Hungary, you cannot use petroleum-based fuels on any lakes," he explains. "We are developing more electric boat models for companies. I needed a faster, cheaper way to create plugs and molds for these projects."

The CEAD Robot Extruder was Juhász' Christmas present last year. "I already had a 5-axis CNC machine," he says, "so we just bought the Robot Extruder print head and attached it." The CNC machine measures 4,850 by 2,635 by 1,460 millimeters and uses stepper motors with Mach3 motion controller software. Designed and built by Juhász six years ago, it was available to convert to a 3D printer when he purchased a new Hungarian-built CNC system last year to take over milling and machining.

One of the first projects completed with this new 3D printing system was a fiberglass mold for a composite sleeper cab for custom truck and trailer manufacturer Krismar (Waardamme, Belgium). "This is quite a big component, measuring 2,550 by 2,200 by 1,200 millimeters," says Juhász. "We wanted to print the maximum thickness possible in order to avoid warping and deformation when cooling down." The 30-millimeter thickness was printed in two layers of 15 millimeters each and used almost 400 kilograms of glass fiber-reinforced polypropylene pellets.

Rapid Prototyping printed the mold using its CEAD Robot Extruder mounted into a CNC machining system. Source | Krismar

The mold was printed in four pieces, including separate left and right sideskirts. "We CNC milled the molding faces of each piece separately," he says, "and then screwed and clamped them together before applying sandable gelcoat and hand-laminating with four layers of 300-grams-per-square-meter chopped strand mat and polyester resin."

Though the project was successful and 3D printing saved time, Juhász admits there is a lot to learn. "One of the biggest challenges with this approach is after the printing we need to find a 0 point [origin] with the milling machine and software. We do the printing vertically and the milling horizontally — so, the starting point and the direction of each operation is different." It also seems expensive to print solid instead of using an infill? "For this project, we were at the beginning," he explains. "An extruder head using pellets is cheaper than a large-format filament printer, but not as easy for printing infill. But we are planning to print a piece of furniture with infill in the future, so we will adapt the lessons learned to our toolmaking." CW

Composites Events

Editor's note: Events listed here are current as of May 11. Visit short.compositesworld.com/events for up-to-date information.

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

June 4-6, 2020 — Beijing, China — POSTPONED
SAMPE China
sampechina.org

June 14-28, 2020 — Houston, Texas, U.S. — NEW DATES
Corrosion 2020 Conference & Expo
nacecorrosion.org

Aug. 25-26, 2020 — Detroit, Mich., U.S. — NEW DATES
Automotive Lightweight Materials Joining, Forming and Manufacturing Innovation 2020 Summit
global-lightweight-vehicle-manufacturing.com

Aug. 25-27, 2020 — Novi, Mich., U.S.
Foam Expo North America
foam-expo.com

Aug. 26-28, 2020 — Stockholm, Sweden — NEW DATES
AAC Epoxy and Resins Technology Conference
advancedmaterialscongress.org/ecmt20

Aug. 31 - Sept. 2, 2020 — Hamburg, Germany — NEW DATES
9th International Conference on Advances in Rotor Blades for Wind Turbines
iqpc.com/events-wind-rotor-blades

Sept. 8-10, 2020 — Moscow, Russia — NEW DATES
COMPOSITE-EXPO
composite-expo.com

Sept. 8-11, 2020 — Istanbul, Turkey
METYX Fifth Composites Summit
metyx.com/metyx-fifth-composites-summit

Sept. 9-11, 2020 — Novi, Mich., U.S.
SPE ACCE
SPEautomotive.com/acce-conference

Sept. 15-16, 2020 — Chicago, Ill., U.S.
Additive Manufacturing Conference
additiveconference.com

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

Sept. 22-23, 2020 — Cleveland, Ohio, U.S.
Ceramics Expo 2020
ceramicsexpousa.com

Sept. 29 – Oct. 1, 2020 — Tampa, Fla., U.S.
IBEX
ibexshow.com

Oct. 1-3, 2020 — Atlanta, Ga., U.S.
Techtextil North America
techtextil-north-america.us.messefrankfurt.com

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

Oct. 29-31, 2020 — Parma, Italy — NEW DATES
MECSPE
mecspe.com

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

Nov. 10-12, 2020 — Stuttgart, Germany
Lightweight Technologies Forum
lite-forum.com/en/

Nov. 17-29, 2020 — Salt Lake City, Utah, U.S.
CW Carbon Fiber Conference 2020
carbonfiberevent.com

March 9-11, 2021 — Paris, France
JEC World 2021
jec-world.events

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New Products

Source | Polygon

» FILAMENT WINDING

Composite tubing for pneumatic and hydraulic cylinders

Polygon Composites Technology (Walkerton, Ind., U.S.), manufacturer of composite tubing solutions for bearings, dielectric applications, surgical devices and more, has launched PolySlide composite tubing for pneumatic and hydraulic cylinders. PolySlide tubing can reportedly replace metallic material in a variety of cylinder applications.

Supplied as a cylinder tube for customer assembly, or as fully engineered cylinder assemblies for equipment manufacturer applications, the tubing is made of continuous, filament-wound glass fiber and polymer resins. The fiberglass filament and resin materials combine together to form a high-strength component that exhibits dimensional stability and is non-corroding, impingement-resistant and non-conductive. The tubing is said to perform in high and low temperatures, and withstands grease, grit, salt, chemicals and other extreme conditions.

PolySlide tubing sizes range from as small as 0.25-inch inner diameter (ID) up to industrial-sized 24-inch IDs. The features of the tubing allow the seal to slide over the bore surface contour, minimizing interlocking friction. The inside diameter of the tubing has a smooth finish. Contact with the non-metallic rod guide bearing prevents galling and provides for a low coefficient of friction. A wear-resistant material incorporated into the bore surface increases the lifespan of the composite cylinder tubing.

According to Polygon, common applications of this product include use with pneumatic and low-pressure hydraulic applications, such as fifth wheel actuation, gate valve actuators, water treatment flow control mechanisms, tie rod cylinders and more. A translucent version of the composite tubing is also available.

polygoncomposites.com

Source | Thermwood

» ADDITIVE MANUFACTURING

Lower-cost, walled, large-scale additive option

Based on demand from customers, CNC machinery manufacturer Thermwood (Dale, Ind., U.S.) has developed the LSAM 1010, a lower-cost enclosed version of its large-scale additive manufacturing (LSAM) system. The LSAM 1010 uses the walls from the company's larger LSAM systems with the gantry, control and sub-systems from the similarly-sized LSAM MT.

The LSAM 1010 features a fixed 10-by-10-foot table. A single moving gantry carries the print and trim heads as on the MT and, like the MT, it can print and trim, though not at the same time. The print and trim heads on all Thermwood LSAMs are the same, and are said to be able to process virtually any reinforced composite thermoplastic materials.

Although the LSAM 1010 is slightly higher in price than the MT, it is lower in price than the larger LSAMs and generally less than the cost and complexity of trying to add an external enclosure to the MT, Thermwood says.

In addition, even though the LSAM 1010 is slightly wider than the larger LSAMs to accommodate mounting the print and trim heads on the same gantry, the overall footprint of the 1010 is slightly smaller than required for the MT. Like the MT, the 1010 can be purchased as a print-only machine.

Thermwood believes that, since it is enclosed like the larger LSAMs, the LSAM 1010 can be built to meet European CE requirements like its larger machines.

thermwood.com


Source | YG-1

» MACHINING

Solid-carbide routers for faster composites machining

YG-1 (Incheon, South Korea) has launched four new solid-carbide routers for CNC or hand routers to machine fiberglass and other high-performance fibers.

The company says the new routers are optimized in composition, cutting angles, flute strength and stability for longer life and lower cost per part. Four distinctive cutting ends reportedly make these routers ideal for roughing, finishing, edge trimming, slotting, grooving, drilling or interpolation, achieving the same quality results on a CNC machining center or via hand routing, YG-1 says.

The four routers include:

- Type I (NC end): Mostly for side milling, roughing or finishing passes for high-quality finish
- Type II (burr end): Suited for plunging without damaging side flutes
- Type III (mill end: Best for surface milling molds or grooving with surface finish requirements
- Type IV (drill end): Use as a router and a drill; said to be suited for interpolation to achieve final hole diameter or slotting with a corner radius

The routers are designed for use on carbon fiber, Kevlar and aramid blends, natural fiber-based composites and thermoset or thermoplastic resin blends.

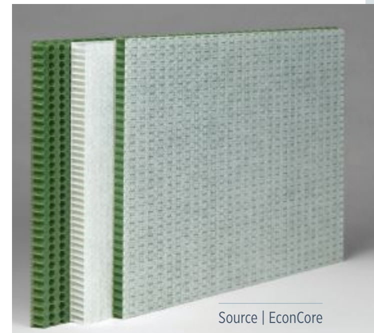
YG-1's router designs are intended to resolve the challenges of machining composites and stacked materials, enabling shops and production facilities to help customers maximize benefits of composites such as cost and weight reductions. YG-1 says its routers are made with best-in-class solid carbide and feature special CVD coating for superior cost and time savings. The company's engineering teams developed the routers' double-angle point geometry specifically to counteract or eliminate the machining problems typically encountered with composites. The CVD coating is said to increase abrasion resistance from the fibrous materials and extends tool life by a factor of five to 10, at minimum.

Combined with guidance margins and open flutes, these specialized routers are also said to drill holes with no dust jams or pressure overload. Suited to manual hole-making, countersinks and counterbores, hand drilling reduces delamination and fiber pullout, and increases opportunities for dust-free drilling, improving operator comfort, health and safety.

The company's routers are available in a range of sizes, including market standards and custom designs. yg1usa.com

» CORE MATERIALS

Recycled PET honeycomb core technology


Source | EconCore

Core technologies specialist EconCore (Leuven, Belgium) is now offering its recycled polyethylene terephthalate (rPET) honeycomb for commercial licensing. The company reports two years of successful research to optimize processing of the reusable resource-based polymer into its continuously produced honeycomb core. EconCore was awarded a grant to fund research over a two-year period from Flanders Innovation and Entrepreneurship (VLAIO), a government agency that finances strategic and industrial research.

Recycled PET honeycomb cores, with the widespread availability of collected plastic, including bottle grade rPET flakes, offer potential as an eco-alternative core material. The material is also reported to show superior temperature resistance and mechanical properties compared to conventional thermoplastic core materials. According to EconCore, the biggest benefit to this product is a substantial decrease in CO_2 emissions, especially combined with the reductions that already come from using honeycomb core technology.

The company's rPET honeycomb core is typically made from more than 95% recycled PET from a variety of sources such as bottles and food packaging. According to EconCore, this is a cost-effective solution because it requires little pre-production processing to achieve stable temperature and strength performance that outperforms polypropylene (PP) honeycombs.

For this product, EconCore has partnered with MEAF Machines (Yerseke, Netherlands), which designs, develops and builds extrusion machines for the global packaging and plastics processing industry. According to MEAF, the partners optimized the production process to extrude up to 1,200 kg per hour while using only 0.20 kWh per kg.

Furthermore, EconCore says its ThermHex technology plays an essential role in enabling the use of honeycomb materials in cost-sensitive applications. Applications include the sidewalls of delivery trucks and trailers, vehicle interiors such as parcel shelves, headliners, trunk floors and other interior panels. It can also be used for concrete casting molds and facade panels in the commercial construction and building sector.

EconCore says its rPET honeycomb cores are set to be used in a project by Eindhoven University of Technology, which will design and build a road-legal car completely made from waste, recyclable and biodegradable materials. EconCore is a gold sponsor of the project and its product will be used for the chassis. The project is called Luca and is part of a project called TU/ecomotive.

econcore.com

» SCANNING & METROLOGY

Portable 3D laser scanner for large objects

Source | Exact Metrology

Leica Geosystems' (St. Gallen, Switzerland) Leica RTC360 3D laser scanner, distributed by comprehensive metrology service provider **Exact Metrology** (Brookfield, Wis., U.S.), is a portable coordinate measuring machine designed to measure large-scale objects.

The RTC360 3D laser scanner is designed for professionals managing project complexities with accurate and reliable 3D representations. This scanner combines a high-performance 3D laser scanner with Leica Cyclone Field 360, a mobile device app for edge computing that automatically registers scans in real time, and Leica Cyclone REGISTER 360, an office software that integrates the 3D model into the workflow. Additional features include the ability to capture scans, including HDR imagery, in less than two minutes. The system also automatically records moves from station to station and augments data capture with information tags.

This laser scanner uses 3D reality capture, a process of scanning and capturing any site in a 3D digital model, combining measurements and imagery. The model can be used for design and comparison purposes in various situations, capturing details with to-the-millimeter accuracy, says Exact Metrology. This technology combines one-touch operation with portability and speed to deliver accuracy, automation and the ability to create 3D environments in minutes.

According to Exact Metrology, many industrial sites present inhospitable environments, where the health and safety of the employees and visitors are at risk due to temperature, corrosive materials, moving machinery and heavy objects. In addition, sites often have networks of pipes, tunnels, storage vessels and other structures that need to be examined. 3D reality capture is said to permit complete site visualization for safety training. Site visibility also greatly improves plant management efficiency. Accurate measurements are said to help designers create extensions without visiting the site.

Thanks to 3D reality capture, Exact Metrology says, Building Information Modeling (BIM) experts save time and money as BIM processes become more efficient, from the accuracy of construction documentation to design and build quality assurance. The latest laser scanning technological developments improve understanding and documentation of the build environment through the use of millimeter-accurate laser scanning and High-Dynamic Range (HDR) imagery. By using 3D reality capture, previews of data and imagery are viewable onsite directly from a tablet, enabling scans to be checked and verified before going to the office.

With a measuring rate up to 2 million points per second, automated targetless field registration (based on VIS technology) and automated transfer of data from site to office, the device and software is also said to reduce time spent in the field, thereby maximizing productivity.

Furthermore, the scanner's portable design and collapsible tripod are designed to fit into most backpacks. Low noise data allows for better images, resulting in crisp, high-quality scans that can be used in a variety of applications.

As part of the RTC360 solution, the Cyclone FIELD 360 links the 3D data acquisition in the field with the laser scanner and data registration in the office with Cyclone REGISTER 360. The user can automatically capture, register and examine scan and image data.

exactmetrology.com

Source | GRP Solutions

» DISINFECTANTS

Biocide disinfecting spray

Composites distributor **GRP Solutions** (Havant, U.K.) and partner company GRP Consumable Solutions have developed Ramsol, a sanitizer disinfectant spray that contains active biocides specifically designed for the cleansing and disinfecting of hard and soft surfaces. The Ramsol spray is a mist product designed to sanitize and disinfect difficult-to-reach and intricate areas with full surface coverage. The ingredients in this product are said to be effective as a rapid neutralizer of an extensive list of bacteria, viruses, fungi and molds.

According to the company, the ingredients have been tested and proved effective against small non-enveloped viruses (hardest-to-kill category), including poliovirus, norovirus and feline calicivirus. The ingredients have also reportedly been tested against enveloped viruses (easiest-to-kill category) such as coronaviruses and Type A influenzas.

grp-solutions.com


Source | IDI

» SHEET MOLDING COMPOUNDS

Material solution for battery enclosures

IDI Composites International (Noblesville, Ind., U.S.) has introduced FLAMEVEX, a family of fiber reinforcements and resins designed for the manufacture of battery enclosure systems for the electric vehicle (EV) and new energy vehicles (NEV) market. The FLAMEVEX family of products, which include chopped glass fibers combined with either unsaturated polyester (UPR) or a combination of UPR and vinyl ester, has been used on battery packs that have passed the stringent Chinese Standard GB/T 31467.3 test, commonly known as the "Chinese bonfire test." FLAMEVEX, says IDI, offers designers a strong, lightweight and cost-effective alternative to steel and aluminum traditionally used to enclose battery packs in EVs and NEVs. idicomposites.com

» TOOLING BOARDS

Eco-friendly, dust-free tooling board

As part of its ongoing commitment to supporting the environment, Trelleborg's (Randolph, Mass., U.S.) applied technologies operation has launched TC760X, an eco-friendly, dust-free tooling board.

According to the company, TC760X tooling board does not create dust during machining; the board flakes instead of chips for a cleaner cut. Less dust leads to fewer machine breakdowns, resulting in improved production efficiency and greater cost savings, Trelleborg says.

In addition, the TC760X epoxy tooling board material is said to reduce the amount of airborne particles created during manufacturing compared with traditional epoxy tooling boards, reducing the overall environmental impact.

The product is said to require almost no secondary finishing or polishing before use, Trelleborg says, and requires minimal sealing. The material has a glass transition temperature (T_g) of 140°C and a low coefficient of thermal expansion for faster curing, improved machining and the ability for fast, simple direct-to-part manufacturing, the company says.

trelleborg.com/applied-technologies

» INJECTION MOLDING

Forming, functionalization of organic sheets

With its victory injection molding machine, **Engel** (Schwertberg, Austria) says it is able to demonstrate the forming and functionalization of organic sheets and unidirectional tapes in one injection molding step. The main component of the production cell, which produces components made of continuous fiber-reinforced polyamide (PA), is a tiebarless Engel victory 200/50 injection molding machine equipped with an Engel viper 12 linear robot for handling preforms and finished parts, and a double-sided, vertical Engel infrared (IR) oven.

Source | Engel

The composite blanks are heated in the IR oven, placed in the mold, formed in the mold, and overmolded with PA. Heating the prepregs is one of the process steps that drive the cycle time and quality in the processing of fiber-reinforced preforms with a thermoplastic matrix. The thickness defines the heat-up and cool-down time. Heating the material quickly without damaging it is important, as are short paths for transporting the heated preforms to the mold (hot handling). Engel offers IR ovens from in-house development and production in various designs — both horizontal and vertical — and places them in the production cell in the immediate vicinity of the mold. The ovens and the robots are fully integrated with the machine's CC300 control unit and can be centrally controlled via the machine's display.

Engel says the victory machine's biggest advantage in this application is its fast hot handling. Barrier-free access to the mold area makes it possible to position the IR oven even closer to the mold than is possible for injection molding machines with tiebars. In this way, even very thin preforms can be processed without them cooling too much during transport between the IR oven and the mold.

In practice, Engel says the production of thermoplastic composite blanks can be placed immediately upstream of the manufacturing process and directly next to the processing machine. Engel offers fully integrated systems solutions from a single source, including the processing machine, robots and IR ovens as well as pick-and-place tape stacking units with optical image processing and consolidation units.

Composite parts created using the Engel organomelt process are said to combine light weight with excellent crash safety capabilities. This technology, which is already in series production in the automotive industry, is suitable for organic sheets and unidirectional (UD) glass and/or carbon fiber-reinforced tapes with a thermoplastic matrix.

Engel says using a purely thermoplastic material base enables particularly efficient and fully automated manufacturing processes, because reinforcement ribs or assembly elements, for example, can be injected directly after forming in the same process step. At the same time, the organomelt process reportedly makes a contribution towards sustainability.

engelglobal.com

» ADDITIVE MANUFACTURING

New materials available for small area 3D printer

Part of a recent distribution partnership, build-to-order machine tool manufacturer **Cincinnati Inc.'s** (CI, Harrison, Ohio, U.S.) high-temperature Small Area Additive Manufacturing (SAAM HT) machine will now offer **BASF 3D Printing Solutions'** (BASF 3DPS, Heidelberg, Germany) ABS plastic, carbon PET and recycled PET materials.

Ultrafuse ABS is created from acrylonitrile, butadiene and styrene polymer, known for its strong, flexible and heat-resistant nature combined with light weight, abrasion resistance and affordability. According to CI, it is ideal for manufacture of low-cost prototypes.

Ultrafuse PET CF15 from BASF 3DPS combines easy processability and low moisture uptake with high strength and rigidity, at an affordable price point. With this PET material, users can 3D print new components that are reported to stay functional under high mechanical and thermal loads. Described as suitable for the automotive industry, for jigs and fixtures and any applications with humid operating environments.

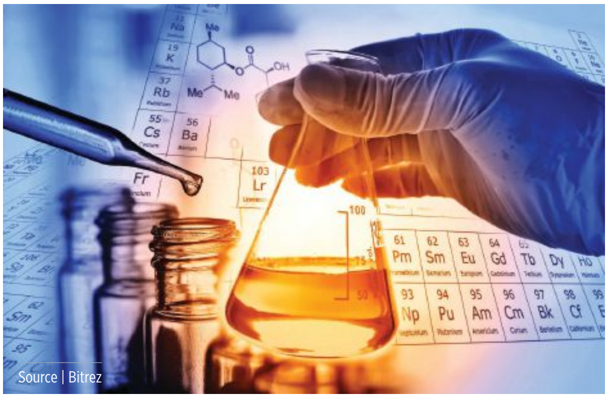

Source | Cincinnati Inc.

Ultrafuse rPET is a recycled PET that is said to look and print just like virgin material. Like Ultrafuse PET CF15, rPET is reported to capably handle jig and fixture applications, automotive work and prototypes.

Other material options for the SAAM HT include ULTEM, PEEK, polycarbonate and any thermoplastic up to 500°C.

basf.us/composites

e-ci.com



Source | Bitrez

» CURING AGENTS

Greener epoxy curing agents

Polymer chemistry consultancy Chemical Process Services Ltd. (CPS, the specialist polymer division of Bitrez, Standish, U.K.) has researched and developed a new series of "green" epoxy curing agents. The company's Furalkamine range of polymers is said to combat the withdrawal of conventional Mannich base grades prohibited in Europe under REACH regulations or due to inclusion of undesirable residual monomers.

The Furalkamines are a new form of Mannich base curing agents, derived from pentosane-rich biomass. Subsequent reaction with a variety of amines influences the processing characteristics and offers a new solution to low temperature cure and cure under adverse conditions, while maintaining regulatory compliance, the company says.

These agents are designed to be principal curing agents or modifiers for other curing agents in the formulation of solvent-free or high solids, low VOC maintenance specialized marine coatings, flooring and adhesives.

A patent is pending for this new chemistry and CPS says it is developing the products further. Bitrez will be manufacturing the Furalkamine grades under license from CPS. **bitrez.com**

» EPOXY RESIN SYSTEMS

Mid-toughened epoxy resin system

Park Aerospace Corp.'s (Newton, Kan., U.S.) E-752-MTS mid-toughened 350°F (177°C) cure epoxy system is designed for primary and secondary aircraft structure applications, such as wing and empennage structures, control surfaces, fuselages and engine nacelles. To provide processing flexibility and access to a wider market, E-752-MTS, the newest member of the company's E-752 product family, can be cured using autoclave, oven (out-of-autoclave) or press cure processes. According to Park Aerospace Corp., trials and testing of E-752-MTS tack levels have yielded a resin system that is optimized for hand layup fabrication as well as automated processes such as automated fiber placement (AFP). The resin system is available with a variety of aerospace grade reinforcements including standard modulus and intermediate modulus carbon fiber fabrics and unidirectional tapes. **parkaerospace.com**

» THERMOSETS, THERMOPLASTIC RESINS

High-temperature polymers

To its current product portfolio, **Bieglo High-Performance Polymers** (Hamburg, Germany) has added polybenzimidazole (PBI) and ultra-high temperature thermosetting polyimide (PI-s) to its product families.

According to Bieglo, PBI is one of the highest-performing thermoplastic materials, offering heat resistance as well as excellent mechanical strength. The company's Dexnyl PBI shapes are reported to have a heat-deflection temperature (HDT) of 410°C, strong mechanical properties, and optimal chemical resistance. The company says this product is ideal for sealing, glide-ring, bearing and various insulation applications.

Bieglo says thermosetting polyimides are the highest temperature-resistant polymers commercially available.

The company now offers PI-s products with heat-deflection temperature (HDT) as high as 500°C.

The company also supplies polyetheretherketone (PEEK) and polyamideimide (PAI). **bieglo.com**

MANUFACTURING SUPPLIERS

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Composite output shaft ready for automotive proving ground

Unlike automotive driveshafts, automotive output shafts cannot leverage shaft length as a factor when making the case for composites. Instead, other beneficial features have made a composite output shaft able to compete with metal shafts, especially in electric vehicles.

By Karen Mason / Contributing Writer

Ready to roll

CFRP output shafts, shown here in two complete assemblies, have demonstrated a tailorable stiffness with the potential to improve vehicle driving behavior.

Source | Dynexa

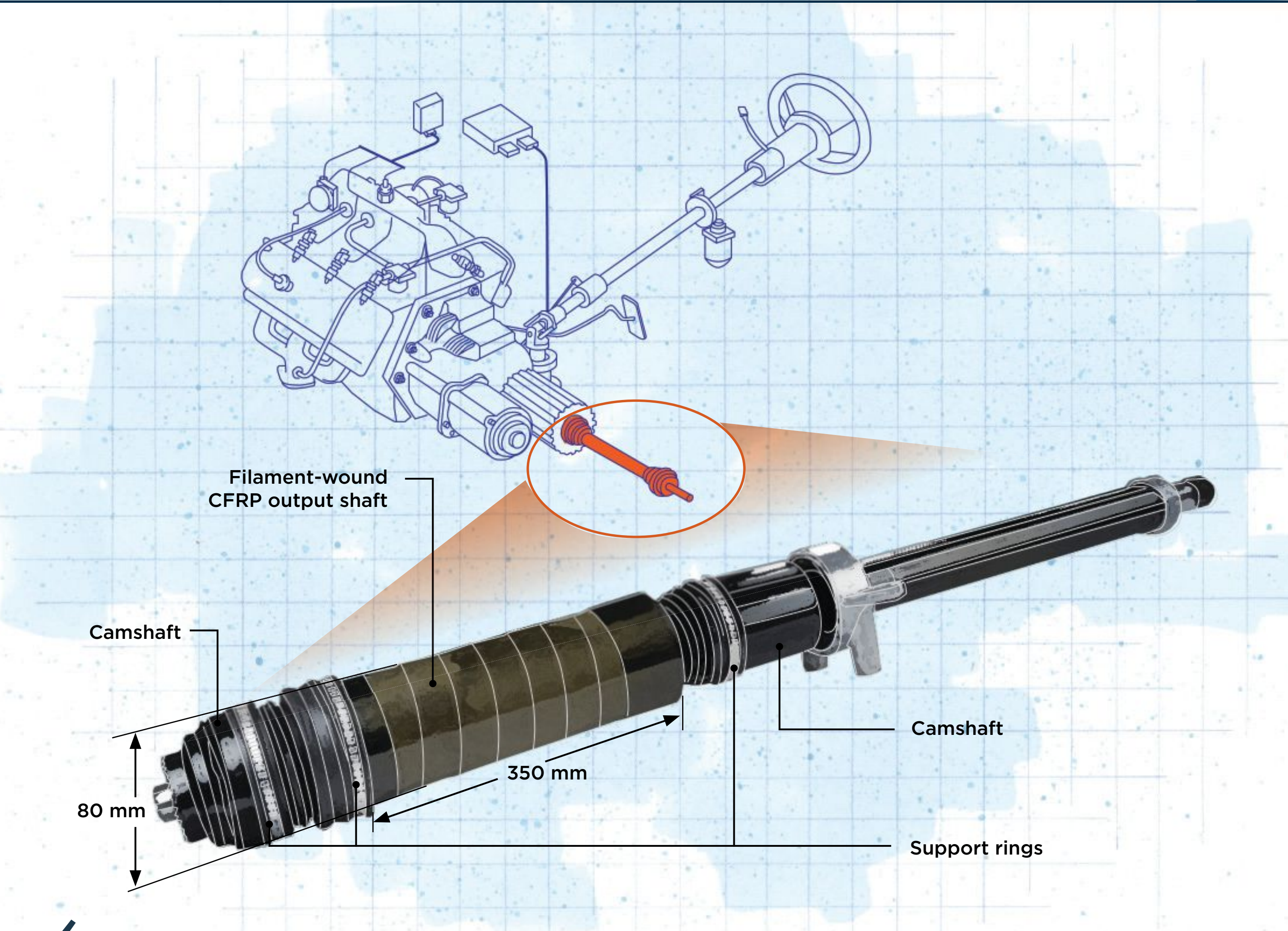
» In many four-wheel drive and all-wheel drive vehicles, steel driveshafts are segmented to provide necessary torque and vibrational performance characteristics. Unlike these segmented steel counterparts, a one-piece carbon fiber-reinforced polymer (CFRP) automotive driveshaft is able to provide the required performance as it spans the full distance from transmission to differential, typically between 1,000 millimeters (passenger cars) and 3,000 millimeters (commercial vehicles). A single CFRP driveshaft can therefore replace not only the steel driveshaft, but also the flanges and intermediate bearings that join the two segments. As a unified component, the CFRP driveshaft enhances performance, contributes less weight and has proven to be cost-competitive in high-performance vehicles.

But is CFRP still a viable option when span is no longer a factor?

This is the case when it comes to output shafts, which connect the short distance (typically 250 to 500 millimeters) from the drivetrain to the wheels. Exploring whether the case could be made for CFRP output shafts on production vehicles, the design team at Dynexa (Laudenbach, Germany) was pleasantly — and admittedly — surprised by the results.

Dynexa, a filament winding and driveline company and a member of the Avanco Group (Herford, Germany), undertook its design and demonstration of a CFRP output shaft as part of a predevelopment study conducted with a German OEM. In 2014, Dynexa began supplying the OEM with CFRP driveshafts that achieved a 40% weight reduction compared to a segmented steel shaft and intermediate bearings. The accompanying reduction in rotating mass also improved the vehicle's driving behavior.

Since 2006, Dynexa has filament-wound more than 100,000 CFRP tubes and shafts for automotive prototype and serial production applications. The company typically employs an epoxy matrix supplied by Huntsman (The Woodlands, Texas, U.S.) or Hexion (Columbus, Ohio, U.S.). Dynexa works with



DESIGN RESULTS | **CFRP output shaft**

- Torsional stiffness tailored to design needs of vehicle
- Improved vibrational performance especially for electric vehicles
- 20-30% reduction in component weight

Susan Kraus / Illustration

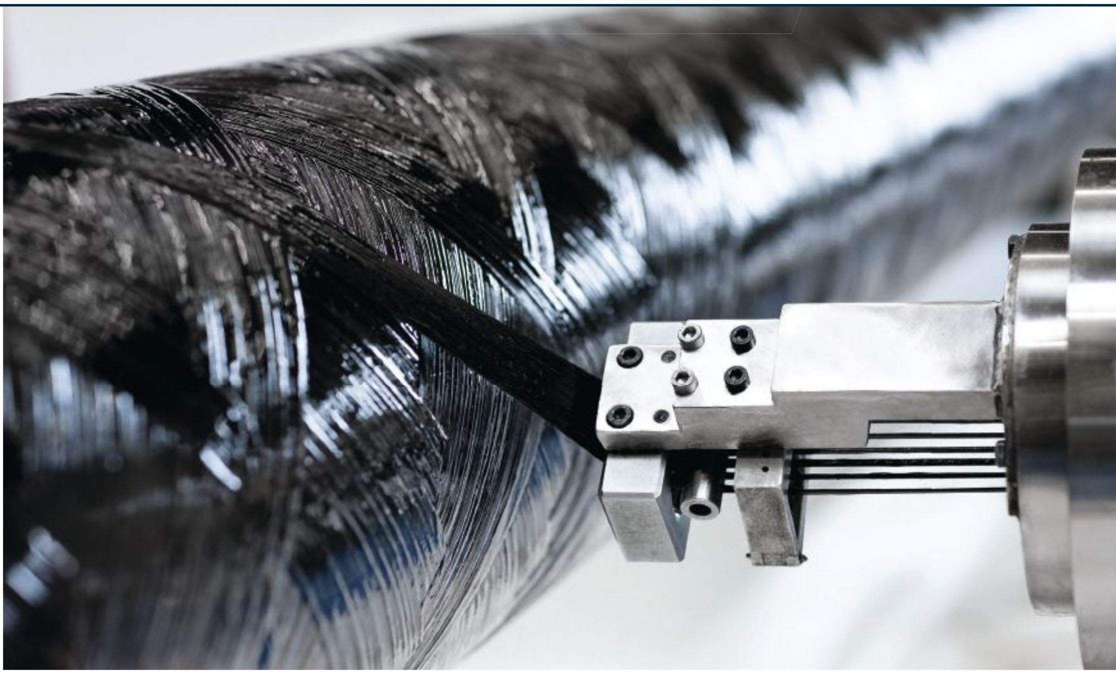
many major carbon fiber suppliers, including Teijin (Chiyoda-ku, Japan), Toray (Tokyo, Japan), SGL Carbon (Wiesbaden, Germany), Mitsubishi (Tokyo), and Nippon Graphite Fiber Corp. (Himeji, Japan). (Fiber for each application is selected according to product and production requirements, making the best use of material properties.) Even with this history and breadth of experience, though, the Dynexa team initially harbored doubts about the use of CFRP for output shafts.

From doubt to demo

A solid metal output shaft is the norm today in production vehicles, and at first, the Dynexa team was unsure what value a CFRP alternative might bring. “In contrast to multi-part metal driveshafts, we would not achieve high weight savings here,” notes Matthias Bruckhoff, head of sales and marketing for Dynexa.

Why switch to CFRP output shafts? CFRP’s high performance could be potentially useful in electric vehicles, in which output shafts are subject to unusually high forces. Additionally, the CFRP output shaft may also prove useful on both electric and gas-powered vehicles because of a phenomenon common to all types of automotive powertrains. Called “power hop,” the phenomenon occurs when low-friction road surfaces cause the tires in front-wheel-drive vehicles to cyclically lose grip with the drive surface during high engine acceleration. “The driver hears a loud, cyclical rattling of the front axle and feels a strong vibration on the seat and steering wheel,” explains Linda Senger, BMW research of hybrid powertrain, mechanics and structure. Power hop occurrence is highly dependent on the output shaft and its torsional stiffness.

“The focus of the development was the influence on power hop of higher torsional damping in CFRP output shafts compared to »

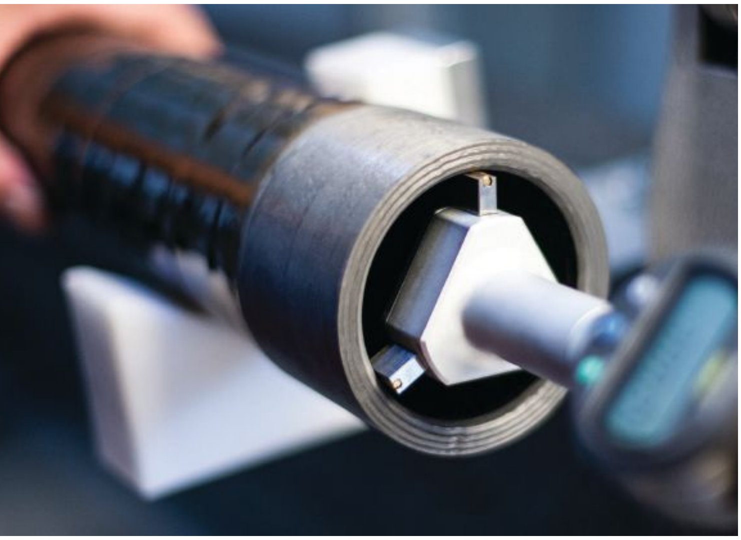


Filament-winding application

Having filament-wound more than 100,000 CFRP tubes and shafts for automotive prototype and serial production applications, Dynexa applied this experience to the new challenges that the output shaft application presented. Of particular interest are the vibrational performance and torsional stiffness of the shafts. Source | Dynexa

steel shafts with the same torsional stiffness," Senger continues. CFRP shafts have been shown to possess five to 10 times the torsional damping of steel shafts. This damping behavior is adjustable to the requirements of the application."

Generally, automotive designers seek to modify the vibration characteristics of vehicle components in order to minimize noise, vibration and harshness (NVH). "When you push the throttle," explains Marcus Schwarz, head of product development at Dynexa, "it increases force and vibration into the system, causing NVH." Dynexa's team is experienced in optimizing the vibrational characteristics of CFRP components. "By designing the fiber composite structure and adjusting the layer structure, a desired frequency can be achieved to influence the dynamics of the part during the run," Schwarz says.



Joining technology

A combination of an outer CFRP support ring and an inner "press-fit connector" on each end of the output shaft ensures sufficient joint pressure for needed torque transmission from the drivetrain to the vehicle's wheel. Source | Dynexa

The differing vibrational characteristics of CFRP and steel are central to Senger's output shaft study. To test whether CFRP vibrational damping would help reduce power hop intensity, Senger provided Dynexa with a set of design parameters for the CFRP output shaft. Because the test would be conducted on an existing assembly for a gas-powered vehicle, including the gearbox connection and joints, the CFRP shaft needed to be designed as a direct replacement for the metal shaft.

Dynexa designed the CFRP shaft to match the metal shaft's ability to handle a static torsional load of up to 3,000 Newton-meters. Importantly, the CFRP shaft also had to match the metal shaft's low torsional stiffness of 225 Newton-meters per degree. "The low stiffness of output shafts in gas-powered vehicles is necessary because of the rotational non-uniformity of the crank shaft," Senger explains. "Torsional vibrations cause a vibration of the powertrain and all adjacent components; with a low stiffness, you can reduce the vibration as well as noise."

Design optimization using the parameters that Senger's team specified resulted in an output shaft 350 millimeters long with an 80-millimeter diameter. The steel shaft, which is solid, has a smaller diameter than the hollow, tubular CFRP shaft, but sufficient space is available to accommodate the larger CFRP shaft.

Also critical to shaft design is how it connects to other — usually metal — components in the drivetrain. "You need to know which forces to account for, how to design the shaft, how to prepare the metal and how to assemble it," Schwarz says. A metal output shaft transmits torque via a welded connection between the shaft and other metal components. With the CFRP shaft, on the other hand, the connection is made with a press-fit joint, in which a metal part is inserted into the CFRP tube. The metal part's outside diameter is slightly larger than the CFRP tube's inside diameter, creating joint pressure necessary for torque transmission. No adhesive is used. Dynexa supports its CFRP-to-metal joint with outer CFRP support rings and an inner, specially designed press-fit connector. Schwarz explains that the latter, a Dynexa technology proven over 20 years, provides torque transmission through a combination of the friction generated by joint pressure and positive locking created by micro-teeth (serration) on the metal part. Galvanic corrosion is minimized by means of a gap seal between the CFRP tube and the metal part. Dynexa's press-fit technology "combines lightweight design with high torsional performance, both under static loads and over long periods of time under fatigue loads," Bruckhoff states.

Compared to the steel output shaft assembly, the CFRP version is 20-30% lighter. Weight savings include both the lighter shaft (despite the added weight of the outer support rings, which are not part of the metal-to-metal joint) and the elimination of vibration absorbers required for the metallic version. Though the actual weight savings is not of significant value for gas-powered vehicles, it could be helpful in electric vehicles, which may achieve greater driving range even with small weight reductions.

Identifying potential value

Testing of the CFRP shaft with low torsional stiffness ended up demonstrating how important torsional stiffness is to power hop reduction. Matching the lower torsional stiffness of the steel shaft, the prototype CFRP output shaft did not improve power hop performance, Senger reports. "Driving tests show that the power hop of the vehicle has the same intensity with the CFRP shafts as when the steel shafts are installed."

The study suggests that, for gas-power vehicles that need lower torsional stiffness in the output shaft, successful reduction in power hop would require modifications to tube geometry. "In order to achieve further added value, the use of a longer CFRP tube is necessary," Bruckhoff concludes. "The reduction of the outer diameter is also desirable for the entry into large series vehicles with composite standard components."

In electric cars, however, Senger believes that the key to success for CFRP output shafts is the high torsional stiffness that CFRP is able to provide. "High stiffness creates a more direct responsiveness of the vehicle, and thus improves the driving dynamics," she says. Electrified powertrains can employ shafts with high torsional stiffness because they do not experience the same non-uniformity of the crank shaft found in gas-powered vehicles. It is the gas engine's combustion process and the resulting forces on the crank shaft that creates the non-uniformity, and electric power does not generate these same forces.

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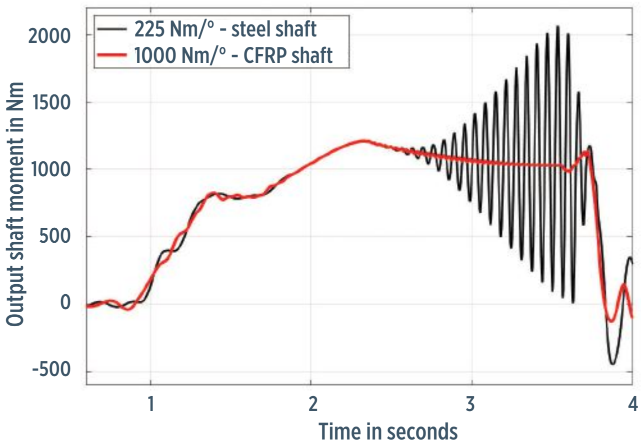
A stiffer output shaft increases the powertrain's torsional natural frequency (the frequency at which an operational vibration causes the component to resonate and amplify that vibration.). "The vibration mode of a shaft with high torsional stiffness causes much lower loads to all components that are excited by the power hop phenomenon," Senger points out. A simulation has shown that, under the same driving conditions, a CFRP output shaft with high torsional stiffness will eliminate the power hop experienced by a metal shaft with low torsional stiffness.



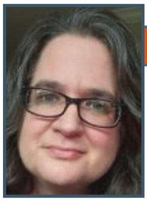
Torsional stiffness makes the difference

A simulation using Matlab Simulink suggests that a CFRP output shaft with high torsional stiffness may eliminate the power hop phenomenon. The driving maneuver simulated is acceleration of a front wheel-drive, gas-powered vehicle from a standstill on a wet and even road surface. Though gas-powered vehicles may be better served by lower torsional stiffness for other driving performance issues, electric-powered vehicles are strong candidates for further development of the CFRP output shaft. Source | Linda Senger

Moving forward

Reflecting on the output shaft work so far, Bruckhoff says, "The CFRP output shaft product group creates new added value in terms of driving characteristics and comfort. Together with our partners, we will work out these advantages and realize a product optimized in terms of requirements and price."

More studies of potential CFRP output shaft applications have not yet been announced by the OEM but seem likely. As for the Dynexa team, this predevelopment project has provided new insights into CFRP applications; in particular, vehicle tests validate theoretical assumptions and continually improve design competence. "It is important that we keep at it and continue to develop this product group together with our OEM partners," Bruckhoff maintains. "Our goal is to transfer successful developments step by step into a series application." 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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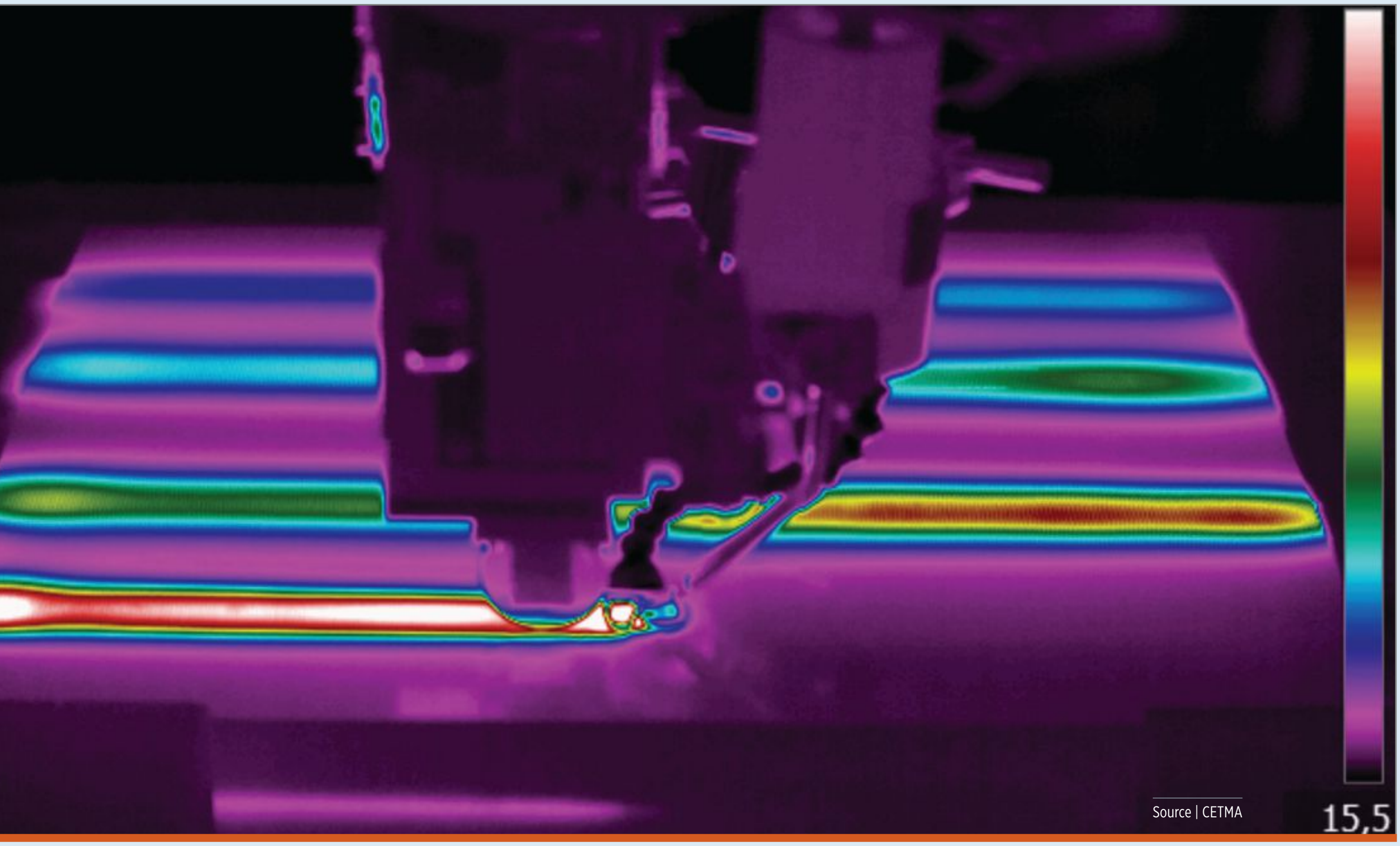
Post Cure

Highlighting the behind-the-scenes of composites manufacturing



Source | CETMA

Watching the heat

This infrared image shows temperature in the weldlines during induction welding of thermoplastic composite (TPC) stringers and skin panel at CETMA (Brindisi, Italy). The composites R&D lab has developed infrared thermography (IRT) for inline monitoring of multiple processes, including welding and continuous compression molding (CCM), used to produce the TPC stringers. CETMA also uses IRT to validate its 3D finite element models for induction welding that couple electromagnetic and heat transfer equations with matrix melting and crystallization. Its technology was used to produce the 250-by-500-millimeter by 1-meter-long keel beam demonstrator made from UD carbon fiber/PEKK for the Clean Sky 2 KEELBEMAN project.

Show us what you have!

The *CompositesWorld* team wants to feature your composite part, manufacturing process or facility in next month's issue.

Send an image and caption to *CW* Associate Editor Hannah Mason at hmason@compositesworld.com, or connect with us on social media.

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