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ON THE COVER

We've seen the likes of early 20th century zeppelins and modern-day blimps, but LTA Research's electric-powered prototype airship, *Pathfinder 1*, under construction here, takes this concept to the next level. Automated and scalable technologies and use of composite materials — a CFRP frame, as well as fins, gondola, motor covers and other components — achieve a strong, rigid and lightweight architecture. See p. 82.

Source | LTA Research

FOCUS ON DESIGN

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»The fall event season is quickly ramping up. I recently attended the Society of Plastics Engineers (SPE) Automotive Composites Conference and Exhibition (ACCE), which is held annually in Novi, Mich., U.S. The event is one that I participated in regularly during my earlier stint with *CW*. For me, returning to the conference after some time away helped to emphasize just how much the automotive industry has changed during the past few years.

The COVID-19 pandemic sparked a multitude of challenges in all areas of manufacturing. It caused so many supply chain and workforce disruptions that writing those words feels cliché at this point. But, it was also a time that brought so many of the problems we have in society into stark focus. Weather events and wildfires brought more attention to the need for environmental and sustainable solutions. Disruptions in the normal routines of business allocated more time for R&D efforts.

The path forward will shift and new questions will be raised.

During the past few years, the interest in electric vehicles (EVs), new energy vehicles and urban air mobility solutions has grown greatly. The SPE ACCE conference put me in the same room with many people associated with these sectors, including designers and engineers for Tier 1 automotive suppliers and OEM representatives. It was interesting to hear about some of the trends that are driving automaking decisions now. Lightweighting, of course, is a big topic these days, driven by the rapid developments in EVs and hydrogen fuel cell-powered vehicles. Many signs point to aluminum as the frontrunner material of choice for automakers for structural components, but there are also numerous areas where carbon fiber and even natural fibers are used.

The flip side of material innovations is the need to consider the entire *lifecycle* of the resulting parts. With each requirement for recycled or naturally sourced options comes the question of how those materials will then be reclaimed or recycled at the component's end of life (EOL). As part of the conference's sustainability track, a panel discussion was dedicated to EOL considerations for vehicles.

Plenty of discussion at SPE ACCE revolved around sustainability — a term that currently encompasses everything from environmental considerations when sourcing materials to energy savings in processing to recycling. Vehicles that are at the end of their life now comprise a different mix of materials than those that will need to be recycled when the *next* generation of vehicles reaches its EOL, prompting the need for new innovations in recycling processes and technologies as we put a growing mix of vehicle types on the road — and aircraft in the skies.

Emerging mobility applications such as advanced air mobility (AAM) vehicles were another large topic of conversation. And while the automotive market may seem to be leaning toward aluminum, AAM will undoubtedly rely heavily on composites, an initiative we are already witnessing.

On the heels of SPE ACCE, I now find myself at FABTECH, North America's largest event devoted to metal forming, welding and finishing, where I'm representing *CW*'s sister brand *Products Finishing*. Of course, many of the overarching manufacturing trends at that show — robotics, Industry 4.0 solutions, artificial intelligence (AI) and machine learning — are also shaping the future of the composites industry. The first day of FABTECH featured a panel that touched on a wide array of interrelated topics, from solutions for data capture to the use of digital twins to the role of AI. These topics are working their way into every aspect of how things are made, no matter which materials are used.

As I walk these shows and talk to the people working in industry, I'm fascinated by how quickly things are changing. *CW* has been reporting on the composites industry for the past 30 years and it's amazing to look back at all of the progress. To put some of this into context, I urge you to check out this month's 30-year retrospective article on p. 58 as well as a new episode of the *CW Talks* podcast online featuring *CW* brand VP and former editor-in-chief Jeff Sloan.

When it comes to all of these markets, the path forward will continue to shift and new questions will be raised. One thing is for certain: The years ahead are sure to be exciting.

SCOTT FRANCIS — Editor-In-Chief

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Aerodynamic considerations when repairing complex composite structures

»It is always a challenge to perform through-damage repairs to a compound-contoured composite sandwich structure, especially when there is a critical aerodynamic (AD) surface to consider. It is *most* problematic when access is limited to one side — the aerodynamic side — where the damage removal and scarfing protocol for repair of the outer AD skin, core and inner skin would remove a significant amount of the original structure around the damage area, resulting in a greater amount of AD surface that would need to be reclaimed.

The first factor to consider is that substantial tooling may be required to regain the AD surface. This type of tooling is either taken from the same area on another part (if available) or made through additive manufacturing (AM) methods using a digital file to generate a 3D-printed tool. A second consideration is whether to approach the repair from the outside or inside of the part. While the example repair above necessitates an outside approach due to single-side access, it is more time-consuming, costly and presents a higher risk of changing the original AD profile. To avoid these factors, we look at repairing the damage from the *inside* using a multistep process.

Repair from the inside

If the repair technician can access both sides of the structure, then it may be preferable to do the repair from the inside (bagside) skin, thus minimizing the amount of original AD surface that must be removed and reclaimed. This can often be done with simple composite caul tooling that can be fabricated from the actual part once the AD surface has been temporarily recovered using common epoxy filler materials and sweep/splining methodologies.

Temporarily reclaim the aerodynamic surface

The first step is to perform a damage assessment/inspection and determine the extent of the damage area to be removed. Next, before removing any structure, remove high spots, clean the surface and mask-off around the periphery with one layer of tape. Fill the damage area to at least 0.5-inch (12.7-millimeter) deep with an appropriate amount of epoxy filler paste (or other stable filler material), spline to match the AD surface (plus tape thickness) and cure the materials. Remove the tape, and carefully scrape or sand back to the original surface profile.

FIG. 1 Removal of damaged materials

Remove damaged skins and core in affected area.

Source (all images) | Kirt Butler/Abaris Training Resources

Fabricate a semi-rigid caul tool

Map out the estimated area that will need to be controlled with a semi-rigid caul tool. This includes supporting inside and outside skin repair areas. Provide temporary index features on the part, just inside of the outer boundaries of the tool coverage area, so that the tool can be precisely located back to the part. Temporarily extend any edge band areas if applicable. Cover the part area with an adhesive-backed layer of polytetrafluoroethylene (PTFE)-coated fabric[1], cutting out around the index locations as needed. Treat

FIG. 2 Machining the inner skin, core

The inner skin and core are machined away in the local repair area for the outer skin. This is followed by taper scarf machining of the inside surfaces of the inner and outer skins that will be repaired.

FIG. 3 Repair material preparation

All adhesive layers and repair plies are precut to size and the caul tool is prepared for installation.

the index features with a coat of carnauba wax or other release agents. Mask-off and cover outside of the tool periphery as needed to keep the rest of the structure clean during layup and processing of the caul tool. Fabricate a 0.1-0.2-inch (2.5-5.1-millimeter) thick composite caul tool using low-temperature cure/high-temperature service wet layup (or prepreg if applicable) materials per standard shop practices. Carefully demold the caul tool without disturbing the index features. Remove the PTFE-coated fabric and thoroughly clean the tool and part surfaces with clean wipes and solvent. Apply a layer of PTFE-coated fabric on the surface of the caul tool to bring the surface back to the AD profile — do not cover the indexes. Cure the caul tool laminate above the glass transition temperature (T_g) of the repair materials to prevent distortion during the repair sequences.

Remove damaged area and prepare for repairs

Route or grind out the damage area through the entire structure as shown in Fig. 1. Cut out the damaged core and inner skin to approximately 0.8 inch (20 millimeter) beyond the edge of the total scarf distance. The scarf distance is based upon the number of plies in the outer skin multiplied by 0.5 inch (12.7 millimeter) per ply from the edge of the damage removal. This enables inner skin repair plus an extra landing for the core replacement. Proceed to machine the taper scarf for the outer skin and inner skin repairs as shown in Fig. 2.

Repair the outer skin from the inside

Clean all inside and outside surfaces, then install the semi-rigid caul tool and secure to part with flash tape. (The vacuum bag will later provide clamping pressure.) Prepare repair plies and adhesives for outer skin repair (Fig. 3). Fabricate a core replacement plug, potted along the tapered edge and set it aside for later. Layup, bag and cure the outer skin repair per standard practices »

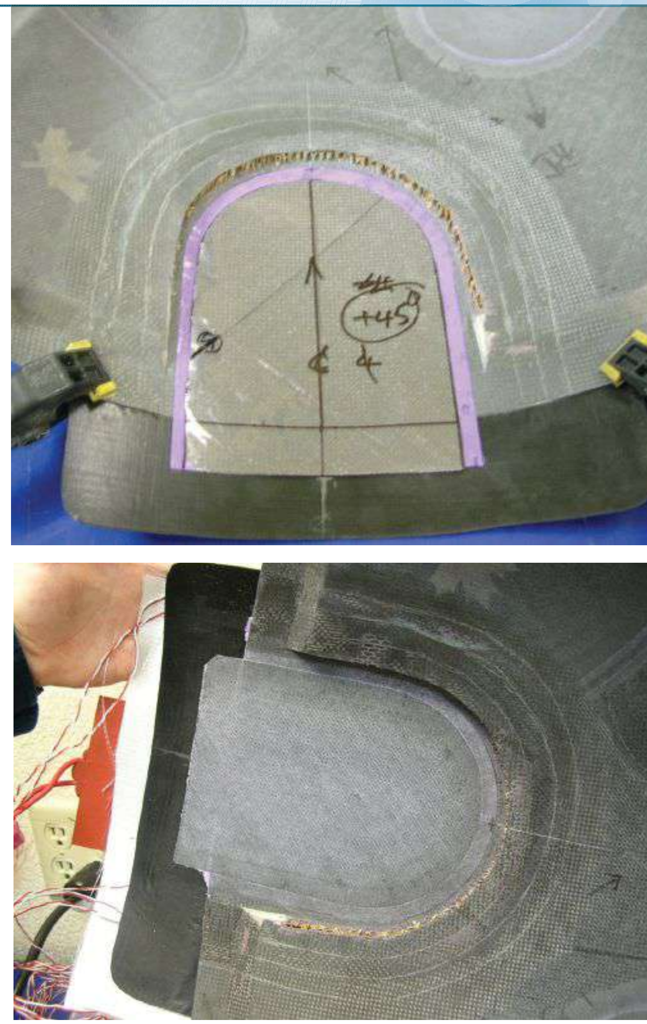

FIG. 4 Layup adhesives and repair plies

The repair patch for the outer skin is laid up (top) and fully cured (bottom), prior to replacing the core plug.

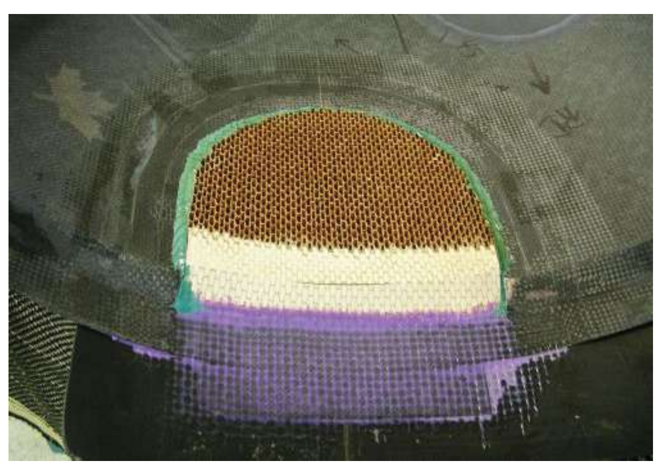

FIG. 5 Bonded core replacement plug

The potted core replacement plug is bonded in place with a layer of adhesive under the core and foaming adhesive around the periphery. It was then cured and is ready for final machining/profiling.

FIG. 6 Completed repairs

These photos show the completed repair of the inner skin (left) and the outer AD surface (right), which has been preserved using the inside repair approach. For reference, the black Sharpie line shows how much original AD skin was sustained.

(Fig. 4). (Note: This repair was cured using insulation behind a heat blanket under the bag, against the semi-rigid caul. Thermocouples were placed between the heat blanket and the semi-rigid caul and inside, on top of a thin (0.06-inch, 1.5-millimeter) aluminum caul plate, to monitor temperature of the blanket and control repair temperature.) Remove bag materials, etc. and lightly abrade and clean surface prior to the core replacement.

Install core replacement plug

Lay up an adhesive layer over the repair and on the landing, up to the edges of the surrounding core. Install a core splice adhesive around the outer edges of the core plug and install in the cavity. Apply peel ply and other bagging materials as needed and draw partial vacuum, ~15 inches Hg. Cure as required. Afterward, the core is machined to the desired profile and all dust and debris are cleaned from the area prior to performing the inside skin repair. Reference Fig. 5 for the cured core plug. (Note: A hot air machine[2] with a localized oven tent made from water heater insulation was used for curing the core bond and the subsequent inside skin repair. Temperature was controlled with a hot bonder and thermocouples located around and inside the core.)

Final repair to the inside skin

The inside skin is repaired in the same fashion as the outer skin — with applicable materials — in accordance with standard methods and practices. After it has been cured, the bagging materials are extracted, and the caul tool is removed from the AD surface (Fig. 6). The temporary indexes are later removed, and the repairs are inspected using nondestructive techniques (typically tap or ultrasonic testing). At this point, the edges can be trimmed back to the original trim line.

The above examples are unique to the part that we used for demonstrative purposes in this column. Although the exact details may change, the basic concept remains the same. Ultimately, by performing the repairs from the inside there is minimal impact to the original AD surface, with no compromise to the structural repair. Always check to see if the repair scheme (size and proximity) is within the boundaries of the Structural Repair Manual or other applicable instructions. Otherwise, an engineering disposition may be required. CW

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[1] Tooltec A500 PTFE-coated glass fabric, adhesive backed from Airtech International (Huntington Beach, Calif., U.S.).

[2] HCS2041-02 hot air curing system from Heatcon (Seattle, Wash, U.S.).

ABOUT THE AUTHOR

Louis Dorworth is the direct services manager at Abaris Training Resources Inc. (Reno, Nev., U.S.). Lou has been involved in the composites industry since 1978 and has experience in material and process (M&P) engineering, research and development (R&D), tooling, manufacturing engineering, teaching and troubleshooting. Lou is a coauthor of the textbook titled "Essentials of Advanced Composite Fabrication and Damage Repair," second edition.

Interlaminar tensile testing of composites: An update


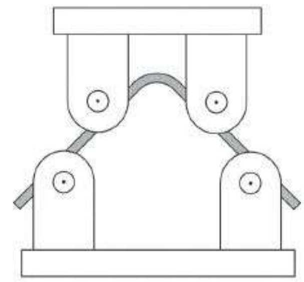

FIG. 1 Curved beam flexure test

ASTM D6415 test fixture and curved beam specimen. Source (all images) | Dan Adams

»Back in April 2015, my *CW* column focused on the two ASTM standardized test methods used for measuring the through-the-thickness, or *interlaminar*, tensile strength of composite laminates. Despite their difficulties and limitations, the ASTM D6415[1] curved beam flexure test and the ASTM D7291[2] flatwise tensile test are still commonly used for measuring interlaminar tensile strength. However, neither test method is viewed as completely satisfactory.

Although less commonly measured than the in-plane tensile properties of a unidirectional (UD) composite, interlaminar tensile strength is an important material property due to its greatly reduced value in comparison to the fiber-direction in-plane tensile strength. Although it is often similar in magnitude to the in-plane transverse tensile strength, changes to the manufacturing method may affect the bond strength between plies of a composite laminate and significantly reduce the interlaminar tensile strength.

Since writing my 2015 column on the topic of interlaminar tensile testing, additional test methods have been proposed and investigated for addressing the problems associated with the two standardized test methods. In this column, I'll provide an update on these additional test methods for measuring the interlaminar tensile strength of composites. Before doing so, however, I'll briefly summarize the difficulties associated with the two current ASTM standardized methods, which use very different specimen geometries and loading methods.

The first test method, ASTM D6415, uses an *indirect* loading method to produce an interlaminar tensile stress state in the central region of a curved beam specimen. As shown in Fig. 1, the specimen is composed of two straight "legs" connected by a central curved region to produce a 90° bend. The specimen is loaded in four-point flexure using the specialized test fixture also shown. Flexural loading of the curved beam specimen results in an opening of the 90° angle and produces a region of through-the-thickness, or interlaminar tensile stress, in the central curved region of the specimen. Although the curved beam flexure test is simple to perform, the fabrication of the curved beam specimens is often problematic, as ply waviness and porosity are commonly produced in the curved region, significantly reducing the measured interlaminar tensile strength.

A second interlaminar tensile test method for composites, the ASTM D7291 flatwise tensile test, produces interlaminar tensile stress through direct out-of-plane tensile loading of a cylindrical composite specimen as shown in Fig. 2. Steel fixture blocks are bonded to the top and bottom of the composite specimen for use in load application. When using specimen thicknesses of 25 millimeters or greater, the standard recommends a tapered

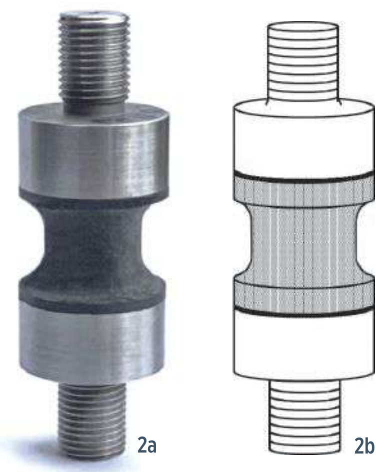

FIG. 2 Flatwise tensile test

ASTM D7291 interlaminar test specimen.

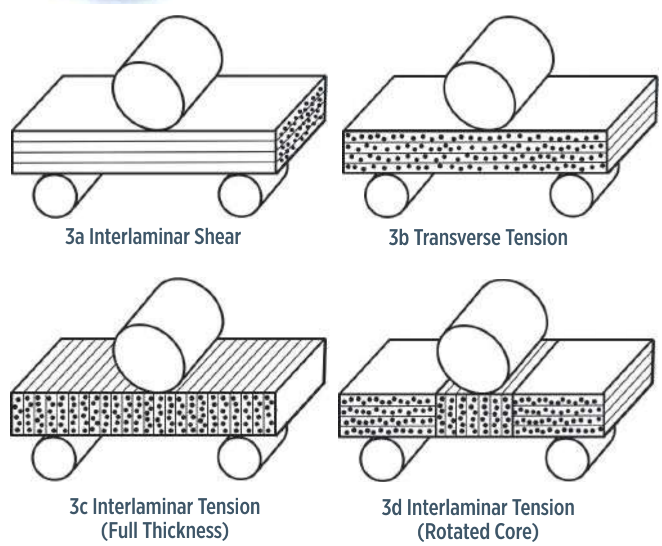

FIG. 3 New short beam flexure testing developments

Short beam flexure testing configurations.

specimen diameter in the central region to produce a reduced-area test section and promote failure away from the bonded end blocks. While simple in concept, the specimen and fixture block assembly is prone to misalignment during the bonding operation, leading to high levels of variability in test results. The test standard details an elaborate bonding fixture for maintaining alignment while bonding the fixture blocks to the cylindrical composite test specimen.

A more recent development has been the use of a short beam flexure test to measure interlaminar tensile strength. This test methodology uses the same three-point flexure loading configuration used in the ASTM D2344[3] short beam *shear* test. In both test methods, three-point flexure loading produces peak bending stresses (compression and tension) in the upper and lower regions of the specimen. Additionally, the maximum shear stress is produced in the mid-thickness region of the specimen. In fact, the only significant difference between the short beam *shear* and short beam *flexure* tests is the fiber orientation within the short beam specimen that's being tested. Whereas the fibers are oriented along the specimen length in short beam *shear* specimens (Fig. 3a), they are oriented perpendicular to the specimen length in short beam *flexure* specimens as shown in Fig. 3b. This difference in fiber orientation within the two types of specimens results in different failure modes occurring in the two types of short beam tests; interlaminar shear failure is produced in the short beam shear tests and transverse tensile failure in the short beam flexure tests.

> A more recent development has been the use of a short beam flexure test.

As illustrated in Fig. 3b and 3c, two different ply orientations are possible when performing short beam flexure testing, allowing two different tensile strength properties to be measured. When the ply interfaces are oriented horizontally as shown in Fig 3b, the test becomes a transverse tensile test and provides a measure of the *transverse* tensile strength. However, when the ply interfaces within the specimen are oriented vertically (Fig. 3c), the test becomes an *interlaminar* tensile test — the subject of this column — and provides a measure of the interlaminar tensile strength. Thus, the flexure-based interlaminar tensile test shown in Fig. 3c may be viewed as an alternative to the two standardized test methods shown in Fig. 1 and Fig. 2.

A significant disadvantage of the flexure-based interlaminar tensile specimen shown in Fig. 3c for measuring the interlaminar tensile strength is that it requires extremely thick UD laminates to be manufactured, from which short beam flexure specimens are oriented in the through-thickness direction as shown in Fig. 3c. Makeev et al.[4] reported using 100-200 ply UD laminates for such specimens, depending on the ply thickness of the composite material. The use of such thick laminates is often problematic due to difficulties with debulking and material consolidation during cure, resulting in voids and other defects.

To address these concerns, Fisher and Czabaj[5] developed a three-piece bonded specimen design using standard-thickness UD laminates as shown in Fig. 3d. The test panels were produced by cutting out and replacing the central region of the panel with an equal-sized panel section that is rotated 90° from the original orientation, such that the ply boundaries extend through the specimen thickness. The three pieces of the test panel were bonded together using a paste adhesive and cut into the "rotated core" specimen configuration shown in Fig. 3d. Thus, when subjected to three-point flexure loading, an interlaminar tensile stress state is produced in the central "rotated core" section of the specimen. Using this configuration, the UD laminate was reduced to a manageable thickness and the associated manufacturing problems were minimized.

Having summarized these test methods for measuring interlaminar tensile strength, the question arises of whether this quantity is a true "material property," such that one should expect similar results from any of the aforementioned test methods. Currently, the general consensus is that interlaminar tensile strength values vary with specimen configuration and the resulting volume of material that is being tested. Additionally, differences in the manufacturing method used for each type of test specimen (different shape, size, thickness, etc.) can affect the bond strength between plies of the composite laminate and therefore affect the measured strength values. As a result, the measured interlaminar tensile strengths should be considered a "structural property," which is dependent on the specimen configuration and manufacturing method used, rather than a true "material property." CW

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Contraction in composites industry activity slowed in August

AUGUST — 47.5

» Just when the Gardner Business Index (GBI): Composites Fabricating seemed to have settled into a mode of continually accelerated contraction for 5 months, August bounced back a bit. The index closed the month at 47.5, up 1.1 points from July. Expansion is still in the distance, but closer in reach than it has been in a while.

All of the index components *except* supplier deliveries contracted in August. In fact, supplier deliveries saw accelerated lengthening, which may, at least in part, be "normalization" of what is typically a widely variable component outside of a disruption-inducing pandemic.

August is a repeat of July for four GBI components. New orders, production and backlog contracted faster again in August, while exports have contracted at essentially the same rate since April 2022.

As anticipated in July, employment contracted in August for the first time in almost three years. Similar to, but less dramatically than supplier deliveries, employment is a component that was largely impacted by the pandemic. August's contraction may, at least in part, be a function of "normalization" post-pandemic.

Future business, a sentiment/outlook metric that is not part of the GBI calculation, but related to it, expanded at a faster rate in August, indicating more people think business is looking up in the next 12 months. CW

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Jan Schafer, MBA, is the director of market research for Gardner Intelligence, a division of Gardner Business Media (Cincinnati, Ohio, U.S.). She has been an essential part of Gardner Intelligence for over five years, and has led research and analysis in various industries for over 30 years.
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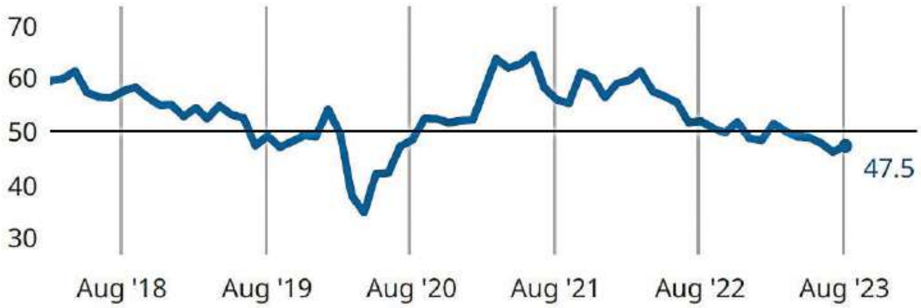
GBI: Composites Fabricating

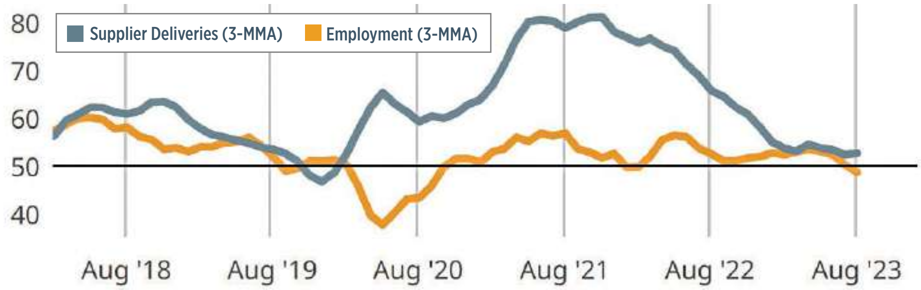


Looking up

GBI: Composites Fabricating in August is up 1.1 points vs. July.

Source (all images) | Gardner Intelligence

GBI: Composites Fabricating — Supplier Deliveries and Employment (three-month moving average)



Making its mark

Components disproportionately affected by the pandemic, supplier deliveries and employment may be starting to manifest post-pandemic impact.

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GARDNER BUSINESS INDEX

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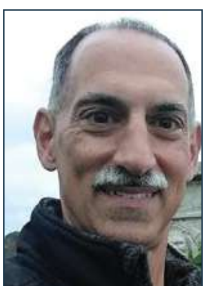
In a *CW Talks* episode, Composite Energy Technologies discusses its experience with deep sea submersibles; ABM Composite offers bioabsorbable, biodegradable options for glass fiber-reinforced composites; reports confirm Russia's step away from the CR929 widebody aircraft and impending delays in MS-21 deliveries.

Chase Hogoboom



TJ Perrotti

Episode 41: Chase Hogoboom, TJ Perrotti, Composite Energy Technologies Inc.

In the wake of the loss of the OceanGate *Titan* submersible, there was much discussion and speculation about the materials used to manufacture the vehicle. Many pointed to the use of carbon fiber as a potential source of failure, yet there has been a good deal of success in the use of the material for undersea applications including pressure vessels and unmanned submersibles.

In this episode of *CW Talks*: The Composites Podcast, Scott Francis, editor-in-chief of *CW*, is joined by two representatives from Composite Energy Technologies Inc., a Bristol, R.I.-based company that manufactures a wide range of composite structures from racing sailboats and architectural designs to defense applications including deep sea submersibles. Chase Hogoboom, president, and TJ Perrotti, senior Naval architect and chief design engineer, discuss their experience working with the U.S. Navy on submersible designs and the rigorous testing that goes into the use of carbon fiber for undersea applications.

This Q&A is excerpted from the *CW Talks* podcast and is edited for clarity. To hear the entire interview, visit www.compositesworld.com/podcast or click on the QR code at the end of this article.

Scott Francis (SF): In the wake of OceanGate, there was a lot of speculation about what might have caused the implosion — and a fair amount of speculation was placed on *Titan*'s use of carbon fiber. As you've mentioned, carbon fiber has a history of use in high-performance applications. Can you talk a bit about what's unique about these undersea applications that you've been working on?

TJ Perrotti (TP): I think the dominant difference with dealing with deep oceans is the incredible pressures that are exerted. Just to put that in perspective, here on the surface of the Earth, we deal with basically one atmospheric pressure, about 15 pounds per square inch. For craft that go up into space where you're essentially operating in a vacuum, you are dealing with a differential, again of about 15 pounds per square inch.

If you're going down to 6,000 meters at the depths of the ocean, you're dealing with something like 9,000 pounds per square inch of pressure exerted on that object. So, roughly 600 times the magnitude of pressure exerted. And so a good portion of the challenge to develop pressurized vessels that go down to [various depths in] the ocean is simply dealing with that intense pressure distributed over the surface area, which of course, is an enormous amount of force.

In addition to that, we have to understand the reliability of the materials chosen to create that structure. Can they handle repeated fatigue cycles? Do we understand how the mechanical properties of the material are maintained at depth in cold waters under pressure as things compress because of the pressure? Are those mechanical properties characterized with testing on the surface and labs? Or do we need to do more stringent testing to qualify what happens to mechanical properties at depth?

SF: Let's get a little deeper into some of the specifics of your work with underwater carbon fiber pressure vessels — actually taking some of these vessels to the point of implosion. Can you talk about some of the specifics of the work, and some of the variables that you were looking at when you would conduct tests? How were the tests performed and what were some of the findings and results?

TP: We were contracted through the Office of Naval Research to help explore the possibility of applying carbon fiber toward deep sea pressure vessels. The Navy has various craft that have to take electronic components down to ocean depths in a dry environment. And so they put the electronic components in pressure vessels, basically a can that maintains atmosphere pressure on the inside when subjected to large pressure on the outside. Traditionally, those types of pressure vessels are made out of materials like titanium. They can be very expensive — it's hard to procure the large billets of solid block material needed to machine those cylinders.

Carbon fiber, as you know, and as your audience knows, is a very strong, but particularly lightweight material, about a third of the density of titanium. And there is interest from the Navy in exploring materials that are lighter in density, so that the craft tasked to take that payload down to ocean depth has a lighter payload to carry.

That was the interest as we began to dip our toes in the deep end of the pool, so to speak. We had some assumptions about the mechanical properties of carbon fiber and how they might apply to the construction and verification and function of a carbon fiber pressure vessel. But again, we didn't want to make the assumption that those quantified mechanical properties on the surface maintain themselves at ocean depth.

So we set forth to do a very stringent systematic series of scaled pressure vessels, designed, fabricated and tested in a controlled, wet, pressurized environment. In this case, we've used the pressure chambers at Woods Hole Oceanographic Institute extensively and have developed a family of scaled pressure vessels that we've designed, built and in some cases taken directly to implosion intentionally, to see if the predicted strengths and failure mode of the pressure vessel was consistent with what was evidenced in the pressure chamber.

And in other cases, we've taken things shy of implosion and fatigued them, meaning that we take them down to some depth, hold them for a certain amount of time, and then take them back to surface pressure, and then repeat that over and over and over a finite number of times and then take *that* to implosion. And we will compare it to a counterpart that was taken directly to implosion in order to see if there's evidence of the influence of fatigue cycles.

SF: How many successful vessels have you created that are actually in service?

Chase Hogoboom (CH): Everything in service has had no issues, including one item that has seen over 6,000 hours at depth, which is quite considerable. We've manufactured and tested and imploded on purpose far more items than those that we have in service. So, if you look at this statistic of items that have broken versus items that happened, the items that have broken far outweigh those that have not. However, it was intentional. The ones that are in service and are being operated right now have performed very well.

Bioabsorbable and degradable glass fibers, compostable composite parts


Source | ABM Composite

What if glass fiber-reinforced polymer (GFRP) composites could provide the improvement in light weight, strength and stiffness, corrosion resistance and durability that has been proven for decades, but also be composted at the end of their service life? This is what ABM Composite is offering.

Arctic Biomaterials Oy (Tampere, Finland) was founded in 2014. It developed a degradable glass fiber made from what is called *bioactive* glass, says Ari Rosling, R&D director for ABM Composite. "This is a specific formulation developed during the 1960s that enables the glass to degrade within physiological conditions." When inside the body, the glass breaks down into its component mineral salts, releasing sodium, magnesium, phosphate, etc. This then creates a condition which stimulates bone growth.

"Its properties are similar to E-glass," says Rosling, "but this kind of bioactive glass is very difficult to make and draw into fiber. Previously, it was only used as a powder or putty. To the best of our knowledge, ABM is the first company to make high-strength glass fibers from it on an industrial level and we now use these ArcBiox X4/5 glass fibers to reinforce different types of plastics, including biodegradable polymers."

"There are a lot of biodegradable, bioresorbable polymers that are used for implants," he continues. "But their mechanical properties are far from those of natural bone. We are able to reinforce these biodegradable polymers so that the implants have the *same strength* as natural bone." Rosling notes that adding ABM's medical grade of ArcBiox glass fibers can provide a 200-500% increase in the mechanical properties of biodegradable poly-L-lactic-acid (PLLA) polymer.

In addition to medical implants, ABM Composite has developed household and technical applications, such as kitchenware, utensils and other household items. "We provide more sustainable end-of-life [EOL] options," notes Rosling. "The value proposition is that we can place these biodegradable composites into industrial compost operations, where they turn into soil." Traditional E-glass is inert and would not degrade in these facilities.

ArcBiox fiber composites

ABM Composite has developed ArcBiox X4/5 glass fiber in a variety of formats for composites, ranging from chopped fibers and injection molding compounds to continuous fibers for processes like textile weaving and pultrusion. Its ArcBiox BSGF series combines the degradable glass fiber with bio-based polyester resin, available in a general technical grade and the ArcBiox 5 grade approved for food contact.

ABM Composite has also worked with a variety of biodegradable and bio-based polymers, including polylactic acid (PLA), PLLA and polybutylene succinate (PBS). Its research has found that X4/5 glass fibers increase performance, making them competitive with standard glass fiber-reinforced polymers such as polypropylene (PP) and even polyamide 6 (PA6).

Durability versus compostability

If these composites are biodegradable, how can they be durable? "Our X4/5 glass fiber is not like sugar that will dissolve within five minutes or overnight," says Rosling. "Its properties will reduce over time, but not that dramatically. To efficiently degrade, we need prolonged elevated temperature and humidity, as you would find inside the body or an industrial compost pile."

However, it is important that when these composites are treated at the product's EOL, they meet the required standards for composting. ABM Composite has performed a series of tests to prove it meets these standards. "According to ISO standards (industrial compost), *biodegradation* should happen within 6 months and *disintegration* within 3 months/90 days," says Rosling. "Disintegration means the test sample/product is placed into a biomass or compost. After 90 days, the test is made by technicians passing the biomass through a sieve/mesh. After 12 weeks at least 90% of the product should be able to pass through the 2 × 2 millimeter mesh."

ABM Composite confirms that it has passed requirements for both disintegration and biodegradation — in industrial *and* home composting conditions — noting that tests showed adding its X4 glass fiber actually improved biodegradation. "For example, an unreinforced PLA blend only reached 78%," he explains, "but when we added 30% of our degradable glass fiber, biodegradation increased to 94% while the disintegration remained good."

Industrial applications, production, cost and future growth

ABM Composite materials are being used in a range of commercial applications, but many more are covered by nondisclosure agreements. "We have tailored our materials to fit sectors such as cups, dishes, cutlery and food storage boxes," says Rosling, "but they are also being used in cosmetic containers and in larger household items, as an alternative to petroleum-based plastics. More recently, we've been selected for parts in large industrial machinery installations … that need to be changed every 2 to 12 weeks."

"There is also growing interest to use our continuous fibers in different types of textiles and nonwovens to make structural components for building and architecture applications," adds Rosling. "We're also seeing interest to use our degradable fiber with bio-based but nondegradable PA or PP as well as inert thermosets."

Another key advantage to ABM Composite materials advantage is their ability to reduce greenhouse gases produced and non-renewable energy used by as much as 50-60%, per kilogram of material. "There are so many incentives pushing circular technology forward now, and the world needs it to go faster," Rosling says. "I think society will only increase its push toward more bio-based products for the future."

This has been edited down for editorial purposes. Read the full article online short.compositesworld.com/ABMComposites

AEROSPACE

Russia exits from Comac CR929 program, MS-21 experiences delays

Source | Getty Images

In August 2023, *Aviation Weekly* released an announcement that confirms Russia has withdrawn from the Comac CR929 widebody aircraft project with China. It is believed this is due to long-term consequences following the Ukraine invasion about 18 months ago. Delays concerning the Irkut (Moscow, Russia) MS-21 single-aisle commercial aircraft, owned by United Aircraft Corp. (UAC, Moscow), suggest additional challenges. Both aircraft programs use a healthy amount of composite materials.

While China has not commented on the change of plans for the CR929, for months reports have indicated that the region had decided to pursue the widebody on its own. According to *Aviation Weekly*, if these reports hold some truth, they may stem from the fact that keeping Russia on, after Western-posed sanctions, could pose their own challenges to lifting the program off the ground; the CR929 has already "accumulated years of delays and is not expected to enter service until well after 2030 due to lengthy negotiations about sharing work and intellectual property." China currently has no sanctions on Russia and the China-Russia Commercial Aircraft International Corp. (CRAIC), formed in 2017, seems to still be intact.

UAC CEO Yury Slyusar notes that Russia still hopes to remain involved in the Comac CR929 program, and plans to continue as a "normal supplier and builder of the composite wing, PD-35 engines and other subsystems for the aircraft." However, it is still unclear how Western suppliers previously working on the program — Eaton, Honeywell, Liebherr, RTX, Safran, Thales, Zodiac Aerospace and an engine manufacturer — could take part. *Aviation Weekly* cites that, in addition to the Russian PD-35 engine, China plans to use the CJ-2000 currently in development.

A widebody similar in size to the Airbus A330, the CR929 is designed to carry between 258 and 320 passengers with a range of up to 12,000 kilometers.

The MS-21 (also known as the MC-21) program's timeline has also slipped, another direct result of Western suppliers withdrawal. The Russian-financed program was "expected to hand over the MC-21s in 2024 and roll out 270 of them through 2030." Russian manufacturers have been given additional time to substitute imported components, including actuators, avionics and air conditioning. Russian PD-14 turbofans and a Russian-made infused composite wing were approved in December 2022.

"We hope that the first six aircraft will be handed over to Aeroflot [a subsidiary of Rossiya Airlines] in the beginning of 2025," Anatoly Gaidansky, Yakovlev's first deputy general director, acknowledged in a podcast with the Moscow Aviation Institute on Aug. 13.

An MC-21 prototype is under development, with "70% substituted Western-made equipment," and is expected in December 2023. The fully import-substituted version, dubbed MC-21-310RUS, is to make its first flight in April 2024 and then receive its supplemental type certificate by the end of that year.

Welcoming you back to CAMX: 2023 exhibit previews

Source | *CW*

What:
Composites and Advanced Materials Expo (CAMX) 2023

Who:
American Composites Manufacturers Assn. (ACMA, Arlington, Va., U.S.); Society for the Advancement of Material and Process Engineering (SAMPE, Diamond Bar, Calif., U.S.)

When:
Oct. 30 – Nov. 2, 2023

Where:
Georgia World Congress Center in Atlanta, Ga., U.S.

By Katie Leesmann / Editorial Assistant and **Grace Nehls /** Managing Editor

The largest composites trade show in North America, CAMX delivers unlimited collaboration with access to everything composites. This year's event will take place Oct. 30 – Nov. 2, 2023, in Atlanta's Georgia World Congress Center. Organizers are promoting a program promising 100+ sessions led by experts, cutting-edge topics in wind energy, hydrogen solutions, sustainability, digital manufacturing and more, engaging tutorials, featured sessions, technical papers and panels, inspirational keynote speakers, robust awards ceremonies, live demonstrations and networking opportunities with industry peers.

What's new?

- Three guided tours in the Atlanta area, held at the Massivit Americas Experience Center, Delta Techops Center and Lockheed Martin – Marietta, respectively.
- A custom art installation at CAMX Park Place by multidisciplinary artist Meredith Connelly.

What's returning from last year?

- An increasingly robust international and new exhibitor presence. Stop by their booths!
- The on-site *Composites Weekly* podcast hosted by Jonathan Taylor. Industry innovators, award winners and experts will be interviewed throughout the week.
- Conference tutorials, campfire chats, CAMX Theater sessions and other complimentary education opportunities.
- "Good Day, CAMX" panel led by industry leaders to discuss current industry projects, including *CW*'s brand vice president Jeff Sloan.
- And much more!

Exhibit previews

Every year, prior to the event, *CompositesWorld* asks CAMX exhibitors to share the innovative technologies and products that will be featured at their booths, as well as any composites service highlights. We heard back from many of them — in fact, *CW* received 132 previews, surpassing last year's total. They cover everything from software and materials to machines and process equipment.

To accommodate as many previews as possible, *CW* has split them into two batches. The first report was published in the *CW* September 2023 issue, which is offered in print and online; what follows is the second report. For the complete preview list, visit the #CAMX hashtag on CompositesWorld.com, and follow our coverage of CAMX during and after the show.

Core materials readily accept mechanical fasteners, screws

3A Core Materials (Colfax, N.C., U.S.) is introducing Airex W.I.S.H. core for lightweight sandwich panels that can readily accept mechanical fasteners and screws. W.I.S.H., standing for "With Integrated Screw Holding," is a combination of low- and high-density PET foam to balance high R-values and maximum screw holding. The state-of-the-art technology can be provided in custom lengths, widths and shapes to reduce labor, process time and waste.

Source | 3A Core Materials

W.I.S.H. core's cost and weight are said to be significantly reduced while the net R-value is fully maximized without any compromise on stiffness or strength. According to 3A Core Materials, customers will no longer have to overdesign their core or composite panels to improve fastener performance.

W.I.S.H. products may also be supplied with the company's Airex T90 fire resistant PET foam. Lengths up to 16' are available as well as options including SealX surface finish (reduced resin uptake) and custom configurations for infusion and other processes.

3A Composites Core Materials Baltek Inc., Booth V47, 3accorematerials.com

Innovating high-temperature composite solutions for aerospace

Accudyne Systems (Newark, Del., U.S.), a custom automation equipment manufacturer, is developing custom equipment solutions to address manufacturing challenges associated with novel material systems in the aerospace industry. There are many active programs in the company's laboratory, including CMC tape placement, carbon-carbon pitch infusion and complex-curved thermoplastic component preform manufacture.

Source | Accudyne Systems and Rolls-Royce PLC

The Accudyne Systems team continues its innovations in composite manufacturing technology development and the integration wave. Building on its history of supporting primary and secondary aircraft structures as well as rotating composite component manufacturing, Accudyne says it is also working on the next generation of wing and fuselage structure manufacturing solutions for emerging platforms. New-start programs are benefiting from the company's experience in automated tape/material laying, stringer forming, automated compaction and ultrasonic trimming — all of which is wrapped up into integrated manufacturing cells. **Accudyne Systems Inc. | Airborne, Booth P59, accudyne.com**

Technology investment contributes to complex industrial tooling services


Source | Accurate Pattern Inc.

Accurate Pattern Inc. (Butler, Wis., U.S.) is ready to discuss precision tooling projects and showcase its capabilities in a wide range of materials, whether a customer is manufacturing small or large parts, one-off or for low-run production. Throughout its 38-year history, the family-owned business has continually expanded its capabilities to serve clients in the aerospace, automotive, transportation, agricultural and construction industries.

"We have a unique ability with our five-axis machine capabilities to make parts that are the size of a glove box up to 16′ × 12′ × 7′ range," says vice president and COO Kevin Williams, who owns and operates Accurate Pattern with his wife, president and CEO Polly Sackett. End users include a multitude of fiberglass fabricators, thermal formers, carbon fiber parts manufacturers and plastic injection molders.

With its purchase of a high-end C.R. Onsrud (Troutman, N.C., U.S.) five-axis CNC router earlier this year, Accurate Pattern has expanded its tooling capabilities even further. The new router reduces production bottlenecks. Its rigid construction also holds tighter tolerances, allowing for more precision than current capabilities. And with its added horsepower, the new router makes it possible for Accurate Pattern to machine more dense materials. "Now we can cut a wide range from low-density foam to high-density epoxy, as well as aluminum," Williams notes.

Accurate Pattern, Booth U54, accuratePattern.com

Thermally conductive mandrels enhance filament winding capabilities

Source | Acrolab Ltd.

Acrolab Ltd.'s (Windsor, Ont., Canada) trademarked Isomandrel is an enhanced mandrel that permits the curing of filament-wound pipe and tube sections by heating the mandrel while rotating via induction heating. Enhancing the mandrel's thermal conductivity and reactivity, the process applies heat in a localized concentration that is then rapidly and homogeneously redistributed over the complete mandrel working surface.

Benefits include a completed cure in a shorter time with less energy expenditure, all while providing a more uniform and consistent cure and resin-rich surface on the internal diameter of the cylinder/wind.

Unlike conventional isomandrels, which are typically heated at only one end with a heat source that is usually separate from the part area of the mandrel, Acrolab's Isomandrel technology applies heat to this area and then instantly redistributes it along the mandrel's entire length. This heating can also occur during or after winding, providing the freedom to cure while winding or on a separate station. An oven can be used, but is no longer required.

Acrolab Isomandrels are either monel or stainless steel. Many heat type sources can be incorporated, though electric resistive heaters or induction heat are the most common options. Moreover, cooling can be integrated if required. Cooling type depends on the Isomandrel design. The Isomandrels also use an IR-style sensor to monitor temperatures.

Acrolab, Booth GG49, acrolab.com

ASTM D5528

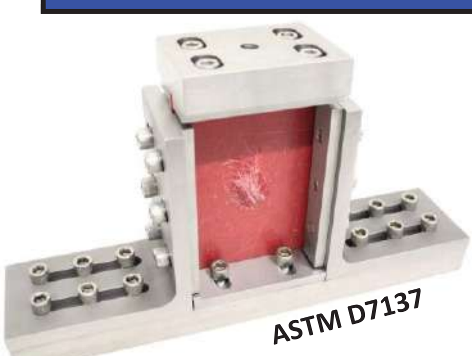
ASTM D695

ASTM D7136

ASTM D4255

ASTM D3410

ASTM D5448



ASTM D7137

ASTM D2990

ASTM D6484

Composite process materials provider focuses on innovation, customer-centered support

In close partnership with Composites One (Schaumburg, Ill., U.S.), **Aerovac** offers a wealth of experience in low- to high-temperature composite processing. Aerovac develops, manufactures, supplies and supports innovative vacuum bagging for customers that demand the best for prepreg processing, vacuum infusion, resin infusion, glass lamination and other closed mold composite manufacturing processes.


Source | Aerovac

The Aerovac range of high-performance bagging films ensure precision, quality and efficiency. They are available as roll stock or as engineered kits. Aerovac also offers reusable rubber vacuum bags (RVBs) using advanced sealing systems. The company's bagging films are high quality, accessible, easy to customize and supported by experienced technical experts.

Innovation is at the heart of everything Aerovac does, in addition to offering a truly customer-first approach. Alongside technical expertise, Aerovac's team listens, advises and responds by delivering products, formulated to meet customer requirements. Along these lines, the company has fostered strong relationships in every territory in which it operates to ensure highly skilled, responsive and reliable service.

Composites One, Booth W36, compositesone.com

Gripper attachment precisely handles rolled materials


Source | Autometrix Inc.

Autometrix (Grass Valley, Calif., U.S.) remains committed to providing customers with the best solutions for accurately handling rolled goods. Its latest offering, the Fusion Gripper, is designed with versatility and durability in mind. Operation is simplified via seamlessly integrated controls in the cutting machine's touchscreen and PatternSmith software.

The Autometrix Fusion Gripper serves as the ideal complement to the company's Radium or Argon cutting systems. It functions as an attachment, enabling users to effortlessly grip and pull materials from Autometrix's diverse range of material rack systems. When paired with the Radium/Argon cutting system, the Fusion Gripper is programmed to retrieve material from the cutting bed and unroll it to a precise home position — especially useful when working with wide materials that traditionally require the assistance of two individuals. Proprietary "grip fingers" are purposefully designed to securely hold the material throughout the pulling process. Moreover, the Fusion Gripper's construction incorporates a robust carbon fiber beam, ensuring its resilience and longevity under demanding industrial use for many years to come.

The genesis of the Fusion Gripper can be attributed to feedback and requests received from Autometrix customers expressing a need to minimize direct contact with the material. Addressing this demand, the Fusion Gripper delivers high precision and is said to significantly reduce the manual effort required to pull the material by hand. **Autometrix Inc., Booth FF52, autometrix.com**

Source | BYK USA

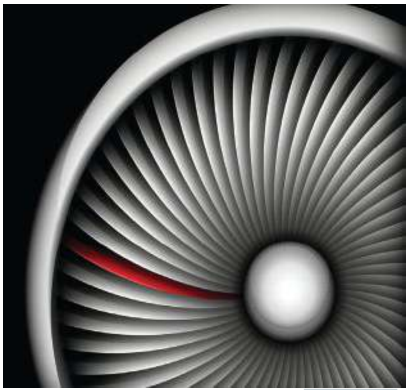
Processing additives achieve improved fiber wetting

BYK USA (Wallingford, Conn., U.S.) presents BYK-P 9920, a processing additive specifically designed for advanced composite fiber-reinforced applications. It offers a number of benefits for composite systems, including significantly improved fiber wetting, which reduces and eliminates dry spots in the finished part, dramatically improving scrap rate and reducing rework. The increased fiber wetting also decreases mold fill times, allowing for faster part production and part turnover.

BYK-P 9920 is also an effective defoamer and air release additive, especially in epoxy systems. This air release behavior is beneficial in composites and floor coatings to eliminate porosity and air voids.

As BYK-P 9920 is high solids and emission-free, it is particularly well-suited for closed-mold advanced composite applications such as epoxy and vinyl ester systems with either glass or carbon fiber reinforcement. The epoxy-functional groups contained in the additive enable embedding into the resin matrix when the material is cured. BYK-P 9920 also mixes easily into liquid resins and is easy to incorporate into any production line at any processing stage. **BYK USA Inc., Booth P22, byk.com**

Inert mineral additive enhances composite resin systems



Source | Cimbar

Cimbar (Chatsworth, Ga., U.S.) is a global supplier of alumina trihydrate, a halogen-free flame retardant and smoke suppressant. ATH is inert and compatible with all composite resin systems.

The company offers a variety of particle sizes and surface treatments to improve mechanical properties and lower overall viscosity. Industrial applications include thermoset plastics (SMC, BMC, pultrusion), elastomers, latex backers, coatings and sealants.

Cimbar's product portfolio also includes barium sulfate, calcium carbonate and recycled mineral filler used in a wide range of markets, including CASE, engineered polymers, friction materials and drilling fluids.

Cimbar, headquartered in Chatsworth, Ga., U.S., operates 18 production sites in the U.S., Mexico, China and Pakistan. **Cimbar Performance Minerals, Booth L16, cimbar.com**


Source | Composites One, the Closed Mold Alliance

Live demonstrations present closed molding advancements

Once again, **Composites One** (Schaumburg, Ill., U.S.) and the **Closed Mold Alliance** — comprised of industry experts from Composites One, Aerovac, Magnum Venus Products (MVP) and RTM North Technologies — along with 15 industry partners, will take center stage when presenting the latest advancements in vacuum infusion, reusable bag molding, light RTM and other technologies. These live demonstrations will take place inside a large, enclosed staging area on the CAMX show floor.

Attendees will see closed molding processes used to build real-world parts for the marine, aerospace, corrosion, automotive and other key markets. Several demos feature the Aerovac Composites One line of vacuum bagging and process materials.

"Our demos are short, easy to understand and provide enough information about a specific process so that manufacturers can decide if they are interested in learning for their operation," says Marcy Offner, director of marketing communications, Composites One. "They will also be filled with tips and tricks that the manufacturer can share with their co-workers at home."

Running continuously from Oct. 31 – Nov. 2, demos include:

- Closed mold three ways: Watch as the same part is built three different ways using reusable bag molding, light RTM and vacuum infusion featuring Aerovac process materials.
- Aerospace demos using different materials and techniques to improve processing efficiency.
- Closed mold tooling demos featuring vacuum infusion and Aerovac process materials.
- An innovative technology demo featuring fast-flow hybrid light RTM by MVP.
- Kitting efficiencies for vacuum infusion and advanced processing ideal for aerospace, wind energy, marine and other industrial markets.
- Light RTM for corrosion-related industries.
- Presentations on OptiSpray Pro from Owens Corning, 3M dustless sanding and AI automation.
- Supplier spotlights and videos to round out each day.

Be sure to bring your safety glasses because the demo area opens up to CAMX attendees on Thursday, Nov. 2, enabling visitors to see finished parts, talk to technical experts and interact with team members.

"Our demos would not be possible without the support of our Closed Mold Alliance partners," says Offner. They include 3A Composites Core Materials, 3M, Aerovac Composites One, AOC, A&P Technology, Chem-Trend, Chomarat, Polytek/Custom Polymer Design (CPD), MVP, Owens Corning, Polynt, RTM North Ltd., United Initiators Inc. and Vectorply Corp., along with *Composites Manufacturing* and *CompositesWorld*, the event's media sponsors. **Composites One and the Closed Mold Alliance Demo Zone, Booth W18, compositesone.com**

Composites distributor highlights product offerings, technical support

Stop by **Composites One**'s (Schaumburg, Ill., U.S.) booth where the company will be featuring the latest products from more than 700 industry suppliers. In addition, displays will showcase safety and aerospace solutions, as well as Composites One's own brand, Aerovac.


Source | Composites One

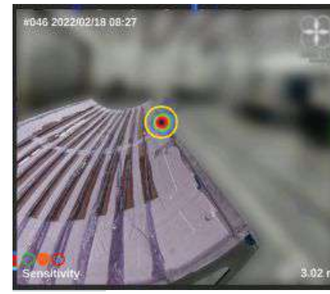
Technical sales representatives will be available to answer questions and offer product-related suggestions. Located throughout North America, they are adept in the latest technologies, products and equipment available in today's marketplace. Together, the reps are said to comprise one of the largest teams of CCT-certified sales representatives in the industry.

The Composites One sales team works one-on-one with customers. Sales representatives share their expertise with customers, providing them with solutions that can help increase their competitive edge.

Regionally based technical support managers provide added support and help to ensure that customers get the answers they need when they need them. In addition to its extensive product line, Composites One offers the technical assistance to educate customers on the proper use of these products in their shop.

Leading the Closed Mold Alliance, Composites One provides manufacturers with the resources and training to help them successfully convert to closed molding. Live process demonstrations will be presented on the exhibit hall floor. **Composites One, Booth W36, compositesone.com**

Acoustic imaging enables vacuum leak detection

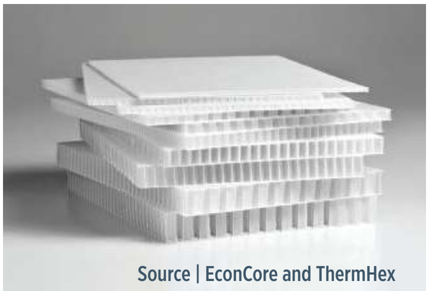


Source | Distran

Distran (Zürich, Switzerland) brings its know-how in gas and vacuum leaks detection through acoustic imaging to composites manufacturing, seeking to eliminate the traditional time-consuming, tedious and user-dependent methods of finding leaks.

Specifically, the company is demonstrating its quick, efficient and easy-to-operate ultrasonic camera. A microphone array of 124 elements and active noise filtering makes triangulating leaks easy and immediate; the locations of leaks provided by the camera are also highly accurate. Moreover, by detecting more leaks before treatment, Distran supports waste reduction, not only during the vacuum bagging process, but also in regard to requiring repairs or new part production.

This technology does not solely detect vacuum leaks through the ultrasound it emits. Rather, through a 180° field of view, it accurately pinpoints leaks in seconds from several meters away, recording pictures and videos to document leak surveys and repair activities. Similar to augmented reality technologies, the Distran ultrasound camera reconstructs the position of the sound source detected in real time and overlays it on a wide-angle optical image. Once pinpointed, bag repair can be carried out immediately. **Distran USA Corp., Booth E30, distran.swiss/en/home/**



Source | EconCore and ThermHex

Thermoplastic honeycomb, lightweight solar modules demonstrate sustainability

EconCore (Leuven, Belgium) and **ThermHex** (Halle, Germany) are providing U.S. industry professionals a first look at new product variations made in Germany. These demonstrations include honeycomb cores in a range of chemistries, such as PP cores and high-performance thermoplastics for aerospace applications, as well as in panels for lightweight solar modules.

ThermHex's production process is based on EconCore's patented production technology, which enables the company to continuously produce honeycomb cores that combine the mechanical properties and the minimal weight of honeycomb with automated and low-cost production, with a thickness range of 3 to 30 mm. Besides weight savings and cost reduction, they also offer improved surface quality over competing materials.

Sandwich panels with glass fiber-reinforced PP UD tape skins and a ThermHex PP honeycomb core will be highlighted at CAMX. These panels are said to offer high rigidity at minimum weight, and are versatile for a range of applications. The use of thermoplastics not only enables the forming of complex, functionalized components, but also has a more resource-efficient and less expensive production process than conventionally produced sandwich components.

A large-sized solar panel module will also be on display. ThermHex and Solarge have intensively collaborated to reduce panel weight by replacing heavy glass with a composite honeycomb structure and polymer frontside. The result is a fully recyclable alternative to more traditional non-sustainable materials. A panel measuring a little more than 2.66 m^2 is said to weigh 14.5 kg, compared to more than 28 kg with the old glass-type model.

EconCore's high-performance thermoplastic cores are based on PPS and PEI polymers. PPS and PEI honeycomb cores offer high levels of strength and stiffness in compression and shear, high-temperature stability and optimized weight-to-cost ratios. HPT honeycombs build on the pre-existing intrinsic benefits of lightweight honeycomb structures by increasing heat stability and fire resistance, making them a suitable choice for applications in railway and aircraft interiors. Together with Airbus, the Technical University of Denmark (DTU) and Fraunhofer, EconCore is currently working on a new technology for a more sustainable type of rudder for a short- and medium-range aircraft based on thermoplastic honeycomb sandwich composites. **EconCore, ThermHex, Booth CC26, econcore.com**

Closed cell foam relied on for high-quality, high-tolerance applications

Elliott Co. of Indianapolis (Ind., U.S.) is a manufacturer of Elfoam, a rigid unfaced polyiso/polyurethane closed cell foam. Elfoam products are available in 2-6 lb/ft^3 densities supplied in blocks, sheets and custom shapes. With a ±300°F temperature range and good compatibility with polyester, vinyl ester and epoxy resin, the foam can be used in a wide variety of applications.

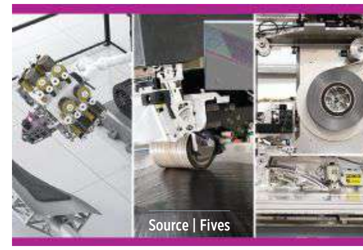

Source | Elliott Co. of Indianapolis

Elfoam sheets can be finished with scoring, perforating, grooving and tapering options. According to the company, its compatibility with numerous composites manufacturing processes, in addition to its high strength-to-weight ratio, makes Elfoam ideal for most core needs.

Other attributes composite customers historically value include radio frequency transparency, a high thermal insulation value and easy machinability when using Elfoam as a lightweight core material. Additional technical information can be found at the company's website.

Elliott Co., a third-generation family-owned business, has been supporting the composite industry with the development of new and innovative product solutions for more than 40 years. **Elliott Company of Indianapolis Inc., Booth AA53, elliottfoam.com**

End-to-end solutions for increasing productivity


Source | Fives

Fives (Hebron, Ken., U.S.) provides highly automated end-to-end solutions for composites manufacturing, covering lamination, forming, inspection and curing processes. Its focus is on precision and efficiency to minimize waste and promote quality.

Comprised of legacy names Cincinnati, Forest-Liné and Lund, Fives is said to hold the world's largest install base of tape lamination and fiber placement machines. Fives offers both standard and customizable composite equipment and automated solutions based on customer needs. Some technologies used in these solutions are the Cincinnati Robotic Viper, Cincinnati Supercharger and in-process inspection (IPI) technology.

Cincinnati Robotic Viper is an AFP machine known for its versatility and large install base. It is designed for various machine configurations, capable of accommodating different shape and size applications.

Fives' Cincinnati SuperCharger ATL machines feature on-head scrap management, high-speed cutting on the fly, configurable platforms and the ability to handle contours and high layup rates.

The IPI technology integrates seamlessly into AFP machines and uses optical coherence tomography imaging to measure defects and tow placement in real time, making it suitable for various composite applications. **Fives, Booth R46, fivesgroup.com**

Your Proven Material Partner for a Sustainable Future

Since Toray's founding, it has been our mission to deliver innovative technologies and advanced materials that provide solutions to global challenges.

Our expansive carbon fiber, thermoset, and thermoplastic composite materials portfolio support structural and non-structural applications while furthering efforts to produce renewable energy, reduce fuel consumption through lightweighting, and improve manufacturing efficiencies.

• Unmatched composites portfolio • Fully integrated supply chain • Material partner from prototype to high-volume production

Visit us at CAMX 2023 to learn more:

CAMX 2023
Atlanta, GA
Oct. 30 - Nov. 2, 2023
Booth # AA9

TORAY
Innovation by Chemistry

www.toray.com

Source | Hennecke Inc.

Hybrid injection technique achieves aesthetic, resilient product surfaces

Hennecke Inc. (Bridgeville, Pa., U.S.) is showcasing the clearmelt process, a technique that combines polycarbonate injection molding with polyurethane flood injection. It coats thermoplastic substrates with transparent or colored polyurethane, yielding scratch-resistant, resilient and functional surfaces for consumer goods and automotive exteriors. This achievement stems from a collaboration with machine manufacturer Engel (York, Pa., U.S. and Schwertberg, Austria), where clearmelt technology was incorporated to safeguard the iconic kidney-shaped front module of the all-electric BMW *iX* and represents one of Hennecke's high-quality, functional surface solutions for automotive.

Hennecke and Engel, with input from suppliers, toolmakers and cleanroom experts, developed a tailored solution for BMW's Landshut plant in Germany. In a cleanroom setting, a heated functional film is backmolded with polycarbonate, flood injected with polyurethane and promptly prepared for further processing. **Hennecke Inc., Booth L54, henneckeinc.com**

Source | herone GmbH

Complex recycled CFRTP parts demonstrate discontinuous fiber advantages

Besides **herone GmbH**'s (Dresden, Germany) standard high-performance thermoplastic and continuous fiber-reinforced hollow profiles, the company is launching a product branch with rCF, with a focus on complex-shaped parts. Available products are offered with an isotropic fiber architecture and a PA6, PPS, PEI and PEEK thermoplastic resin matrix.

At CAMX 2023, herone is showcasing a set of different rCF products primarily based on a PPS resin system. They range from tubes and shafts with integral flanges to complex profiles with changing cross-sections along their profile axis. All of the products displayed are molded in one process step from an almost straight preform, demonstrating the advantage of rCF discontinuous fibers to mold complex composite parts.

Today's available semi-finished, hybrid thermoplastic rCF materials are limited in their level of orientation to provide high-performance, load-adapted fiber architectures. Herone has started to develop these materials further for highly orientated rCF pre-impregnated thermoplastic tapes. The company's aim is to, within the next two years, provide the first rCF hollow part with highly aligned rCF-thermoplastic tapes.

Moreover, herone's primary UD tape production waste is refurbished into tape chips and can be pressed or injection molded to functional elements, which are combined with the rCF profiles, further achieving zero waste production. **herone, Booth N58, herone.de**


Source | Kent Pultrusion

Servo-based pultrusion machines

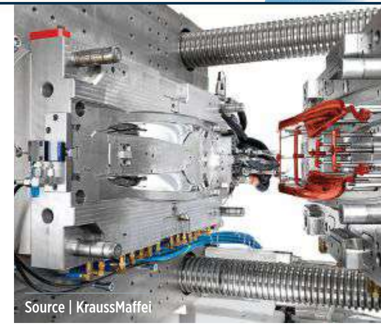
Kent Pultrusion (Kent, Ohio, U.S.) specializes in innovative pultrusion technologies. A division of MNM Manufacturing Inc., the company is established with the support of sister companies Kent Automation and Criterion Machinery Co. which contribute to Kent's ability to manufacture ServoPul pultrusion lines and secondary equipment.

Kent Pultrusion's ServoPul machines introduce servomotor and drive technology into the pultrusion process. These modern technologies enable electric, high-precision control of pulling and clamping forces, feedback monitoring registered to the operating system and an HMI that efficiently provides PLC controls.

The turnkey pultrusion systems are manufactured for flat sheet, structural, complex and custom processing solutions. The ServoPul design is specialized at handling pultruded profiles made of composite materials, consisting of synthetic organic resins composed of long fibers and mats, and glass fiber- and carbon fiber-reinforced polymers.

The company's team of engineers, control specialists and assembly specialists have been built to deliver results through rigorous testing, case studies, and field service and installations. **Kent Pultrusion a subsidiary of Kent Automation Inc., Booth K42, kentpultrusion.com**

3D printing, thermoplastics processing highlights


Source | KraussMaffei

KraussMaffei (Munich, Germany and Hebron, Ky., U.S.) is presenting several technologies — RTM, FiberForm, ColorForm, 3D printing and aviation-related activities — developed by its Lightweight Competence Centre.

KraussMaffei references experience with more than 80 supplied RTM plants including presses, dosing and mixing equipment. Most of these machines have been supplied for automotive applications. Since 2013, KraussMaffei has been active in the technology transfer of HP-RTM to aviation applications, along with in-situ process monitoring.

FiberForm, another technology from KraussMaffei, combines the thermoforming of organosheets and injection molding into one process, resulting in fiber-reinforced thermoplastic components that are particularly lightweight yet feature a high level of strength and structural rigidity.

KraussMaffei's ColorForm technology is based on the principle of multicomponent injection molding, with the second stage involving flow-coating the substrate of the basic body with PUR or PUA.

In the AM field, KraussMaffei has made use of its extrusion know-how, presenting the company's new large-scale, extruder-based 3D printer powerPrint. A variety of thermoplastic materials can be used to create parts up to 2 × 2.5 × 2 m. **KraussMaffei Corp., Booth K15, kraussmaffei.com/en/home**

Source | L&L Products

Versatile two-component, foam-in-place composite material

L&L Products (Romeo, Mich., U.S.) is exhibiting Phaster, a proprietary two-component, ambient temperature curing technology with high adhesion and processing ease in various environmental conditions. Phaster is said to empower numerous design possibilities through a distinctive combination of attributes, enabling customers to solve complex challenges for various fabrication and design needs.

L&L Products will feature Phaster XP-607, a two-component, ambient temperature cured, foam-in-place structural material that can bond to a variety of substrates, fill variable gaps and match irregular surfaces. Phaster XP-607 provides high strength at low density, fast reaction times and optimal adhesion to a variety of substrates and minimal exotherm. This product also provides watertight sealing and corrosion protection to metallic surfaces.

Durable and strong, Phaster XP-607 can be used as a load-bearing grout, structural gap filler and foamable adhesive in architectural repair applications, new construction or other industrial applications. It is well-suited for cavity reinforcement for various substrates where low density, high strength and energy absorbing capabilities are desired, for example, as a crash-durable, lightweight structural reinforcement in vehicles.

Phaster XP-607 also provides strength for structures and panels. The material can retain mechanical fasteners without pullout, including bolts, screws and inserts. It is sandable, machinable and paintable, inherently flame resistant and free of isocyanates and organic volatiles.

L&L Products says it can be cast with polyolefin-based molds, which are more economical and more easily machinable than metal molds and well-suited for low-volume production. Because it foams at sufficiently low pressures, it does not require high tonnage presses, does not deform molds and is easily demolded.

In addition to Phaster XP-607, Phaster product categories include adhesives, sealants and other developments. Phaster foaming and non-foaming adhesives are a range of customizable products that exhibit good adhesion and rapid curing to a variety of substrates with intrinsic flame retardancy. Phaster foaming and non-foaming sealants are engineered to cover a large range of applications from rigid, low-density reinforcements to flexible encapsulants.

L&L Products, Booth EE12, llproducts.com

Kent Pultrusion

ServoPul®

Pultrusion Machines

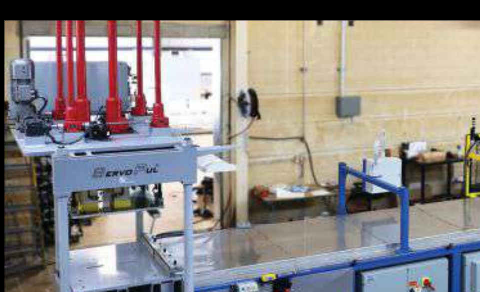
Kent Pultrusion's ServoPul machines introduce Servo Motor and Drive Technology to control pulling and clamping forces and register monitored feedback to the operating system.

In the 1980s, Kent Automation was one of the first to introduce automated solutions utilizing servo electric drives. With this background and expertise, Kent Pultrusion was formed, and entered the market with the first servo electric Pultruders; Kent Pultrusion ServoPul™ Lines.

STRUCTURAL SHAPES

COMPLEX PROFILES

Since then, Kent has revolutionized the pultrusion industry with over 30 ServoPul™ lines installed globally. Using the experience-derived innovation of servo motor and drive technology, Kent Pultrusion's ServoPul™ lines have transformed the conventional hydraulic machines into a thing of the past.



FLAT SHEET

SECONDARY EQUIPMENT

At Kent, we continue to strive for innovation and execution, just as we did over 40 years ago. Our goal is to continue to service worldwide industry leaders with our highly effective and efficient ServoPul™ Pultrusion technologies, one line at a time.

Kent Pultrusion, a division of MNM IND INC, is proud to be leading the way in our industry with our ServoPul® Pultrusion lines and exceptional team of innovators.

www.kentpultrusion.com | +1-330-678-6343 | sales@mnmind.com

Source | Macrodyne

Hydraulic composite presses designed for high-volume production

Macrodyne (Concord, Ont., Canada) is a supplier of hydraulic composite presses and press lines to the plastics industry. Harnessing the power of the latest design tools, including 3D modeling and FEA, the company's team of engineers enable Macrodyne to offer the design, manufacture and servicing of hydraulic presses with up to a 30,000-ton capacity, handling equipment for molds and dies weighing up to 100 tons, as well as the supply and integration of ancillary press line equipment.

A Macrodyne hydraulic composite press is designed for the high-volume production of components ranging from small, thin, precision parts to large, thick parts featuring myriad intricate shapes. The presses are used to produce composite parts of varying complexities in the manufacturing process of thermosets, thermoplastics, elastomers and natural rubbers. Macrodyne presses are available as standalone production equipment or can be integrated with automation to offer complete solutions that are backed by turnkey supply and shipping and logistical support.

Precision, functionality and repeatable performance are key variables considered during the design phase of every project. Hydraulic, electrical and control system components are standard on all equipment manufactured by Macrodyne. The company's focus on quality, innovation and value is said to enable the construction of competitively priced, reliable and technologically advanced production equipment, built with replacement components that can be sourced worldwide.

In addition to supplying new custom hydraulic presses, Macrodyne provides a list of repair and upgrade options for existing presses of all makes and models. Macrodyne's presses, press lines and die-handling equipment serve customers and OEMs in complex industries such as automotive, aviation, oil and gas, and pulp and paper. The company says its team of experts can engineer a solution to meet a customer's needs and offer service and support long after the sale is complete. **Macrodyne Technologies Inc., Booth GG25, macrodynepress.com**

Improved Production Efficiency in Aviation Component Manufacturing with sensXPERT

The aviation industry is facing a monumental challenge: flying must become more carbon-neutral while maintaining consistent safety standards. This not only requires the use of innovative fuels but also the integration of novel, low-emission aircraft components.

However, manufacturing companies find themselves significantly constrained due to a lack of transparency in processes and limited insight into material behavior. The development and production of high-performance components often results in long production cycles and, consequently, substantial costs in both production and energy consumption.

By harnessing cutting-edge technologies such as sensors, robotics, artificial intelligence, and big data analysis, the stability of manufacturing processes is enhanced, development times are reduced, and higher production capacities are achieved—all while simultaneously reducing production and energy costs. This, in turn, leads to an improved environmental footprint.

The sensXPERT Approach

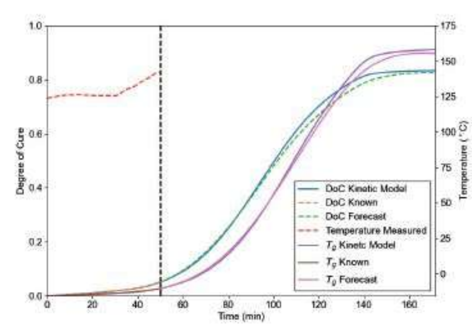
sensXPERT combines the power of data, the latest insights, and advanced AI to fundamentally revolutionize the manufacturing process, making a significant contribution to the concept of the Smart Factory.

The sensXPERT system comprises four main components: material characterization sensors, a corresponding edge device, an interface for the edge device (web app), and a digital cloud service.

Throughout the entire cycle, manufacturing companies gain precise insights into various material and process parameters within the tool. Examples of these parameters include:

- Degree of Cure (DoC)
- Polymerization degree
- Glass transition temperature (Tg)
- Viscosity and flow front position
- Temperature within the tool

And finally, material deviations—caused by aging, non-specification-compliant material, the presence of impurities, storage conditions before shaping, and more.



In conjunction with the sensXPERT Digital Cloud Service, companies optimize even cross-factory, complex production processes. The Edge Interface (Web App) connects multiple machines and locations, enabling real-time monitoring of all production operations across all facilities and immediate intervention when needed.

This efficiency enhancement leads to shorter cycle times, reduced waste, lower energy consumption, and comprehensive cost control. With sensXPERT Digital Mold, cycle times can be shortened by up to 30%, existing waste can be reduced by up to 50%, and energy savings of up to 23% can be achieved.

Achieve sustainable increases in productivity and profitability while simultaneously surpassing all your sustainability goals. With sensXPERT, you stay at the forefront of aviation manufacturing.

Source | Matec Instrument Companies Inc.

Robotic inspection systems maintain process efficiency, productivity

For more than half a century, **Matec Instrument Companies Inc.** (Northborough, Mass., U.S.) has built nondestructive ultrasonic testing solutions. The company provides a full range of in-house services every step of the way, from initial design through system commissioning and training.

Recent years have seen significant advancement in robotic integration technology, and Matec recognizes the potential of robotics in the ultrasonic testing process. Its robotic inspection systems provide machine operators with increased efficiency, reduced physical strain and improved job satisfaction as they can now focus on more complex and engaging tasks. At the same time, companies can enjoy increased scalability, flexibility, quality and consistency and significant time savings.

In light of workforce shortages, automated machine tendering enables a single team member to oversee multiple systems simultaneously. This "one man, one cell" approach is said to deliver increased productivity at a lower cost than the traditional model.

Overall, Matec's ultrasonic testing solutions not only improve inspection accuracy and efficiency, but also enhance safety and reduce downtime. As industries increasingly adopt robotic automation, Matec will be there to provide creative answers to meet its clients' evolving needs. **Matec Instrument Companies Inc., Booth DD49, matec.com**

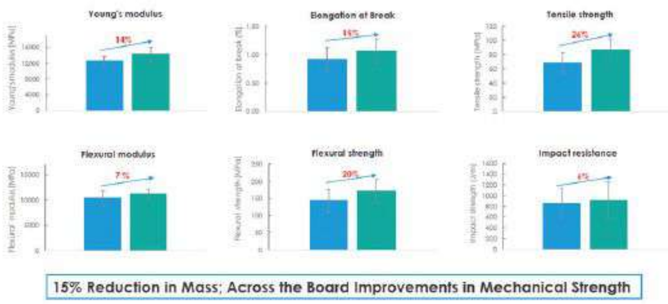
Web tension controller handles composite process needs

Source | Montalvo Corp.

Montalvo Corp. (Gorham, Maine, U.S.) is introducing a generational leap in its family of web tension controllers. Building upon the successes of its Z4, S4 and U4 series of controllers, the company highlights the new Zeus Multi-Zone Web Tension Controller. Configurable for up to eight tension control zones, the Zeus touchscreen puts all of this control in one place. The new controller can handle a majority of process needs, whether they need to include open loop with tension indication, closed loop with load cells, closed loop with dancer, unwind zones, rewind zones or NIP (process) zones in any combination.

Real-time visual feedback provides precise insights into machine operation. Standard features include soft start/anti-coast, web break detection, splice control, progressive fain, set it and forget it technology, recipe storage, Ethernet connectivity and inertia compensation. Montalvo exclusives — open loop torque-sensing and indication and range expansion — are also included.

Rounding out these Montalvo innovations, the company is also introducing the GR series of core chucks. These chucks are entirely customizable and engineered to system needs. With various sizes and grip specifications available, they are built to order and backed by Montalvo Blue Assurance. **Montalvo, Booth U60, montalvo.com**



Source | NanoXplore Inc.

Graphene-enhanced SMC boosts molded component properties

NanoXplore Inc. (Montréal, Quebec, Canada) has developed a graphene-enhanced SMC currently sold under GrapheneBlack SMC. It provides up to 15% weight reduction versus conventional SMC of the same specific gravity at neutral costs to the OEMs through downgauging, which enables the use of less material per part. Other benefits include increased strength (up to 26% higher tensile, compressive and torsional) and stiffness (better vibrational loading resistance), which provides concurrent opportunities to reduce nominal wall stock and a host of other features. The GrapheneBlack SMC high-density grade is currently approved and in production for a large transportation OEM exterior panel application.

Along with SMC materials, the NanoXplore group of companies also offer SMC molding services to end users and OEMs with multiple large-scale SMC presses available. **NanoXplore Inc., Booth S63, nanoxplore.ca**

Source | Nexx Technologies

Resin systems, prepreg architecture

Nexx Technologies (New York City, N.Y., U.S.), the Advanced Materials division of Mitsubishi Gas Chemical America, is focused on providing composite solutions that can improve both fabrication productivity and parts quality.

Nexx Technologies' family of "no freezer" prepregs includes the NT-300, which is well-suited for cosmetic and general purpose applications. It generally produces parts straight from the tool that are paint ready with zero or minimal body shop work required.

For higher demand primary and secondary aerostructure applications, the NT-350HT is a higher strength and higher T_g product intended for these types of applications. The company says the NT-350HT also provides an excellent surface finish and can provide very low void content parts (often less than 1%). It also enables the production of autoclave-quality parts by vacuum bag only. The NT-350HT is also a variable cure material enabling vacuum bag, autoclave and snap cure capabilities (4 minutes at 350°F) with the same material.

In addition to the modified epoxy products, Nexx Technologies also offers the NTC-425 cyanate ester system and NTB-500 BMI, a toughened BMI, designed for high-temperature structures or any application requiring a high T_g and high mechanical properties. **Nexx Technologies an MGC Company, Booth DD36, enduredge.com**


Source | Park Aerospace

Epoxy-based structural film adhesive intended for aerospace, MRO

In May 2023, **Park Aerospace Corp.** (Newton, Kan., U.S.) launched the company's new Aeroadhere FAE-350-1 structural film adhesive product for use in bonding of primary and secondary aerospace structures. Aeroadhere FAE-350-1 is the first offering in the company's new aerospace adhesives product line.

Aeroadhere FAE-350-1 film adhesive is a 350°F (177°C) curing epoxy formulation film adhesive designed for composite-to-composite, composite-to-honeycomb, composite-to-metal, metal-to-metal and metal-to-honeycomb bonding applications. Aeroadhere FAE-350-1 has demonstrated strong toughness and high temperature capabilities. It is intended to be used in aerospace original equipment and MRO applications.

In addition to Aeroadhere, Park's offerings include thermal protection system (TPS) resin systems, reinforcements for TPS, structural polymer material systems for space applications, structural design and composite strut fabrication.

Park Aerospace Corp. develops and manufactures solution and hot melt advanced composite materials used to produce composite structures for the global aerospace markets. **Park Aerospace Corp., Booth N28, parkaerospace.com**

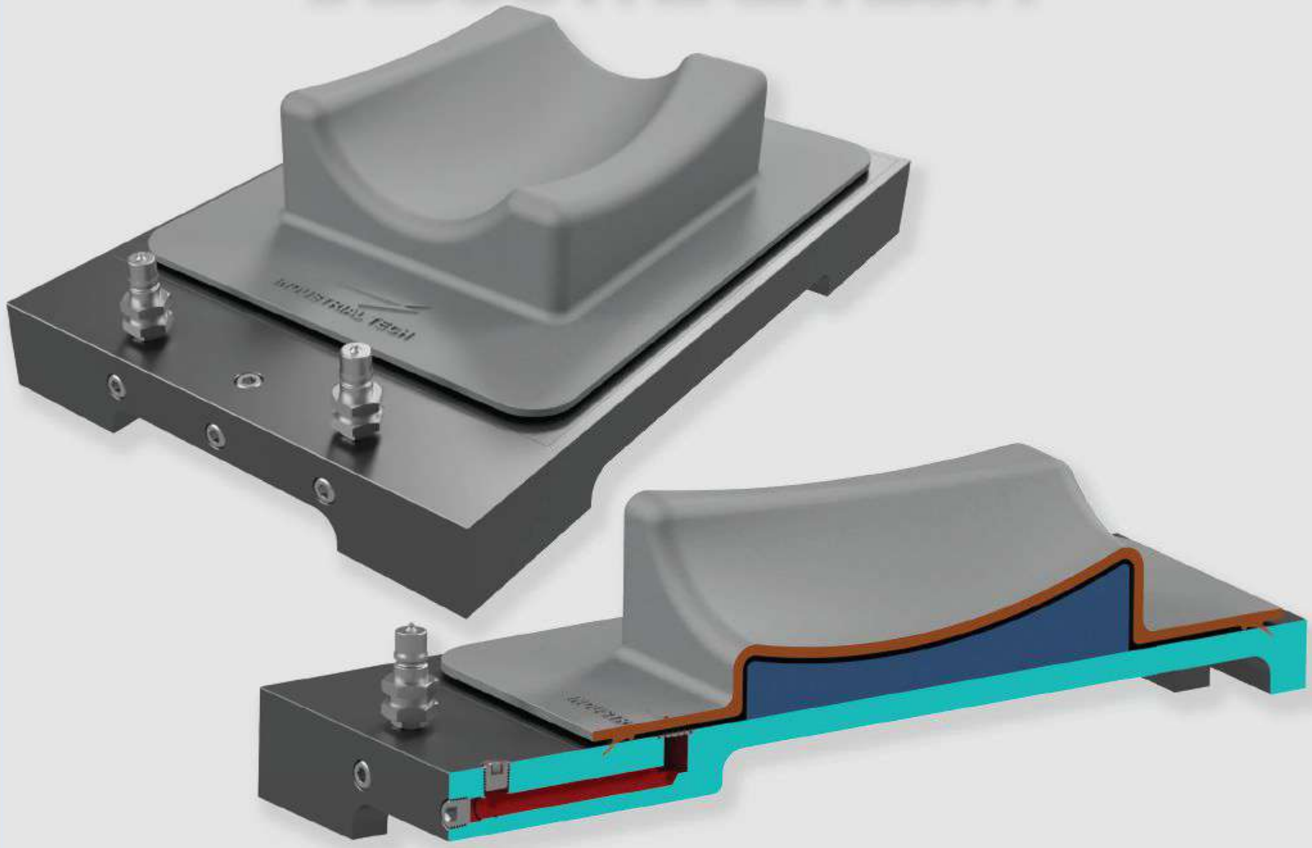

Source | Pelican Wire

Custom wire solutions

The composites industry is a strategically significant market for **Pelican Wire** (Naples, Fla., U.S.). Specializing in custom wire manufacturing, the company focuses on crafting solutions using fine gauge copper and copper alloy wires, along with high-temperature insulation used in resistance heating. These solutions serve diverse applications, including resistance heating, temperature measurement, sensing and hook-up wires. The company's capabilities across engineering and manufacturing enable it to address a range of needs — from commonplace uses to more niche requirements.

In one instance, Pelican Wire was approached by a company facing a distinct challenge — it needed help obtaining a specific resistance wire for a composite mold heating requirement. A combination of alloy selection, gauge determination and strategic stranding techniques was selected as a result — in addition to the selection of proper insulation for the wire, considering the wire's small outer diameter. The insulation's custom violet shade was selected to facilitate easy differentiation from other wires.

This example is typical of how the process works at Pelican Wire — the company transforms customer concepts into tangible solutions. Its team of engineers collaborates to use the company's manufacturing capabilities, encompassing custom wire stranding, polymer insulation extrusion and insulation methods involving tapes, glass, textiles, as well as serving and braiding techniques. **Pelican Wire, Booth AA55, pelicanwire.com**



Source | Plasmatreat

Plasma surface treatment applicable across industries

Openair-Plasma treatment from Plasmatreat (Elgin, Ill., U.S.) is said to be able to be used in almost all industrial manufacturing processes.

In industrial application areas, materials like plastics, metals, glass, textiles or films are bonded, printed or painted. The combination of two dissimilar materials imposes difficulty on the way to obtaining new and customized material properties. Without plasma surface treatment, many materials cannot be bonded at all or are bonded poorly. High bonding strength and durable bonding of glass, metal, ceramic and plastics also present challenges for the manufacturing industry. Adhesion improvement via surface modification using Openair-Plasma treatment with simultaneous ultrafine cleaning produces better adhesion capability and bonding strength on the surfaces to be joined.

The process is dry, noncontact, location-specific and fast. Using a comprehensive process control system, the technology is robot-compatible and inline-capable. The production speed is increased by several times, resulting in a reduction in manpower and an increase in productivity. These manufacturing processes are entirely possible without liquid chemical waste because of plasma technology and modern, solvent-free adhesives. **Plasmatreat USA, Booth EE47, plasmatreat.com**

Wide fabrics, powder binders for composites

Source | Saertex USA

Saertex USA (Huntersville, N.C., U.S.) offers a variety of technologies and services to the composite industry. Among these offerings are the XXXL NCFs, powder binders and the company's US Carbon Basic Line.

XXXL NCFs from Saertex USA are 150" wide fabrics that are made in the U.S. A noted feature of this product is its width which enables new areas of application and results in increased efficiency. The fabric is also characterized by its versatility. Despite its width, up to four layers of reinforcement fibers can be processed simultaneously in different angle orientations. The company has created additional capacity to ensure short lead times.

Saertex USA also offers powder binder capabilities for automotive and defense applications. Powder binder is applied to the entire or specific tape widths of Saertex multiaxial fabrics to achieve dimensionally stable preform production, no wash-out (e.g., RTM) to ensure improved quality and second shaping possibilities.

The US Carbon Basic Line from Saertex USA is a standard product range with fast delivery because of available inventory in North America. The products of the Basic Line are available from stock in North Carolina with the potential to be delivered to North American customers in a few working days, offering an economical solution for small- and medium-sized order quantities. **Saertex USA, LLC, Booth R18, saertex.com**

Source | SWORL

Reusable vacuum bagging, vacuum sealing

SWORL (Hutto, Texas, U.S.) has developed a new tool for use in the vacuum sealing of reusable silicone bags (membranes, foils). The proprietary, reusable sealing profile can be easily added to existing or new molds for forming redundant vacuum-tight seals between tool flanges and production-friendly SWORL spray-applied, reusable silicone vacuum bags. These advantages eliminate open molding, disposable bags or heavy upper molds, scrap parts, and excess resin consumption and voids. Demonstrations of the spray-fabricated vacuum bags and sealing technology will be demonstrated at SWORL's booth.

Based on SWORL's proven V-groove sealing technology, this new product is capable of reducing the time required to perfect a vacuum seal and contributes to more efficient manufacturing of void-free composite parts with high glass content that are processed via oven, autoclave or infusion. The new product is also ideal for creating robust silicone bags with high-integrity vacuum seals on legacy tooling or molds with narrow flanges; the seals are said to meet and exceed aerospace vacuum requirements for leak tests and eliminate blown bags.

SWORL reusable silicone vacuum bags are spray-made to net shape, reducing labor time when installing or removing and reducing resin waste, increasing part strength while also improving part quality. **SWORL Reusable Vacuum Bags, Booth Z48, sworl.net**

Advanced thermoset, thermoplastic carbon fiber lines

Source | Teijin Carbon America

Teijin Carbon America (Rockwood, Tenn., U.S.) presents its Tenax carbon fibers and composites as solutions for aerospace, automotive, industry, energy, infrastructure, electronics and sporting goods.

Tenax high-strength continuous filament fibers include a range of standard, intermediate and high modulus products and are available in tow sizes from 1K to 48K. Ideally suited for all common processes, Tenax filament yarn is surface treated to improve fiber-to-resin interfacial bond strength. In addition, fiber sizing is applied to protect the fiber and to improve handling and wetout.

Tenax short fibers enhance properties in thermoset and thermoplastic applications. Their easy-to-handle bundle sizes and modifications enable use in high-temperature thermoplastics.

Pyromex is an oxidized PAN fiber with non-flammable and non-melting characteristics. Pyromex is ideal for critical aerospace applications and is widely used in welding blankets, fleece insulation and carbon/carbon brake applications.

Tenax ThermoPlastics are materials that, when combined with rapid production processes, allow for fast processing, low scrap rates, high mechanical performance, chemical resistance and recyclability.

Teijin has more than 30 years of expertise in the manufacture of carbon fiber. **Teijin Carbon America Inc., Booth S8, teijincarbon.com**

Dry carbon fiber reinforcement for resin infusion

TeXtreme Gapped UD from **TeXtreme** (Foretagsgatan, Sweden) is a flat, UD reinforcement material integrating 0.3-mm gaps between fiber tows, designed for resin infusion processes. These gaps function as efficient resin and air evacuation conduits, expediting consistent wetting of the material while preserving its mechanical attributes. With an FVF of more than 60%, TeXtreme Gapped UD offers mechanical characteristics aligned with UD prepreg solutions.

Source | TeXtreme

The TeXtreme Gapped UD material is designed to fit the format of standard AFP and ATL machines. TeXtreme says the material has easy handling, cutting and preforming, leading to reduced layup time and waste. TeXtreme Gapped UD provides other advantages, such as high permeability, enabling fast wetout over large surface areas. The material is a cost-effective solution that minimizes the need for cold storage and short-term considerations.

TeXtreme Gapped UD is available in a variety of sizes and fiber weights, including ¼", ½", 1", 1.5", 2", 12", 24" and 50" UD formats employing carbon fiber, with other fibers available upon request. The material can be supplied with fiber areal weights (FAW) spanning from 100 gsm to 400 gsm. The product is also offered in woven 0/90° and woven +/-45° formats, with the woven variant supplied with FAW ranging from 200 to 800 gsm, spanning a width of 1m. **TeXtreme (Oxeon Inc.), Booth BB47, textreme.com**

Infrared NDT well-suited to demanding in-service, manufacturing and research applications

Thermal Wave Imaging Inc. (TWI, Madison Heights, Mich., U.S.) exhibits its high-performance thermographic NDT solutions. These systems are high-precision, cost-effective solutions well-suited to some of the most demanding inspection challenges when compared to ultrasonic testing (UT) or X-ray systems. From portable handheld units for in-service inspection to fully integrated test cells for quality assurance (QA), TWI technologies offer several benefits.


Source | Thermal Wave Imaging Inc.

TWI's patented thermographic signal reconstruction (TSR) method uses a quantitative signal-based approach to provide precise, repeatable output with optimized depth range and resolution. Its systems enable high sensitivity and range in flaw detection, but they are distinctive in their ability to provide physical information about the part under test. TWI systems are used to measure thickness, depth, thermal diffusivity, conductivity or porosity in manufacturing and QA. Moreover, the company's thermographic NDT line provides dedicated hardware such as Precision Flash Controller which allows high-resolution control of flash duration and timing for critical measurement applications, and the ProjectIR system for TSR capability.

TWI works closely with customers to match systems and components with their specific requirements and help integrate thermography into their NDT/quality process. **Thermal Wave Imaging Inc., Booth AA48, thermalwave.com**


Source | Vartega

Carbon fiber recycling to make composites more accessible, circular

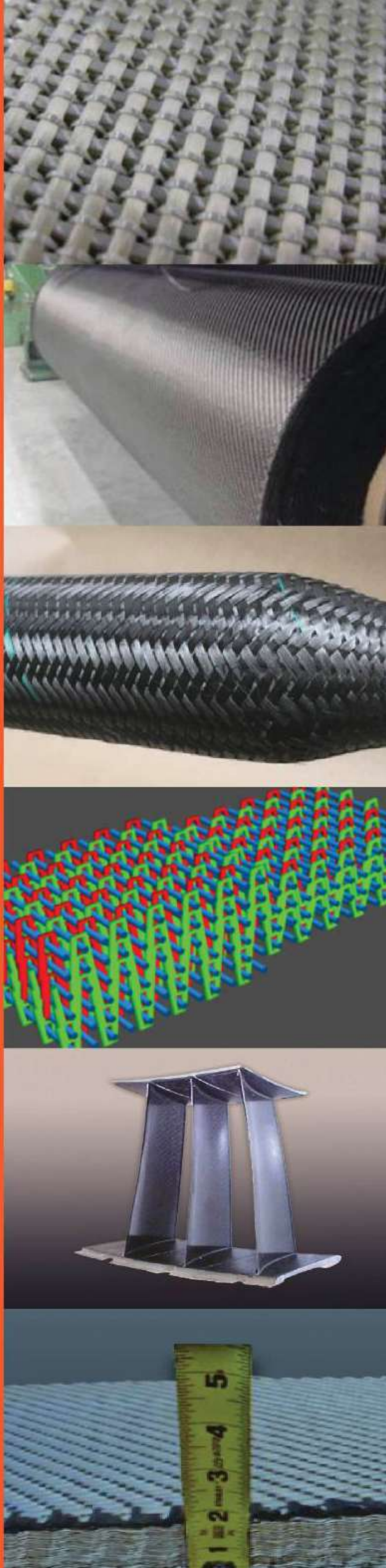
Vartega (Denver, Colo., U.S.) recycles carbon fiber and composite materials into near-virgin-quality chopped fiber to support manufacturing of high-strength thermoplastic and thermoset components.

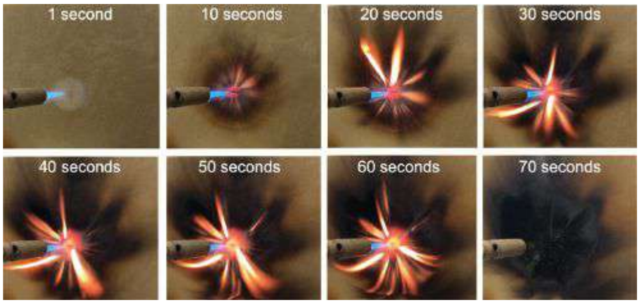
The company's patent-pending fiber postprocessing technology converts discontinuous virgin and recycled carbon fiber into easy-to-handle feed bundles, maintaining original mechanical properties at a lower cost than the virgin material. The process densifies loose, fluffy fibers into aligned fiber bundles with higher bulk density and improved flowability for use as a drop-in replacement to traditional virgin carbon fiber in pellet, flake or stick form.

The resulting EasyFeed Bundles are low dust, with fairly uniform fiber lengths. The bundles enable thermoplastic compounding via traditional equipment to serve injection molded composite material applications; they are compatible for use with various thermoplastics including ABS, PLA, PP and PA. Vartega also supplies recycled carbon fiber in other formats for compression molding, AM and other composite material manufacturing processes.

Vartega is showcasing its recent partnership with Mito Materials (Indianapolis, Ind., U.S.) to launch a combination of Vartega's carbon fiber, Fenix Fiber, with Mito's functionalized liquid graphene Ligra, under the Vartega product name Fenix Fiber+. This development is capable of creating composite structures with higher stiffness and strength than carbon fiber alone.

Vartega's EasyFeed Bundle chopped fiber format, along with several examples of highly filled thermoplastics incorporating Vartega's recycled carbon fiber into structural applications, will be on display. Specific parts include a cross-car beam, automotive seat structure, bicycle wheels and more. **Vartega, Booth S36, vartega.com**





Source | Trimer Technologies

FST-rated thermoset resin with rapid, tunable cure is designed for infusion

Trimer Technologies (Plymouth, Mich., U.S.) has developed Harp Rapid, a low-cost, nonhalogenated and styrene-free thermosetting resin for resin infusion processes, which can greatly exceed the fire, smoke and toxicity (FST) rating for aircraft interiors defined in FAR 25.853, while featuring a V0 and Class A E84 rating. Moreover, Harp Rapid offers a fast, tunable cure profile; the novel resin system can cure in as little as 30s at 250°F, achieve a T_g >700°F and is said to attain mechanical properties equivalent to the highest performance polymers used in the aerospace industry.

Trimer says it has developed the technology required to control the resin system's latency such that the reactivity can be tailored to provide a designed working life and cure rate. While the company's fastest resin cure is achieved in as little as 30s, this system provides a 1-hour working life, enabling the infusion of large structures. Specifically, the resin is designed as a low-viscosity infusion resin that can be processed through RTM, VARTM or casting processes, providing significant cycle time reduction compared to existing state-of-the-art materials. For instance, Trimer has demonstrated a cure cycle that is eight times faster than current state-of-the-art resins used in Ford's F150 fiberglass leaf spring.

The company has also developed internal mold releases that enable the manufacture of fire-resistant pultrusions. Traditional FST-rated pultrusion resins either require bromination or use phenolics which produce low-quality and low-strength pultrusions. Alternatively, Trimer's Rapid resin system can enable pultruded composites with a short beam strength over 10 ksi while producing better fire behavior than phenolics. In addition to high strength and FST properties, the Harp Rapid resin system offers pull speeds as high as 10 ft/min for efficient manufacturing.
Trimer Technologies, Booth S58, trimer-tech.com

Noncontact, optical testing system takes the guesswork out of traditional test methods

Trilion Quality Systems' (King of Prussia, Pa., U.S.) Aramis optical testing system is a noncontact, material-independent measuring system that provides critical data such as full-field optical strain, 3D displacement and vibration analysis with ease. Aramis is said to be a clear alternative for foil gages and extensometers while being 10 times cheaper than a traditional mechanical gage, 50 times less labor/time-intensive and provides 100 times more data. It offers countless applications from FEA validation, material/structural testing/structural health monitoring and high-speed measurements.


Source | Trilion Quality Systems

At Aramis' core is 3D digital image correlation (3D-DIC), a noncontact measuring technique based on advanced image processing. DIC is capable of mapping 3D coordinates and evaluating displacement and strain maps on the surface of measured samples. This technique uses a stochastic pattern and/or point markers to track the surface of the materials with subpixel accuracy or microns of motion.

Just how accurate? Aramis 3D-DIC can provide precision measurements, matching any clip gage, strain gage or extensometer, according to Trilion. Aramis is certified as ISO 9513 class 0.5 extensometer. Measurements provide thousands of data points in all three axes with high accuracy for material property evaluations.

Trilion's engineering services are provided for customers who want to see how the technology works before committing to a purchase. The company's services are ideal for solving complicated applications or developing measurement methods for critical tests. Trilion provides experienced engineers, with industry-specific experience from material characterization to advanced testing, in a multitude of industries. Engineering services include full-field 3D displacement mapping during component testing, optical strain field for FEA validation, high-speed measurements and vibration analysis and large-scale structural testing.
Trilion Quality Systems, Booth P53, trilion.com

Equipment investment achieves wide-width carbon fiber fabric proficiency

Companies interested in wide-width carbon multiaxial fabrics will have the opportunity to visit **Vectorply Corp.** (Phenix City, Ala., U.S.) at CAMX to learn about the recent installation of a Liba (Naila, Germany) Max 5 spread-tow machine capable of producing carbon fiber fabrics up to 100" wide, in addition to seeing the display of material swatches produced on this new machine. Its addition at the company's headquarters in Phenix City will enable customers to capitalize on the many benefits of wide-width carbon fiber fabrics.

Source | Vectorply Corp.

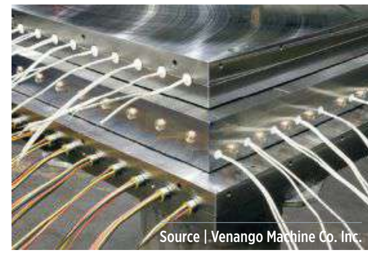
Vectorply produces a wide variety of spread-tow carbon fiber NCFs in various weights and architectures designed for customer-specific applications. Products range from UD to quadraxial, as well as multilayer products combined with various veils, substrates and cores to improve properties and processing performance. The installation of the new 100" wide machine gives customers a source for wide-width fabrics and has also enhanced Vectorply's carbon fiber production capacity for standard width products.

Vectorply says this new capability and capacity increase the company's chance to support the growing carbon fiber production market in North America and abroad. **Vectorply Corp., Booth AA37, vectorply.com**

Heating platens deliver precise, uniform compression molding temperature control

Venango Machine Co. Inc.'s (Erie, Pa., U.S.) MultiZone heating platens with an included control system are said to reduce mold surface temperature variation by almost 400%. This delivers the precise and uniform control necessary when compression molding for a good product and faster recoveries.

When comparing single-zone and MultiZone heating platens, temperature uniformity improved from 25° off target to only 0.4°. Further, the process capability index increased from -1.47 to 2.94 while lowering the standard deviation from 3.2 to 1.08. During molding, the process window reportedly dropped from ±9.6 to ±3.2, ultimately leading to shorter cure times and lower scrap rates.



Source | Venango Machine Co. Inc.

The company's Single-Zone and MultiZone platen control panels include an initial control panel engineering design and specifications; standalone control panel options; single-zone control panel options with complete operator interface HMI system; multiZone control panel options with complete operator interface HMI system; control panel schematics; on-site setup and training for electric platen control panels; and on-site troubleshooting for electric platens and control panels. **Venango Machine Co. Inc., Booth T58, venangomachine.com**

Source | Wabash MPI

Hydraulic presses for compression molding of rubber, plastics, composites

The Genesis Series reflects more than a half century of **Wabash MPI/Carver Inc.** (Wabash, Ind., U.S.) experience in hydraulic press design and construction. Genesis Series presses are hydraulic presses for compression molding of rubber, plastics and composites. They can also be used for laminating and bonding or pressure applications where positive ram control is needed. The company says the presses are rugged enough for 24-hour performance on the production floor, but work equally well as a precision laboratory press.

The hydraulic presses of the Genesis Series are available in 15- to 150-ton models with single or multiple openings. The hydraulic system produces fast closing and opening speeds, making it good for use with many advanced molding compounds. Optional heated platens are available for 500°F, 800°F and 1,200°F operating temperatures, which are required for many other applications.

Wabash MPI/Carver Inc. are manufacturers of compression, vacuum and transfer molding presses for the composites industry. The companies also have a full line of standard hydraulic and pneumatic presses. Wabash and Carver also custom engineer press systems for specific applications. **Wabash MPI/Carver Inc., Booth V52, wabashmpi.com**

Online Masters program is geared toward flexible, affordable learning

Source | Weber State University

Weber State University's (WSU, Ogden, Utah, U.S.) Online Master of Science in Systems Engineering (MSSE) offers the ideal balance of flexibility and affordability, enabling those enrolled to work while pursuing an industry-based program that can be completed anywhere in the world. Offered for under $15K, WSU faculty bring years of industry experience to the academic setting.

Systems engineering is an interdisciplinary field of engineering and management that addresses the analysis, design, implementation, operation, maintenance and retirement of systems. Other systems engineering programs focus on engineering disciplines such as design, industrial, manufacturing, software or management.

The MSSE is created such that the content for professional certification is built into the course. Students will spend 16 weeks learning and studying the bodies of knowledge with faculty members. Quizzes and exams are delivered in similar testing environments and semester projects reflect applications of this knowledge, in preparation for the Certified Systems Engineering Professional (CSEP) exam. **College of Engineering, Applied Science & Technology, Weber State University, Booth H60, weber.edu/east/ms-programs/default.html**

Source | Walton Process Technologies

Thermal processing workflow software effectively monitors composites equipment

Walton Process Technologies (WPT, Mansfield, Texas, U.S.) celebrates the fifth year since its launch of PCS 2.0, the successor to the company's process control software for composite processing equipment.

PCS 2.0 is said to take the best from WPT's established solutions to create even more effective tools and insights to illuminate facility-wide process data, running on a local web server to provide convenient and secure access to that data — from any device and any location.

PCS 2.0 control all autoclaves, presses and ovens, in addition to performing automatic part quality inspections. A View Run screen provides users with run data from all cures, past and present. Pre-run warnings show a series of automatic system checks to ensure the run is configured as intended. This is just two of many features offered.

PCS 2.0 can be paired with the optional Enterprise Server, a locally hosted and centralized server, running reports and monitoring equipment statuses across the entire facility in real time. Analytical features include OEE and queries for detecting performance issues. **Walton Process Technologies Inc., Booth BB53, autoclaves.com**

Source | WSU NIAR

Multi-disciplinary lab supports automated manufacturing research, prototyping

The Advanced Technologies Lab for Aerospace Systems (ATLAS) facility at Wichita State University's National Institute for Aviation Research (NIAR) is a makerspace for industry-scale automated manufacturing research. As a manufacturing innovation center, ATLAS has created a multi-disciplinary manufacturing environment and an engineering education program to prepare engineers and educators for the factory of the future and to aid current workforce in seamlessly adapting to advancements in the workplace through workforce education programs.

ATLAS integrates state-of-the-art technologies at industry scale, including AFP and ATL from multiple vendors, FPP for complex geometries, thermoplastic welding and thermoplastic overmolding for multifunctional integrated structures, and the recent addition of an Electroimpact scalable robotic additive manufacturing (SCRAM) system.

ATLAS staff works closely with industry partners to develop ways to increase efficiency, productivity and quality. Companies that don't have access to advance automated manufacturing technologies can assess state-of-the art manufacturing capabilities, prior to making a large investment. **National Institute for Aviation Research, Booth L36, niar.wichita.edu**

Celebrating 30 years of *CompositesWorld*, Part 2

CW covers key composite developments that have taken place from the 1990s to today in the second part of this two-part retrospective.

By Scott Francis / Editor-in-Chief

The first issue of *High-Performance Composites* — one of two magazines that would later merge to become *CompositesWorld* — was published in September 1993. Source | *CW*

This year, *CompositesWorld* is celebrating its 30th anniversary. The *CW* brand debuted in 1993, encompassing two bimonthly magazines that served the composites industry (*High-Performance Composites* and *Composites Technology*). In 2007, Gardner Business Media acquired the *CW* brand, and in 2015 the two magazines were combined into the monthly *CW* magazine you know today. Since its inception, *CW* has made it its mission to bring readers the latest industry news and product announcements, insightful technical articles, composites manufacturing facility tours and much more.

As part of our 30th anniversary celebration, we continue our look back at some of the composites industry milestones of the last three decades, and highlight some of the relevant stories that *CW* reported during that time as additional references. Part 1 of our two-part retrospective can be found online or viewed in the September 2023 issue.

1990s

Composite materials have enabled wind blade designs to increase in size.
Source | Thinkstock

The 1990s were a time of significant growth and development for composite materials in various applications. R&D efforts were yielding material options with improved durability and higher strength-to-weight ratios, as well as fatigue and corrosion resistance. Increased interest in using composites for lightweighting led automakers to begin exploring composites for applications such as body panels and interior parts.

During the '90s, composites also continued to grow in popularity in sporting goods applications and the marine industry. The wind energy market adopted composites for use in wind turbine blade designs, which were growing in length and required increasingly lighter and stronger materials. Because of their high strength and corrosion resistance, composites also found their way into civil engineering projects such as bridge components, architectural elements and more.

Another big story of this decade was the incredible strides that were taking place regarding composites use in the aerospace sector. In 1995, the Boeing 777 entered service, featuring a significant amount of composite components — the complete tail assembly, including horizontal and vertical stabilizers, elevators and rudder, were all constructed of composite materials.

The 1990s also saw a great deal of innovation in composites manufacturing techniques. This included improvements in automated layup processes, leading to increased production efficiency and lower costs. It was also a time of continued research into new composite materials, including nanocomposites and hybrid materials.

LEARN MORE

Composite materials found increased adoption in a variety of markets during the '90s.

Innovation drives automotive SMC | short.compositesworld.com/automotiveSMC

The growth of wind turbine blades | short.compositesworld.com/WindBladesGetBigger

How have composite bridges measured up? | short.compositesworld.com/CompositeBridgesMeasureUp

While ATL and AFP were originally developed in the '70s and '80s, the technologies evolved and improved during the '90s and played a large role in advancing the use of composites in aerospace | short.compositesworld.com/ATLAFPmegatrendsaero

2000s

During the 2000s, the use of composites in commercial aerospace continued to grow. In 2002, the Airbus A340 entered service as the first aircraft to feature thermoplastic composite wing components. Designs for the Airbus A380, the world's largest passenger plane, were finalized during the early 2000s.

In 2007, Boeing introduced the 787 *Dreamliner*, an airplane that marked a major milestone for the widespread adoption of composites in commercial aerospace. Composite materials comprised more than 50% of the aircraft's structural weight.

Of course, during this time, in addition to commercial airliners, composite materials were finding increasing use in a variety of aircraft programs from business class jets to general aviation to defense.

Meanwhile, the automotive industry continued to explore composites for lightweighting. They found their way into body panel components in various luxury cars and larger production programs such as the Chevrolet *Corvette*.

About 22% of the Airbus A380 is made up of composite materials. Source | Airbus

The Boeing 787 *Dreamliner* is the first airliner to feature an airframe constructed primarily of composite materials. Source | Boeing

Lockheed Martin's F-35 *Lightning II* features an all-composite skin. Source | Lockheed Martin

LEARN MORE

Composite components cut weight and boosted performance in defense and commercial aerospace, including Airbus airliners:

A look at the history of thermoplastic composite use in aerospace | short.compositesworld.com/themoplasticaerocomplist

How Boeing set the pace for composites use in large civil aircraft | short.compositesworld.com/Boeing787dreamliner

Composite aircraft propellers | short.compositesworld.com/compositepropellers

Composites use in the F-35 | short.compositesworld.com/compositesinF35

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2010s

The 2010s saw composites use ramping up in infrastructure due to their durability and corrosion-resistant properties. Composite materials also continued to play a role in renewable energy applications, as originally seen in the 1990s, particularly for lightweighting wind turbine blades made larger for offshore wind farms and more efficient repowering of early onshore farms.

As the automotive industry looked to lightweighting as a way to meet stringent fuel efficiency standards, composites found increasing use in mainstream vehicles as opposed to being relegated to luxury and high-performance models.

At the same time, concerns about sustainability and environmental responsibility within all areas of manufacturing were on the rise. Research increased to find new methods for composites recycling and reuse and to recover valuable carbon fibers from composite waste.

By the end of the decade, three of the most advanced airliners in the world — the Boeing 777X and 787 and the Airbus A350 — were all in production, each using composite materials in unprecedented quantities. The time was ripe for the development of a New Midsize Airplane (NMA), which was expected to use an even larger percentage of advanced materials.

And then in late 2018, the Boeing 737 MAX suffered the first of two fatal crashes that would ground the entire fleet. Ramifications of the 737 MAX disaster rippled through the entire aerospace industry. The disruption was soon amplified by the appearance of a new coronavirus variant.

The BMW *i3* marked a shift in the use of composites in vehicles, putting more focus on lightweighting for practical purposes. Source | BMW

LEARN MORE

Composites use grows in construction and infrastructure projects and mainstream vehicles, while new recycling methods are on the rise:

As wind blades grew in length, so too did the need for carbon fiber in reinforcing spar caps | short.compositesworld.com/windblades-carbon-glass

Inside the production of the BMW *i3* | short.compositesworld.com/TourBMWi3

Recycling carbon fiber | short.compositesworld.com/CFRPlifecycle

A series of unfortunate events | short.compositesworld.com/BlackSwans

2020 and beyond

In early 2020, the COVID-19 pandemic quickly spread, and by spring of that year the entire world was in the midst of a medical crisis that touched every aspect of society. Reduced demand for air travel had a ripple effect on the entire aerospace supply chain, disrupting production programs. The pandemic sparked workforce shortages and supply chain breakdowns that plagued all areas of manufacturing. In the face of these challenges, many composites manufacturers and suppliers turned their efforts toward R&D, exploring new advancements in materials, processes, automation and digitalization.

As the global economy continues to recover, the whole of manufacturing will continue to evolve with an increasing focus on sustainable, environmentally conscious materials and processes. We are already seeing this as industry leaders ramp up the introduction of bio-based polymers and fibers and performing lifecycle analysis (LCA) for their products and processes to the development and implementation of equipment to reduce their carbon footprint.

In the last few years, *CW* has seen trends in other applications as well. These include hydrogen storage, increased adoption of thermoplastics over thermosets — both of which have ties with sustainability initiatives — an enhanced focus on New Space exploration and a rapidly growing subset of aerospace: advanced air mobility. Where these trends will take us still remains to be seen, but it is clear that composites, no matter their application, will continue to be explored not only as replacements for traditional materials, but as material solutions that make emerging technologies possible. *CW* — and the composites industry as a whole — are already looking ahead to the next 30 years. CW

ABOUT THE AUTHOR

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Engine vane demonstrates potential for gapped, unidirectional dry fiber for infusion

GKN Aerospace and its partners developed an aircraft demonstrator component made with TeXtreme's latest Gapped UD material, proving out a dry, infusible tape meant to compare in performance to UD prepreg.

By **Hannah Mason** / Technical Editor

Demonstrating high infusibility with high performance

This aircraft engine guide vane demonstrator, built by GKN Aerospace and partners, was developed to test TeXtreme Gapped UD, a unidirectional (UD) spread-tow carbon fiber product from Oxeon AB that shows potential for UD prepreg-like properties in an infusible fabric. Source (all images) | TeXtreme

»As sectors of the aerospace industry look to adopt composite materials for more programs — and programs with high volume requirements, especially — replacing traditional prepreg layup and autoclave cure with lower cost, faster processing methods like resin infusion is increasingly attractive — that is, *if* the same quality standards can be achieved.

In recent years, a number of materials and equipment suppliers have introduced products and solutions that aim to balance high performance with high volume processability such as in automated resin transfer molding (RTM) systems (see Learn More). One relatively new product is a dry, unidirectional (UD), spread-tow tape called TeXtreme Gapped UD, developed by TeXtreme (Boras, Sweden), a registered trademark of spread-tow carbon fiber material developer Oxeon AB.

As debuted at JEC World 2023 in Paris, France, TeXtreme Gapped UD is being used as part of an ongoing demonstrator project with GKN Aerospace (Solihull, U.K.) targeting the aerospace composites market.

Developing TeXtreme Gapped UD

Oxeon first introduced its TeXtreme spread-tow carbon fiber fabrics in 2005. For these materials, UD carbon fiber tows are "spread" into a thinner, flatter form, resulting in a lighter material with straighter fibers and greater impact resistance. These tapes can then be used in automated tape laying (ATL) or automated fiber placement (AFP) processes, or to produce woven fabrics or noncrimp fabrics (NCF).

Andreas Martsman, cofounder and VP of marketing and sales at TeXtreme, explains that TeXtreme Gapped UD was developed in response to requests from customers in the aerospace sector who wanted to replace UD prepreg with infusible materials. "We started by experimenting with infusion of our regular spread-tow tapes, but when you spread out the fibers like this, you also close everything up and there's a very high fiber volume content," Martsman says. "This is a bit of a drawback when you're trying to infuse it with resin."

TeXtreme's team went to the drawing board to develop a dry, spread-tow UD tape specifically suited for infusion, but with the high performance that comes from straight, UD fibers. "The answer was creating gaps in the material for resin to infuse into," Martsman says, "but that was also a challenge. How big do the gaps need to be? How do you keep them uniform and maintained over different surfaces? So, we had to create an architecture that was robust and stable enough to ensure quality and control during infusion and in service."

He explains that to do this, TeXtreme uses an in-line vision system during manufacture of the tapes for the highest possible control of gap width and frequency. Typical gaps are 0.3 to 0.4

millimeter in width, but TeXtreme can tailor the width and frequency to enable slower or faster permeability as needed.

After a 5-year development process, the resulting TeXtreme Gapped UD product was officially released at JEC World 2023. It is available in a variety of sizes and fiber weights — and as woven fabrics, if desired — and is said to enable easy handling and resin permeability with fiber volume fractions (FVF) of up to 60%.

Martsman adds that the tapes can be customized to fit a customer's needs, as they are able to be produced from a wide variety of fibers (various grades of carbon fiber, glass fiber or aramids) and resins (epoxies, various thermosets, even thermoplastic resins). "You can also slice the tapes down to narrower widths, maybe with just one gap in the middle, for example, and then use it for AFP layup," he says.

Since its launch in spring 2022, Martsman reports that TeXtreme has begun selling material to sporting goods and industrial customers, with a few sports applications made with the material already in production.

Working toward commercial applications in the aerospace market, earlier this year TeXtreme debuted the first results of its ongoing demonstrator program with GKN Aerospace incorporating the Gapped UD composite material.

First aerospace demonstrator: GKN Aerospace engine guide vane

"We have worked with GKN Aerospace for several years on different types of materials and development projects, and when they began looking into new materials for use in RTM, we introduced the Gapped UD tape we had been working on," Martsman says.

Previously, the company had worked with typical infusible materials like dry NCF or dry woven fabrics. However, Fredrik Ohlsson, product development director at TeXtreme, explains that any kind of weft-direction stitching in a dry fabric, even the relatively minimal stitching threads in an NCF fabric, "creates a small kink in the warp direction tow, where it is interrupted by the stitch. In compression, that little deviation from the perfectly straight fiber initiates a point where the structure becomes weaker." He explains that to account for this weakness, parts made from infused NCF have to be overdesigned, with additional plies and therefore increased thickness and weight to the part. "With our materials, on the other hand, you have absolutely no deviation both in and out of plane, and you can therefore optimize both the material use and weight," Ohlsson says.

Why not use a UD prepreg? "With a UD prepreg, you have the absolute straightness of the filaments and you have the resin there exactly as you want it, but you also have drawbacks with respect to autoclave curing, and logistics such as cold transport and shelf life, which are especially problematic when you're trying to scale up production," Ohlsson explains. "So, many companies want to move toward infusion, and we want to aid this process with our material. We're aiming at prepreg properties with an infusible material. It's all reflected by the FVF we can reach using our »

Gapped UD tape

TeXtreme claims precise control of gap width and frequency within its UD tape product. The company also offers woven fabrics made with gaps for better resin permeability.

Guided layup

For the GKN guide vane demonstrator, multiple plies of TeXtreme Gapped UD were laid up at varying orientations for the desired thickness and curvature.

Into the press

The GKN demonstrator guide vane is infused with resin under pressure and heat.

Continuing developments

The original guide vane demonstrators were showcased at JEC World 2023, followed by continued work throughout this year by the TeXtreme and GKN Aerospace teams to optimize the materials and process.

materials. Infusible materials normally have very open structures to allow for infusion of the resin and air evacuation, but this means a relatively low FVF. With our material, we have very precise, designated flow channels for introduction of the resin and to evacuate air for that low void content, but the material is tight enough to also reach an FVF up to 60% for the higher mechanical properties possible with more fiber."

In collaboration with testing and demo specialist Produktionstekniskt Centrum (PTC, Trollhättan, Sweden) and with financial support from Tillväxtverket (The Swedish Agency for Economic and Regional Growth) and regional council Västra Götalandsregionen, GKN Aerospace and TeXtreme began a demonstrator project at GKN's Trollhättan, Sweden facility.

An engine guide vane — a curved panel for directing gas, water or air within a turbine — was selected as the demonstrator component, based on a typical customer design from GKN. "It has a complex geometry with double curvatures, and is fairly thick compared to, say, your typical single-ply, flat test panel, which is good for demonstrating infusibility of the material over differing thicknesses and over curves," Ohlsson explains. "The load case is also very complex, so performance, especially in compression, is critical for a part like this."

The part was designed as a multi-ply, rectangular structure with varying thickness along the part, up to 10 millimeters thick in the center section. For this project, an intermediate modulus carbon fiber and Hexcel (Stamford, Conn., U.S.) RTM6 epoxy were used. "We wanted to start with materials most similar to what GKN had been using previously, to give an apples-to-apples comparison," Ohlsson says.

+ LEARN MORE

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

Read about Airborne's work in automated RTM | short.compositesworld.com/AirborneAPP

To manufacture the demonstrator part, the plies were cut via a Zünd (Altstätten, Switzerland) automated cutting system. The goal was to simulate use of the material in a high-volume, automation-driven production process, explains Guillaume Moreau, project manager for product development at TeXtreme, and to show that the material handles well with GKN's automated equipment. "Unlike a typical dry fabric, there is no fraying at the edges when it's cut," he adds.

Guided by a laser projector, technicians then laid up the plies onto a mold and debulked under a vacuum bag to create the preform. The preform was then transferred to a closed mold, and loaded into a Langzauner (Lambrechton, Austria) compression press, where resin was injected under heat and pressure to complete the RTM process.

The first demonstrator parts were completed in late 2022 and displayed in April 2023 at JEC World. Ohlsson explains that after this initial success, the teams are continuing to work on adjusting process parameters and material characteristics for an optimized final product. Next, the teams also plan to evaluate additional materials, such as alternative fiber configurations and tougher epoxies, with the same part, aiming for mechanical testing to compare the properties of various Gapped UD guide vanes with each other and with traditional NCF composite versions.

Ultimately, the goal is to optimize the materials and process for adoption by GKN Aerospace for use on a production part, and for TeXtreme, the learnings gained from this first program will help guide its development of Gapped UD materials for other customers and end markets. "There's a lot of work to do, but there's a lot of potential for a UD infused fabric, both in aerospace and in markets like marine, wind and more," Ohlsson says. CW

ABOUT THE AUTHOR

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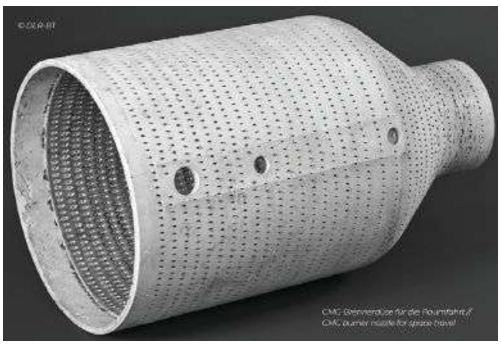


CMC scales for growing, faster, hotter applications

GE Aerospace has pushed CMC production to new levels (top left) to meet aviation's need for faster, more efficient engines. Other growing markets include space, for parts like rocket nozzles (lower left), and hypersonic vehicles, like those being commercialized by Hypersonix (lower right). To meet this demand, faster processing is maturing, such as MATECH's FAST sintering (top center) used to densify C/SiC and SiC/SiC CMC in <10 minutes. CMC fiber is also being produced in Europe, such as DITF's OxCeFi fibers (top right), successfully braided and tested in OCMC parts and being commercialized to industrial scale by Saint-Gobain.

Source | (top left, clockwise): GE Aerospace, MATECH, DITF, Hypersonix and ©DLR via the Ceramic Network

A new era for ceramic matrix composites

CMC is expanding, with new fiber production in Europe, faster processes and higher temperature materials enabling applications for industry, hypersonics and New Space.

By Ginger Gardiner / Senior Technical Editor

»Ceramic matrix composites (CMC) use ceramic fibers in a ceramic matrix to enable high-performance structures at high temperatures. For example, the silicon carbide (SiC) fiber-reinforced SiC matrix (SiC/SiC) CMC that GE Aerospace (previously GE Aviation, Evendale, Ohio, U.S.) produces for LEAP engine turbine shrouds can withstand 1,300°C, providing much higher resistance than metal superalloys like Inconel, but at one-third the density. This unique combination of properties has helped the LEAP engine run hotter with less cooling, improving efficiency to burn 15-20% less fuel, with lower emissions and maintenance. The GE9X engine, with five CMC parts, will reportedly be the most fuel-efficient engine ever built for a commercial aircraft when the Boeing 777X enters service in 2025.

Meanwhile, supersonic (Mach 1-5), hypersonic (Mach 5-10) and high-hypersonic (Mach 10-25) vehicles are in development that may need CMC not just in the engines but also in the airframes. For example, due to air friction from traveling at Mach 5, the nose cone and leading edges of such vehicles can see temperatures up to 1,600-2,800°C. R&D into *ultra-high temperature* CMC (UHTCMC) is aiming for service temperatures as high as 3,500°C.

CMC is also increasingly being sought for use in nuclear energy and other power generation plants (e.g., gas turbine, solar, hydrogen) as well as for thermal processes in industry. Again, higher temperatures increase efficiency. For example, prototype CMC reaction vessels for steam cracking hydrocarbons have shown as much as 50-60% improvement. However, there has been a limited supply of aluminum oxide (Al_2O_3) fibers used to reinforce the oxide matrix in such OCMC applications, says Denny Schüppel, managing director for the Ceramic Composites network. “High-performance OCMC use almost exclusively Nextel 610 and 720 fibers from 3M [Minneapolis, Minn., U.S.]. Other suppliers have left the market, and Nitivy [Tokyo, Japan] fibers with 85%+ oxide content are still in development.”

But now, oxide fiber production is preparing to double, says Schüppel. Founded in 2008, and now part of the global association Composites United e.V. (CU, Berlin, Germany), Ceramic Composites has helped its members bring new CMC fibers to serial production. These include oxide fibers from RATH Group (Mönchengladbach, Germany) working with Fraunhofer ISC-HTL (Bayreuth, Germany) and also Saint-Gobain (Courbevoie, France) in collaboration with DITF (Denkendorf, Germany). Both groups are aiming to start continuous fiber production by 2024-25. BJS Ceramics (Gersthofen, Germany) started producing continuous SiC fibers in a pilot plant in February 2021, and has received investment from aircraft engine and components manufacturer ITP Aero (Bilbao, Spain).

Another challenge is lengthy production times because CMC fibers and parts typically require multiple, high-temperature thermal cycles and process steps. However, global R&D is advancing new manufacturing technologies and also targeting sustainability. This article will explore some of these developments as well as CMC’s evolving applications and supply chain.

Industrial production in Germany

Though Germany has had significant CMC research for decades, the Ceramic Composites network aims to accelerate widespread implementation of new CMC technologies. It works to disseminate information, connect industry players for technology transfer and assist companies with government support and funding. “CU and Ceramic Composites have worked with our members to receive increased EU and German funding for a wide range of projects,” says Schüppel. The network published a CMC global market report in March 2023. This valuable resource — an abridged version is free — details commercially available fibers and producers, types of CMC, their processes and applications, as well as new developments from Ceramic Composites members. Parts of the infographic on p. 68 were developed from this report, along with a position paper published in 2021.

Member Walter E.C. Pritzkow Spezialkeramik is a five-employee company near Stuttgart founded in 1994 by Walter Pritzkow after working with CMC at the German Aerospace Center (DLR). The company’s award-winning Keramikblech OCMC uses fabrics of Nextel 610 and 720 fibers and a hand layup process to create a wide array of parts. “We work mainly with industrial companies,” says Pritzkow, “such as Linde and BASF, but also with companies doing metal casting and heat treatment. We do small series of 10-100 parts but also larger production of parts like burner systems where we deliver 2,000 to 5,000 parts per year.”

Keramikblech currently uses mostly woven fabrics but also braided sleeves. The latter can be supplied affordably by a specialty braider in Germany in lengths up to 200 meters. Pritzkow explains the CMC production process: “We infiltrate the fabric with a water-based ceramic slurry using a doctor blade [squeegee] and then apply the wet fabric onto a special plastic mold. This is dried in a normal drying furnace at 60-90°C (for 4-5 hours up to 20 hours, depending on part thickness, size and complexity). We then remove the green body from the plastic mold and sinter it (1,100-1,200°C), typically overnight, in a standard sintering furnace. We machine the parts with diamond tools, and hole patterns in plates are laser cut.” Parts can be made and shipped in as little as 3 days.

But what about quality, and why not use SiC? “Because SiC/SiC and C/SiC are much more complex materials and require longer processing. My parts are easy to fabricate. Even though we don’t use an autoclave, like CHI [Composites Horizons Inc.] and COIC [COI Ceramics], I’ve compared our bending strength to theirs and found no difference. We use a matrix with alumina and zirconia (ZrO_2) as a binder, which produces good preforms and CMC with good high-temperature properties. Our parts are typically used at 1,150-1,200°C; the maximum would be 1,280°C.”

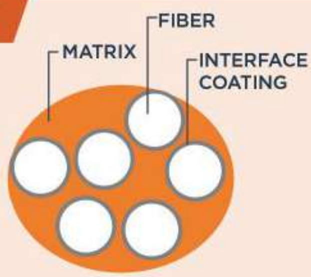
The company also works with R&D centers and completes »

FIG. 1 CMC parts boost efficiency, enable energy transition

Burner lances made from Keramikblech oxide fiber/oxide matrix (OCMC) offer 10 times longer life versus metal alloy burner lances used in steam crackers (top). A hybrid OCMC furnace tube (alumina liner, metal insert, outer OCMC sheath) has successfully demonstrated electrical-powered steam cracking (bottom left). BASF Ludwigshafen has installed the world’s first large-scale electrically heated steam cracker plant, with a potential 90% reduction in CO_2 emissions (bottom right).

Source | Walter E. C. Pritzkow Spezialkeramik

3 PARTS OF A CMC



CMC originated with continuous fiber but can also be reinforced with short fiber, whiskers, particles and nanomaterials.

COMMON FIBERS

C	Carbon
SiC	Silicon carbide
Ox	Aluminum oxide

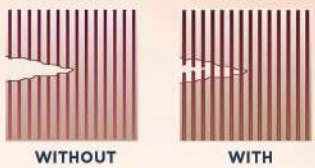
MATRIX MATERIALS

C	Carbon
SiC	Silicon carbide
Ox	Aluminum oxide

INTERFACE COATINGS

BN	Boron nitride
Si_3N_4	Silicon nitride
C	Carbon

CMC interface adhesion is designed to be good/not great, to enable fiber pullout and reduce crack growth.



Ultra-high temp CMC (UHTCMC) may use borides, carbides and nitrides of transition metals like zirconium, hafnium, tantalum, etc.

UHTCMC	Ta/C	3890°C
	HfC	3880°C
	Zr/C	3540°C
	Hf/B_2	3380°C
	Hf/N	3305°C
	Zr/B_2	3245°C
CMC	CC	2000-3000°C
	C/SiC	1350-2100°C
	SiC/SiC	1100-1600°C
	Ox/Ox	1000-1200°C

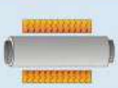
COMMERCIAL FIBER PRODUCERS

SIC	PRODUCT
Nippon Carbon	Hi-Nicalon
UBE Industries	Typranno
COIC	Sylramic
OX	**PRODUCT**
3M	Nextel
Nippon Carbon	Hi-Nicalon

PREPREG

OxOx	PRODUCT
Axiom	AX-780037900 CerFace surfacing film

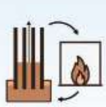
COMMON CMC PROCESSES



Chemical vapor deposition (CVD) | A gas in a reactor deposits matrix onto a heated filament (e.g., SMI and TISICS onto C or W filaments).

Chemical vapor infiltration (CVI) | A gas in a reactor deposits matrix into every pore of a heated porous preform.

Sintering | Preforms impregnated with polymer are heated to form CMC (e.g., Keramikblech OCMC); can be used to densify CMC green bodies.



Polymer infiltration and pyrolysis (PIP)/Liquid polymer infiltration (LP) | Preforms impregnated with polymer are pyrolized to form ceramic matrix; infiltration and pyrolization are then repeated to densify and reduce porosity.

Melt infiltration (MI)/Liquid silicon infiltration (LSI) | Preform with polymer is chemically reacted during heating to form the ceramic matrix (e.g., used in C/C and Ox/Ox parts and as third step after autoclave cure and pyrolysis for GE SiC/SiC parts).

development projects for customers. "We are located near DITF and tested their oxide fibers in unidirectional and woven fabrics in a project with BASF," explains Pritzkow. "The fibers they have developed are at the same level as Nextel fibers." He is optimistic about Saint-Gobain's industrial production of the fibers. "Nextel fabric is the most expensive part of our products," he notes, "and delivery is a problem, often with delays of 3-6 months."

Pritzkow sees a large potential for OCMC parts in the future. "More and more applications are being developed," he says. "In the beginning, we worked with specialty companies and niche applications, but now large companies want to run thermal processes at higher temperatures. We have also worked with engine manufacturers and now have a project with Atmos Space Cargo [Rheinmünster, Germany] to develop a high-temperature fan using OCMC."

Still, industrial applications will move much more quickly, says Pritzkow, "especially if oxide fiber costs come down. We'll get more opportunities to replace metal parts which are destroyed in weeks and months due to coking and corrosion. OCMC parts provide a much higher lifetime — for example, our flame tubes last up to 4 years. Some say that our parts are too expensive, but companies like BASF have found the reduction in maintenance, shutdown and part replacement costs they provide are significant. Time without production is even more expensive. And now these companies can run for longer and at higher temperatures, so their overall efficiency is really benefiting."

Growing use in aeroengines

CMC was originally developed for rocket nozzles used in missiles and space launch vehicles in the 1970s. It expanded into thermal protection systems (TPS) for reentry vehicles and discs/rotors for aircraft brakes by the 1980s. Safran (Paris, France) claims it became the world leader in that technology and the first, in 1996, to qualify a CMC part for aeroengines. Its C/SiC outer flaps for the French *Rafale* fighter jet's M88-2 engine were baselined for serial production, and more than 15,000 have been produced and used successfully. Safran continued developing CMC components including its reported first test of a CMC turbine rotor in 2010.

GE is Safran's partner in CFM International (Cincinnati, Ohio, U.S.) which produces the LEAP engine. GE began developing SiC/SiC engine parts in the 1980s. In 2014, it opened its CMC parts factory in Asheville, N.C., U.S., followed by its continuous fiber and prepreg plants in Huntsville, Ala., U.S. in 2018. GE's fiber is based on the industry standard Hi-Nicalon-S SiC fiber produced since 1980 by Nippon Carbon (Tokyo, Japan). The technology was transferred via the joint venture NGS Advanced Fibers (Tokyo, Japan), formed in 2012 between Nippon Carbon (50%), GE Aerospace (25%) and Safran (25%). In 2021, GE Aerospace reported annual production of up to 10,000 and 20,000 kilograms of SiC fiber and prepreg, respectively, and had built more than 100,000 SiC/SiC high-pressure turbine stage 1 (HPT1) shrouds — 18 for each CFM LEAP engine — which had amassed more than 10 million hours in service. For the GE9X, it produces HPT1 shrouds and nozzles, HPT2 nozzles and the combustor inner liner and outer liner.

Also in 2021, GE Aerospace and Safran launched the Revolutionary Innovation for Sustainable Engines (RISE) program, which

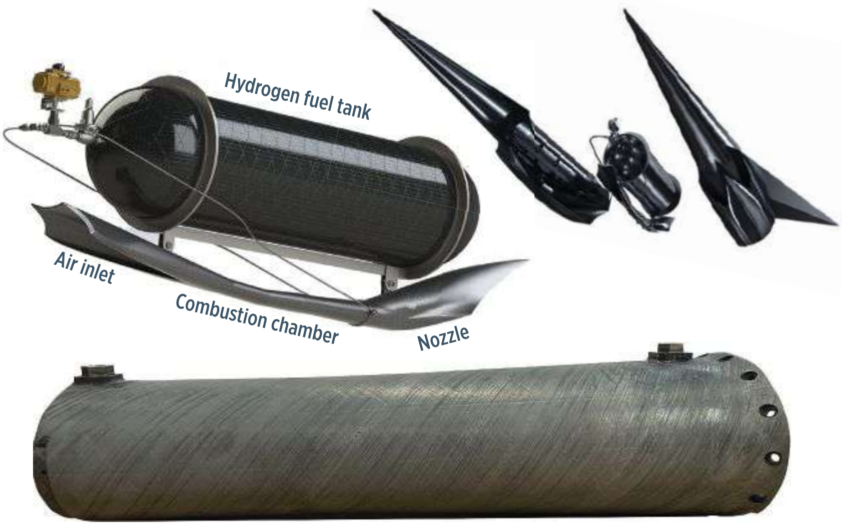


FIG. 2 Hypersonic HTCMC demonstrator

The Spartan scramjet engine (top left) is integrated into the airframes of Hypersonix' vehicles (top right). The C/SiC combustion chamber above (bottom) is not for flight, but to demonstrate the high-temperature ceramic matrix composite (HTCMC) manufacturing needed for future reusability and flight speeds up to Mach 12. Source | Hypersonix

seeks a further 20% reduction in fuel consumption and emissions, centered on the team's open fan design named for its absence of a case around the GE9X-sized turbo fan. Behind the fan is the core which holds the compressor, combustor and turbine, but as developed in RISE, it will be ultracompact — smaller than on a business jet, according to Mohamed Ali, VP of engineering for GE Aviation. In a June 2023 flightglobal.com article, Ali noted that HPT airfoils for the engine have benefited from CFM's capabilities in CMC and were already manufactured and in testing using a modified military engine. RISE is on track for ground and flight tests by 2025 and flight tests using a hydrogen engine before 2030.

According to a GE blog in June 2023, some work for the ultracompact core has been completed through NASA's Hybrid Thermally Efficient Core (HyTEC) project, which also began in 2021. Specific goals of that program include development of CMC liners for combustors, turbine blades and vanes as well as environmental barrier coatings (EBC). Meanwhile, GE's XA100 Adaptive Cycle Engine developed for the F-35 fighter jet uses CMC more extensively than any commercial or military aeroengine to date, according to David Tweedie, general manager for advanced product at GE Edison Works. The engine reportedly delivers 25% better fuel efficiency, 10% better thrust and significantly more thermal capability compared to the current F135 turbofan from Pratt & Whitney (East Hartford, Conn., U.S.). GE began this development in 2007 with the Adaptive Versatile Engine Technology (ADVENT) program, where its prototype set a world record for the highest combined compressor and turbine temperatures, thanks in part to CMC. ADVENT also successfully tested SiC/SiC low-pressure turbine blades in an F414 turbofan demonstrator engine in 2015.

Hypersonix

Development of CMC and UHTCMC has expanded significantly as the U.S. Department of Defense (DOD) seeks to counter threats from hypersonic weapons. Hypersonic speeds are not only reached by current long-range ballistic missiles, but also by reentry and space launch vehicles, like the SpaceX *Falcon*. The rapidly expanding New Space market is thus also driving new hypersonic technology.

Straddling both markets is Hypersonix Launch Systems (Brisbane, Australia) and »

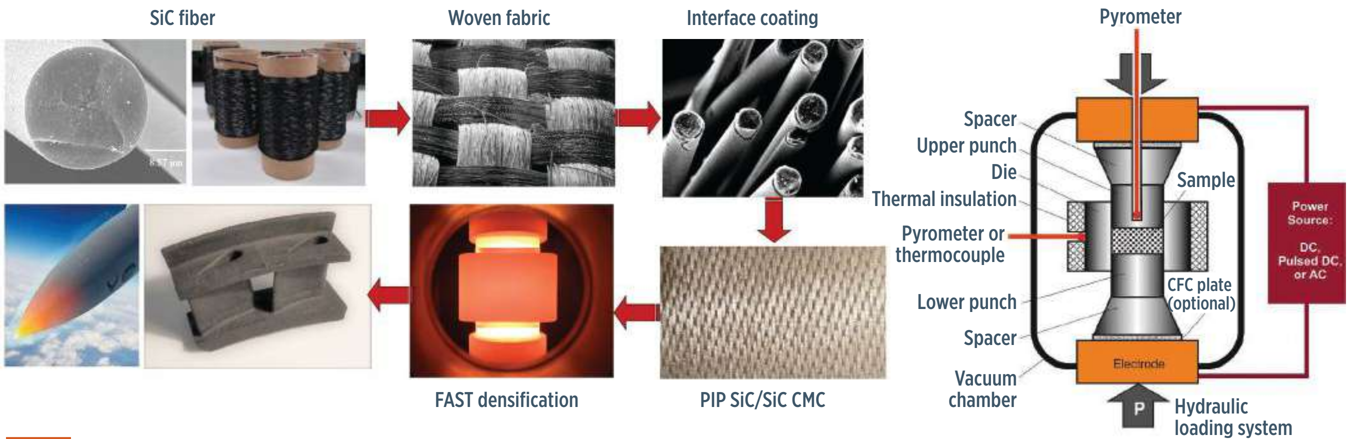


FIG. 3 FAST SiC/SiC parts

MATECH's patented process (above) uses standard field-assisted sintering technology (FAST) equipment (right) which applies pulsed electrical current and a pressing force through a die into a CMC part, so that material reactivity and temperature increases through Joule heating.

Source | MATECH, Fig. 2 from FCT Systeme Booklet FAST/SPS First Edition 2022

its three hypersonic vehicles based on a patented hydrogen-fueled scramjet engine called Spartan that produces no CO_2 emissions. Hypersonix states its mission is to provide reusable space launch technology that is sustainable. The company was founded in 2019 to commercialize 30 years of development by cofounder Michael Smart, whose research spans NASA Langley and the renowned Hypersonics Research Centre at the University of Queensland (Brisbane, Australia). In March 2023, Hypersonix was selected from 63 respondents to provide hypersonic vehicles for the DOD's Hypersonic and High-Cadence Airborne Testing Capabilities (HyCAT) program, overseen by the DOD's Silicon Valley-based Defense Innovation Unit (DIU).

The vehicle chosen by HyCAT is *Dart*. "It is designed to be an affordable, single-use test platform," says Andy Mulholland, head of product for Hypersonix. "Its small size doesn't allow for the equipment needed for recovery and reuse. But the next two vehicles *are* reusable: *VISR*, which stands for Velos intelligence surveillance reconnaissance, and the *Delta-Velos Orbiter*. Both will return to land on a runway. *VISR* is a hypersonic UAV [unmanned aerial vehicle] and *Delta-Velos* is our highly reusable and high-cadence solution for delivering small satellites to orbit."

While *Dart* is fully 3D printed from Inconel metal alloy, *VISR* and *Delta-Velos* will need CMC to address the very high temperatures they will encounter at the faster speeds needed to access space and reenter Earth's atmosphere, explains Sam Grieve, manufacturing lead at Hypersonix. "If we didn't use CMC, we'd need an ablative TPS like other spacecraft." Vaporized during reentry, ablative TPS must be re-applied, which adds complexity, weight and cost. High-temperature CMC (HTCMC) is a better solution, he says, "to handle temperatures that are generated from friction with the air, but also from combustion inside the engine." To that end, Hypersonix recently received a C/SiC demonstrator part that was designed in-house but produced, notes Smart, "using a very complex, never-done-before process working very closely over the last 2 years with a team of experts in Germany."

The C/SiC part is a Spartan scramjet combustion chamber (Fig. 2, p. 69) that is expected to handle temperatures up to 1,400°C. "It's a manufacturing demonstrator that teaches us about the material and the technology," says Grieve. "We're hoping to eventually have these parts produced here by a local supply chain, but we may also produce some parts ourselves."

Mulholland notes it's not a flight piece, "but is just to demonstrate that we could make the variable and intricate geometries needed. C/SiC was chosen as a more basic and well-understood HTCMC to start with, but eventually we'll need much higher temperature materials."

Where will these materials be used? "First for parts where combustion is occurring," says Grieve, "and then other parts of the engine, followed by airframe leading edges that are directly exposed to hypersonic air flow." Will *Dart* use a CMC combustion chamber in *its* Spartan engine? "Not in the engine," says Grieve, "but we are planning for parts like leading edges. CMC technology is important for enabling reusability, but that's not required for our first *Dart* vehicles. Our HTCMC demonstrator and development now is to prove out technology we'll need as we move forward."

The *Dart*'s first flight via the HyCAT program is planned for 2024 using Rocket Lab's (Long Beach, Calif., U.S.) Hypersonic Accelerator Suborbital Test Electron (HASTE) rocket as a booster. Grieve explains why. "Spartan produces thrust as air enters through an inlet, gets compressed, then injected with fuel and combusted, which adds energy to the air flow, and then expands as it exits the nozzle. But unlike a turbojet, we have no moving parts — our compression is done by shockwaves which come off the front of the vehicle. The booster gets Spartan to the speeds above Mach 5 that it needs to operate."

In August, Hypersonix announced an exclusive teaming agreement with Kratos Defense & Security Solutions (San Diego, Calif., U.S.). "This is complementary to our contract with DIU," says Mulholland, "and gives us another channel for commercialization. Kratos also has a lot of experience in the space market and their *Zeus* rockets can also be used as a booster for Spartan."

These first contracts are a key step in the company's vehicle development. “As we continue to develop *VISR* and *Delta-Velos*, we’ll be running up against the limits of materials technology pretty quickly,” says Grieve. “There’s a nonlinear increase in temperature with Mach number, and our scramjet engine is designed to operate up to Mach 10, and we think even Mach 12. So, we’re going to reach pretty crazy temperatures sooner than later, and we’ll need to find and prove out new HTCMC and UHTCMC materials.”

FAST: 99% dense CMC in <10 minutes

A possible pathway for producing UHTCMC materials is spark plasma sintering (SPS), a process used to synthesize metals and ceramics by applying high amperage, pulsed direct current (DC) to powder in a sintering die (Fig. 3). Developed in the 1960s by Sumitomo Coal Mining Co., SPS was reported to achieve uniform, high densification in one-tenth to one-twentieth the time compared to conventional methods and use 60-80% less electricity. Modified to use a pulsed DC or AC power source, the process became known as field-assisted sintering technology (FAST) in the 1990s, according to FCT Systeme (Frankenblick, Germany), which claims it developed a novel process and the first FAST furnace in Europe in 2002. FAST reportedly enables the furnace to be “tuned” to the specific material being processed, which makes heating even more efficient than SPS.

Development has continued, with hundreds of SPS/FAST systems in use for R&D and commercial production. The Penn State Applied Research Laboratory claims FAST can be used to sinter CMC and metal matrix composites, achieving 100% density of near-net shapes at rates 70-80 times faster than conventional methods. In general, higher density enables higher mechanical properties.

Meanwhile, Safran announced in 2022 its investment in Sintermat (Venarey Les Laumes, France), citing its SPS technology that works with composites and biomaterials to produce complex shapes with a homogeneous microstructure. “This investment and our technology partnership will support Safran’s research and technology efforts,” said Eric Dalbiès, Safran senior executive VP of R&T and innovation, “especially concerning the materials and production processes for the components on tomorrow’s aircraft engines, reflecting the disruptive technologies needed to support the development of a more sustainable aviation industry.”

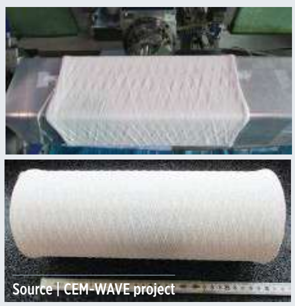
After years of CMC and UHTCMC materials and process R&D, MATECH (Westlake Village, Calif., U.S.), founded in 1989 by Ed Pope, began looking into FAST. Pope knew it worked great with powdered metals, ceramics and ceramic metal composites (cermets), but what about with continuous fiber CMC? “There was interest from the Office of Naval Research,” he says, “which is still pushing today for 2,700°F CMC for higher efficiency turbine engines. So, I talked to industry colleagues to see what had been tried. Their results were disappointing. The main approach was to begin with a 40-50% densified CMC and then use FAST, but what they ended up with was nowhere near 100% dense, and the properties were terrible because » the fiber had been destroyed. I realized this approach was trying to get too much done in one step. The preforms had to be more dense to start with, down to 7-10% porosity. But that could be done with typical polymer impregnation pyrolysis [PIP], chemical vapor infiltration [CVI], melt infiltration [MI] or other processes. You then apply FAST. We demonstrated that this works, and we can get up to 99.9% dense SiC/SiC in less than 10 minutes with the strength and toughness we expect from a CMC."

To prove the process works and measure critical properties, MATECH started with simple geometries including round discs and rectangular plates. More complex geometries, such as the aeroengine doublet vane shown in Fig. 3, are possible using graphite tooling within the FAST die. This was already designed for use with PIP but not yet used to create a FAST-densified part. The FAST process time, pressure and temperature for a shaped part is the same as a flat plate geometry.

SIDEBAR

New CMC developments

Microwave-assisted CVI


Source | CEM-WAVE project

The CEM-WAVE project (2020-2024) aims to produce novel CMC parts using a microwave-assisted chemical vapor infiltration (MW-CVI) process to reduce production time and cost. For example, the University of Birmingham in the U.K. reduced multiple cycles totaling 1,000 hours to a single 100-hour cycle for SiC/SiC parts. CEM-WAVE has produced tubular preforms using filament winding of Nextel 610 fiber with an aluminum phospate ($AlPO_4$) coating and a zirconium matrix which will be sintered in equipment modified by Archer Technicoat Ltd. (ATL, High Wycombe, U.K.). Coatings have been developed by Fraunhofer ISC (Bayreuth, Germany) to help the largely microwave-transparent alumina fibers and matrix to absorb microwaves.

3D-printed CMC


Source | Fraunhofer IKTS

Fraunhofer IKTS (Dresden, Germany) has developed a fused filament fabrication process for ceramics (CerAM FFF) which uses homogeneous, highly filled thermoplastic filaments with a diameter of 1.75 millimeters. They are melted and deposited by the printhead and then densified using PIP to form the CMC. This process offers the possibility to integrate ceramic fibers into the filaments, enabling AM of short to long fiber-reinforced CMC. A variety of ceramic matrices have been demonstrated and SiC/SiC components are in development.

DITF oxide fibers ramping to industrial scale

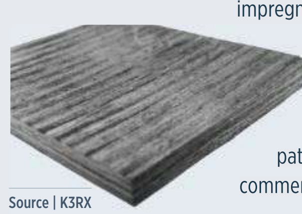

Source | DITF (Deutsche Institute für Textil + FaserForschung)

Having developed oxide fibers since 1990, DITF is now in partnership with Saint-Gobain for the industrial production of alumina (OxCeFi A99) and mullite (OxCeFi M75) fibers, scheduled to start in 2025. DITF fiber R&D continues, aiming at even better properties using multi-phase systems and elements such as Zirconium (Zr) and Yttrium (Y), with pilot production of Zr-toughened alumina (OxCeFi ZTA) and Zr-toughened mullite (OxCeFi ZTM) fibers already well advanced.

New UHTCMC


Source | K3RX

The C[3]HARME project (2016-2020) aimed to develop novel UHTCMC materials for hypersonic and space applications. Coordinated by CNR-ISTEC (Faenza, Italy), the project included partners such as Airbus, Ariane Group, Avio, DLR and others. Subscale rocket nozzles using short and long carbon fiber were fabricated and densified using SPS for densification and tested to technology readiness level (TRL) 6. TPS plates were also made using 2.5D carbon fiber preforms impregnated with zirconium diboride-alumina (ZrB_2) slurry and converted using radio frequency-assisted CVI. Such TPS was tested to TRL 5. The C/ZrB_2 UHTCMC materials developed in C[3]HARME were patented by CNR-ISTEC and have been commercialized by spinoff company K3RX.


Source | K3RX

Filament-wound, laser-sintered CMC


Source | Fraunhofer IKTS

Fraunhofer IKTS produced SiC/SiC parts using filament winding with an integrated laser system for sintering. This eliminates the need for post-winding sintering in a furnace. "We showed the feasibility of the laser process and built a simple CMC tube as a demonstrator. However, the part strength was not sufficient for industry applications," says Clemens Steinborn, testing laboratory manager and researcher at Fraunhofer IKTS. "We are pursuing funding for a follow-up project to reach a higher TRL."

Robot-sprayed short fiber OCMC


Source | University of Bayreuth

The University of Bayreuth is researching the production of oxide CMC using short fibers (14-60 millimeters long) in the FlexFiber project (2023-2026) which aims to develop a robot system that can be operated flexibly and intuitively by technicians.

Pope obtained two patents for this development: a process patent in 2019 and a composition of matter patent in 2020. "We were able to show we can reach near theoretical density for C/SiC and SiC/SiC composites," he explains. "We have done limited testing with both types of CMC parts in rotational detonation engines at Wright Patterson [Air Force Research Lab, AFRL] that performed really well, but we haven't made hot section blades or vanes to put in a test rig yet." MATECH's work so far has focused on precursor CMC made using PIP, which is highly amenable to complex shapes and fiber architectures. "We've found that 1,800°C was the sweet spot for this type of FAST processing of SiC/SiC CMC," says Pope, "to achieve the density and fracture behavior we want."

MATECH's densification of SiC/SiC and C/SiC CMC has used between 30 and 100 megapascals of pressure. "This is a typical range used in FAST processing," says Pope. "The electrical current used ranges between 2,500 and 10,000 amps, depending on sample size. But that is concentrated in a relatively short burst, which makes it much more efficient than hot-pressing techniques. Also, the heat is generated within the material itself — you're not heating from the outside. By using electrical current *and* the pressure of the die, you're efficiently adding thermal energy, but also vibrational energy which makes the material more reactive." He adds that FAST opens the door to performance gains for hypersonic leading edge, nose tip and propulsion applications that were previously unattainable.

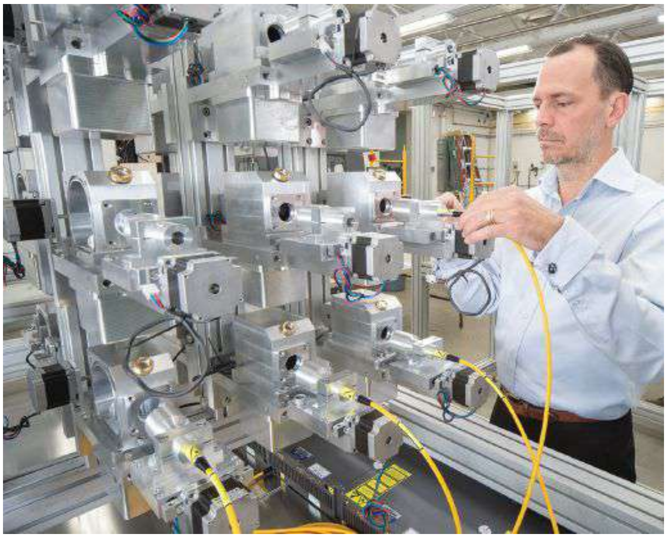
Laser CVD, short SiC fibers

Founded in 2006, Free Form Fibers (FFF, Saratoga Springs, N.Y., U.S.) spent years working on continuous SiC fiber before pivoting its focus to production of fibers no longer than 1.5 inches. The move to discontinuous fiber was based on the science of CMC fracture toughening behavior, says CEO Shay Harrison. "Once you get past a fiber length-to-diameter ratio of 1,000:1, you don't get additional fracture toughening. If we apply that ratio to our 30-micron-diameter fiber, we get a length of 1.25 inches."

So, how does the FFF fiber compare to other SiC fibers on the market? FFF fibers are roughly two times the diameter of the 10- to 18-micron diameters typical for spun polymer precursor fibers such as Hi-Nicalon-S and its competitors, says Harrison. "But our fibers have excellent handleability characteristics, such as being able to wrap them down to a radius of about $^{1}/_{16}$ inch." Fibers are also produced by using chemical vapor deposition (CVD) to deposit SiC onto a carbon or tungsten core, such as those made by Specialty Materials Inc. (SMI, Lowell, Mass., U.S.). "FFF fibers have no core, and thus, no dissimilar [non-SiC] material in the fiber structure," says Harrison. "The SMI fibers also have a much larger diameter, on the order of 75-140 microns, which leads to processability issues when using them as reinforcements in CMC because of the high fiber stiffness."

How is the FFF process different from more conventional CVD? "Instead of heating up the entire volume inside a reactor and then introducing gases that deposit solid material onto a filament," says Harrison, "we're delivering the energy to decompose the gases in a focused laser beam onto a substrate, which initiates the breakdown of the gases to form solid SiC (Fig. 4, p. 74). We're basically growing the fiber by moving the substrate and the laser, to continuously deposit solid material." Another difference is the reactor size. "It's a little bit bigger than my fist," says Harrison. "We have a very low CAPEX, but we use high-purity inputs and have developed our process to produce very high-quality fibers."

CVD is indeed renowned for producing very pure SiC materials, but also for being glacially slow. "For typical hot wall CVD, the coating thickness onto the filament core drives the pull through rate of the fiber," says Harrison. One industry source quotes production rates of 0.1 to 10 inches per minute for this process. "Yes, but that is for production of a single fiber," notes Harrison. "We multiplex the laser so that we grow arrays of 50-100 fibers simultaneously. Even at the bottom end of that scale, we are producing 50 fibers at 1.25 inches long in approximately 10 minutes — which is effectively a production rate of more than 6 inches of fiber per minute. And we have scaled that to make kilograms of fiber per month. We then »



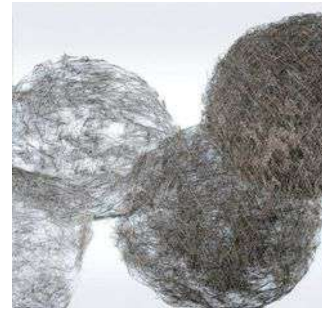
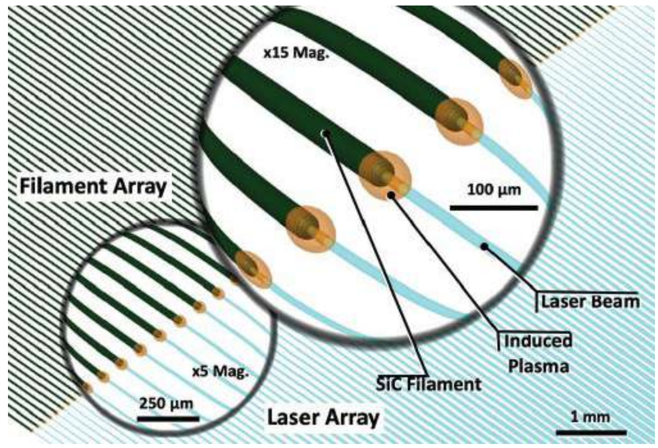



FIG. 4 Laser CVD, scaling short SiC fiber production

Free Form Fibers' patented single production tool (above) comprises 9 individual reactors, each using a multiplex laser to grow arrays of 50-100 SiC fibers up to 1.5 inches long (center), which can be used as nonwoven mats (top right). Current gen2 production tools have 24 heads and gen3 production tools are being developed. Source | Free Form Fibers

further scale by adding reactors, which are not expensive. So, our approach does have an economic basis to be not just competitive, but actually get to lower price points once we are at high volume."

FFF is maturing the technology now from lab to production scale. "We have built our first production tools, which are running 24/7 and we're making material that we're selling to customers. We're on track to double our production capacity by the end of this year," says Harrison. What are the targeted applications? "We've seen a lot of movement over the last year in ceramic-based additive manufacturing [AM], and that's where having the discontinuous fiber has become an advantage. But we're also looking at other material formats. We're working with a partner to convert our fiber into a nonwoven mat, a format that is easily infiltrated with matrix, which reduces porosity, and also provides fibers in the Z-direction, which helps prevent delamination. We're also developing relationships to look at turning our short fibers into a yarn that simulates continuous tow, in response to customers who still want that type of product."

In addition to SiC, FFF is also looking into UHTCMC aimed at hypersonics applications. "One of these is silicon nitride (Si_3N_4) fiber for electromagnetic applications, which is desired but not yet available," says Harrison. "We're working through a DOD program to get that to a point of commercialization." He notes that CMC is becoming a larger part of material solutions for an array of advanced applications, including nuclear energy, where the company is also active. "We want to be a manufacturer that supplies customers with real quantities of material for the higher end of temperatures in these applications," he continues. "We think we have a good product that the market needs. We need to prove that and scale up, but we have good technology that has benefits and we're going to be able to deliver that at a volume and price that matters to the CMC market."

U.K.'s "Ceramic Valley" and NCC

The National Composites Centre (NCC, Bristol, U.K.) has also seen increased demand for CMC. In August 2023, NCC announced its partnership with Lucideon (Stoke-on-Trent) to develop advanced CMC solutions. NCC will lead system and product design, plus industrial scale-up. Lucideon will provide analysis, evaluation and access to the new AMRICC Centre (Staffordshire), which it hosts and has developed with Stoke-on-Trent as a key part of the area's "Ceramic Valley." AMRICC includes the National Advanced Sintering Centre which focuses on flash, cold, microwave and SPS technology and includes a project to use novel sintering and AM to innovate CMC for aerospace engines.

U.K. aeroengine manufacturers do indeed support CMC development at NCC, including the AFP-CMC Core project with partners Rolls-Royce (London), Reaction Engines (Abingdon) and missile manufacturer MBDA (Stevenage). In 2022, NCC successfully demonstrated manufacturing of an oxide CMC part using automated fiber placement (AFP) of 3M Nextel prepreg. Follow-on goals include optimizing AFP parameters for more complex geometries and investigating, with 3M's help, wider material formats to reduce the number of joints between tape courses for higher performance.

NCC has also worked with universities to develop UHTCMC that can withstand temperatures up to 2,000-3,000°C and is working to mature extrusion-based 3D printing and other AM. Another key program is HASTE-F, where NCC and the UK Atomic Energy Authority (UKAEA) report they've developed a step change in SiC/SiC manufacturing that reduces cost to one-fifth that of current

CVI methods while achieving 95% density (versus 75% for CVI) and shorter cycle times plus more complex geometries and thicker sections. NCC claims such SiC/SiC components have the potential to double the electricity generated from every gigawatt of heat produced compared to fusion reactors using advanced steel designs. This is possible because a SiC/SiC breeder blanket, and the coolant within it used to extract energy from the reactor, can withstand higher temperatures up to 900-1,000°C — at the upper end of current R&D metal breeder blankets. This allows more efficient generator approaches to be used. NCC adds that it is pioneering industrialization of U.K. SiC/SiC design, modeling, manufacturing and technology capabilities to support the STEP (Spherical Tokamak for Energy Production) program aiming to construct the first grid-connected fusion reactor by 2040.

Continuous fiber coating

Another key CMC technology being developed in the U.K. is continuous coating of SiC fiber. "There are three main parts to a CMC — the fiber, the interface coating and the matrix," explains John Yeatman, managing director of Archer Technicoat Ltd. (ATL, High Wycombe, U.K.). "For nearly all CMC, at the moment, the interface coating on the fibers is produced using CVD. Typical coatings include boron nitride, silicon nitride or a plain carbon interface." ATL has provided advanced coating solutions for 40 years and interface coating for CMC for 20 years. "We perform R&D, design systems, build and sell coating equipment and also provide coating services," says Yeatman. "Most of the latter has been using batch processes, where you take your woven fiber, preform or layup and put it in a mold, and then you'll infiltrate it using CVI and put the coating on that way. We say CVI instead of CVD if we're coating all of the surfaces in a porous preform."

"But there are also continuous coating methods," Yeatman continues, "where you coat the fibers before layup. As long as you can make the coating both stable and flexible — so that you can handle the coated fiber and lay it up — then it has obvious advantages in efficiency. Pioneered mostly by GE, this is used in its industrial-scale CMC production. But that technology is restricted, so nobody else in the world has access to it." Yeatman says ATL's goal is to develop continuous coating capability for CMC fibers that can be used by pretty much anyone, especially companies outside the U.S.

This was the goal for the Continuous Interface Coating for Silicon Carbide composites (CICSiC) project, led by ATL. "The CICSiC project allowed us to design and build a prototype piece of coating equipment, operate it and test it. And it's been very successful," says Yeatman. The U.K. project partners included the University of Sheffield Advanced Manufacturing Research Centre (AMRC, Rotherham), Cygnet Texkimp (Northwich) and TISICS (Farnborough). "Cygnet provided the fiber handling expertise that could help us run the fiber back and forth through the furnace," says Yeatman. "You have to control the tension and speed, which is quite tricky, because the fibers are very fine, easily abraded and broken." TISICS also provided fiber handling expertise and helped design a specific aspect of the coating equipment, while AMRC tested the flexibility of the coated fiber.

LEARN MORE

See more images in the online article | short.compositesworld.com/CMC-update

With CICSiC completed, ATL is seeking a follow-up project to accelerate the final development needed. "Although the machine works well, and we're using it, you can only put a single coating on when you pass the fiber through the furnace," explains Yeatman. Multiple coatings are typical, he adds, and used by GE, for example. "Each layer has a separate function, be it as a diffusion barrier, debonding [good not great interface] or oxidation resistance. For now, if you want a multi-layered coating, you have to wind it through one way and then wind it back through the other way. So, we need to improve our fiber handling for this and also to enable longer runs. We want to get to a point where we can build a piece of equipment with multiple coating stages that we can sell, so our customers will be able to produce their own coated fibers."

Customers interested in this technology include the major aerospace companies outside of the U.S. and a growing supply chain to produce SiC fibers in Europe. "But there is now an operation in Germany and one of the ideas is to basically add coating as a part of the fiber production process," says Yeatman. "Just put a CVD system on the end, so that as the fiber comes off the production line, it gets coated continuously straight away. And to me, the potential that could have has already been proven."

Needs for expanded CMC future

When asked what is needed to increase the use of CMC, Ceramic Composites network's Schüppel says it varies by each of the four major types. "Industry is looking for reactor tubes that also have good thermal shock resistance. For Ox/Ox, the challenge is to get CMC parts dense enough to hold gases." For SiC/SiC, he notes GE has fiber, coating and parts production all in-house. "The challenge is that European SiC fiber producers don't necessarily have that know-how in coatings and their interaction with the SiC matrix nor in the intricacies of CMC parts production." To expand C/SiC applications, says Schüppel, "simulation is needed to create a virtual twin along the entire process chain. This will help reduce trial and error, and thus cost. For C/C, aircraft brakes are the largest market. Safran has said it is researching new CVI. The challenge is to get high-quality parts but also meet targets for less energy, cost and carbon footprint."

Indeed, sustainability of CMC is a nascent, but growing topic. For a discussion of energy use, lifecycle analysis and bio-based materials, see "Increasing the sustainability of CMC." CW

ABOUT THE AUTHOR

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Urban furniture project demonstrates green potential for composite 3D printing and recycled materials

Large-format AM specialist Caracol and partners designed custom, 3D-printed outdoor furniture with glass fiber-reinforced recycled polypropylene, and conducted an LCA to evaluate and improve the process.

■ Caracol and its partners used glass fiber-reinforced recycled polypropylene to design and additively manufacture a series of urban furniture pieces, aiming to demonstrate potential for 3D printing and recycled materials as a circular economy solution.

Source | Caracol

The MASAU project, led by large-format additive manufacturing (LFAM) equipment supplier Caracol (Barlassina, Italy), demonstrated and evaluated the sustainability potential for 3D printing composites and recycled materials.

In June 2022, the Lombardy region in northern Italy invited local companies to submit applications for funding related to building up the local circular economy supply chain. Caracol and Italian partners including the ComoNExT Innovation Hub (Lomazzo), the Polytechnic University of Milan and Lifecycle Engineering SpA (LCE, Turin) participated with their 1-year project MASAU, which stands for “Manifattura Addittiva Sostenibile per Arredi Urbani” in Italian, or “Sustainable Manufacturing for Urban Furniture.”

For this project, outdoor furniture was chosen as a focus application to demonstrate the technology. Caracol’s application engineering team designed a series of seating pieces and planters that were then manufactured at its facility using the company’s Heron AM system. The ComoNExT Innovation Hub provided support and coordinated with the city of Lomazzo for placement of the final demonstrator parts in public spaces. LCE conducted a lifecycle assessment (LCA) to provide information on the environmental impact of the process.

The furniture design aimed to positively impact the environment and society. For example, the seating was designed into organic shapes for a semicircle setup to foster inclusivity and social interaction, and a series of planters were designed and fitted with solar-powered smart sensors that trigger an automatic irrigation system.

According to Violetta Nespolo, chief marketing and strategy officer at Caracol, one of the first steps of the process was evaluation of materials that would meet the requirements of the Heron AM process and project goals for the lowest environmental impact. The Polytechnic University of Milan helped test materials, including characterization of a variety of recycled materials to ensure repeatability, durability and performance.

“We looked for the best local supplier who could provide a good quality material with a high percentage of recycled content,” Nespolo says. Ultimately, the project partners selected a recycled polypropylene made from post-consumer or post-industrial plastic materials, reinforced with 30% chopped glass fiber. The material combination “gives us much better printability as well as resistance for the finished parts, which will have to withstand outdoor environments,” Nespolo says.

Caracol’s Heron AM was used to fabricate the demonstrator parts. The extrusion-based 3D printer is mounted on a six-axis KUKA (Augsburg, Germany) robotic arm, set up within a climate-controlled cell and operated by Caracol’s in-house, integrated design and manufacturing software. The company’s highest accuracy print head was used for this project. “As the parts weren’t post-processed, we wanted to achieve good quality right off the machine and use the minimum quantity of material necessary,” Nespolo explains. Compared to traditional composites manufacturing processes, she adds that Caracol’s process minimizes energy consumption, material use and generated waste, as well as cycle time per part.

To further demonstrate this and provide learnings for further improvement, project partner LCE conducted an LCA after the demonstrators were built, to quantify the current environmental impact of the manufacturing process, based on ISO standard 14040-44. Several key performance indicators (KPI) were evaluated, including carbon emissions, energy sources used, fresh water use, hazardous and nonhazardous waste produced and quantity of material recovered/recycled at the end of the process.

“The LCA served to really quantify the impact of our process on several KPIs. The aim was to have a clear understanding of what we are doing now, and therefore to immediately begin introducing action to improve how we work every day,” Nespolo says.

The study also provided insights into the ways the process can still be improved further, Nespolo adds. Thanks to these results, Caracol has taken on additional sustainability-minded measures like investing in solar panels to power its facilities and improving its waste management system with a goal of 100% recycled waste. CW

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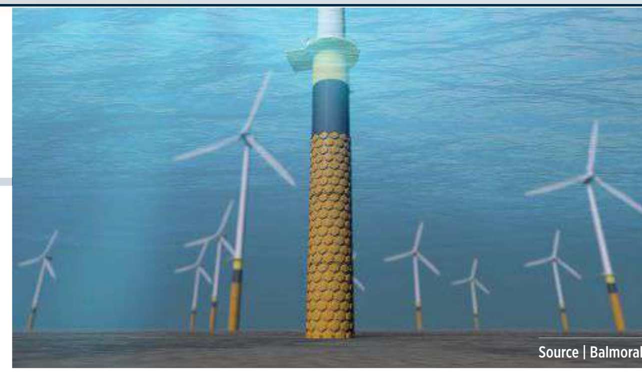

Source | Balmoral

» OFFSHORE WIND TURBINE PROTECTION

Integrated scour prevention solution for fixed offshore wind turbine systems

Balmoral (Aberdeen, U.K.) has adapted and transitioned several of its buoyancy and protection solutions — cable protection, bend limiting devices and crossover solutions among others — for use in the fixed and floating offshore wind sector. Now, following extensive research and investment, the company is introducing Balmoral HexDefence, a lightweight composite construction that aims to drastically reduce scour phenomena around fixed wind turbines.

Scour refers to the erosion of seabed sediment caused by currents and waves. These conditions can lead to turbine foundation instability and interarray cable damage, ultimately resulting in expensive cable failure. To mitigate these consequences, scour protection is used to defend the seabed around a monopile structure.

Moreover, these measures need to be carefully monitored to avoid damage to the turbine, seabed and any associated cabling. Balmoral HexDefence, an integrated scour protection and flow reduction system, minimizes offshore operational costs and potential cable failure. The HexDefence structure eliminates the requirement to dump rock, instead providing a non-invasive approach to protecting the monopile and the immediate surrounding area.

Its lightweight composite construction and streamlined installation method is said to make it easy to install without the need for additional vessels, resulting in an improved carbon footprint for all operations. The system can also be used with antifouling coatings and does not require special equipment for end-of-life recovery.

"The interlocking panels are generally 10m long and custom-sized to fit varying monopile diameters and feature integrated lifting and access points," Fraser Milne, the company's engineering and projects director, says. "In simple terms, the installation process involves sinking the foundation, sleeving it with HexDefence, fitting the transition piece and assembling the pylon and blades. The system is also suitable for retrofitting to existing monopile structures."

"We believe the system can save wind farm developers around 70% in installation costs when compared to traditional rock dumping methods," Milne adds. **balmoral-group.com**


Source | Renishaw Inc.

» OPERATION DATA MANAGEMENT

Smart manufacturing data platform for industrial process control

Renishaw (West Dundee, Ill., U.S.) Central is a new smart manufacturing data platform that collects, presents and initiates accurate process and metrology data, enhancing the productivity, capability and efficiency of manufacturing operations. The platform connects to measurement devices across the manufacturing process and provides valuable insights that manufacturers can use to analyze, identify, predict and correct process errors before they occur.

Renishaw Central collects metrology, status and alarm data from connected devices across the shop floor. Devices include additive manufacturing systems, on-machine measurement systems, shop floor gaging and coordinate measuring machines.

"The platform operates on-premises, allows shop administrators to own their data and ensures that process control is automated without depending on an internet connection," Brandon Golab, machine tool product manager at Renishaw Inc., says. **renishaw.com**

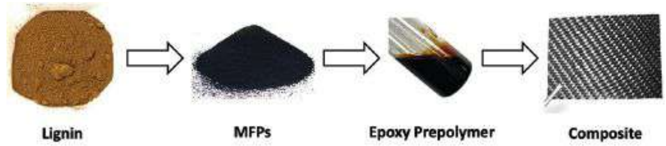
» BIO-BASED EPOXY PREPOLYMERS

Prepolymers enable high-performance epoxy resins with up to 80% bio-based content

Spero Renewables LLC (Galeta, Calif., U.S.) explains that despite the growing use of epoxy resins, their traditional petroleum-based formulations are not sustainable. This is why it has developed the Sperlu process to produce 100% bio-based epoxy prepolymers from lignin, which is an abundant and low-cost byproduct of papermaking. Lignin's aromatic chemical structure provides Sperlu products with thermal and mechanical performance, rivaling petroleum-based alternatives.

Spero Renewables reports that Sperlu technology overcomes the traditional challenges with lignin — e.g., brittle nature, low solubility, high viscosity and incompatibility with other polymers — and instead delivers high solubility, reactive and compatible epoxy prepolymers that enable tunable strength and the ability to achieve up to 80 wt.% renewable content in epoxy resin (epoxy prepolymer + hardener) using Sperlu epoxy prepolymers. Spero Renewables claims this is much higher than bio-based epoxies with renewable content advertised to be ~20%.

The Sperlu process uses a novel catalytic lignin depolymerization process to produce multifunctional phenols (MFPs) with a controlled narrow molecular weight distribution. This enables MFPs to directly react with epichlorohydrin in the same style as in the glycidylation of bisphenol A. However, unlike bisphenol A made from the coupling of phenol, or other renewable phenol monomers that need to be modified into multifunctional dimers and/or oligomers, Sperlu MFPs are reportedly multifunctional by nature and no coupling modification is needed.



Source | Spero Renewables

Process for producing SPERLU™ renewable lignin-based epoxy resins.

Sperlu epoxy prepolymers have viscosities comparable to leading epoxy prepolymers, and can be cured with traditional hardeners. These novel epoxy prepolymers also have high miscibility with bisphenol A diglycidyl ether (DGEBA), allowing formulators to easily tune renewable content and mechanical properties. By mixing Sperlu epoxy with bisphenol A diglycidyl ether, renewable content of 45-80 wt.%, glass transition temperature (T_g) range of 65-160°C and storage modulus of >2,000 MPa can be achieved. The wide range of T_g and high strength make Sperlu epoxy resins suitable for a wide range of applications including automotive, wind turbines, sporting goods and fiber-reinforced composites.

Spero Renewables is seeking commercialization partners and customers. Sperlu epoxy resin samples are available for formulators seeking a direct bio-based replacement for DGEBA.

sperorenewables.com

» COMPOSITES GUIDE

Best practice guide for composites tooling

Composites UK (Berkhamsted, U.K.) has launched the latest in its series of good practice guides. This latest edition focuses on "Mould Tooling for Fibre-Reinforced Polymer Composites."

Good tooling for molding composites is intertwined with process selection and is critical for manufacturing repeatable and accurate parts. Tooling choices are an important part of reducing the environmental impact of parts, potentially reducing energy use and material waste, both in process scrap and failed parts, as well as enabling faster, more cost-effective manufacturing of parts which contribute to our pathway to net zero in transport, renewable energy, construction and other sectors.

Composites UK would like to sincerely thank the authors of this guide, including Nigel Keen, Creative Composite Connections; Stella Job, Grazebrook Innovations; Richard Bland, Composite Integration; as well as reviewers, Stu Morris, Pentaxia and Michel Marie, Ineos Britannia and the guide's co-funders, the NCC.

"This guide provides a wealth of information about a fundamental part of composite manufacturing that is not talked about enough, and it will be a really useful resource," says co-author Stella Job.

The guide includes chapters on tooling types and specification; tooling as the key to process selection; tooling design; automation and production/process line integration; sustainability considerations; tooling materials; process control, safety and operation; tooling durability and service life; no tool and specialist tooling; and next steps and future developments.

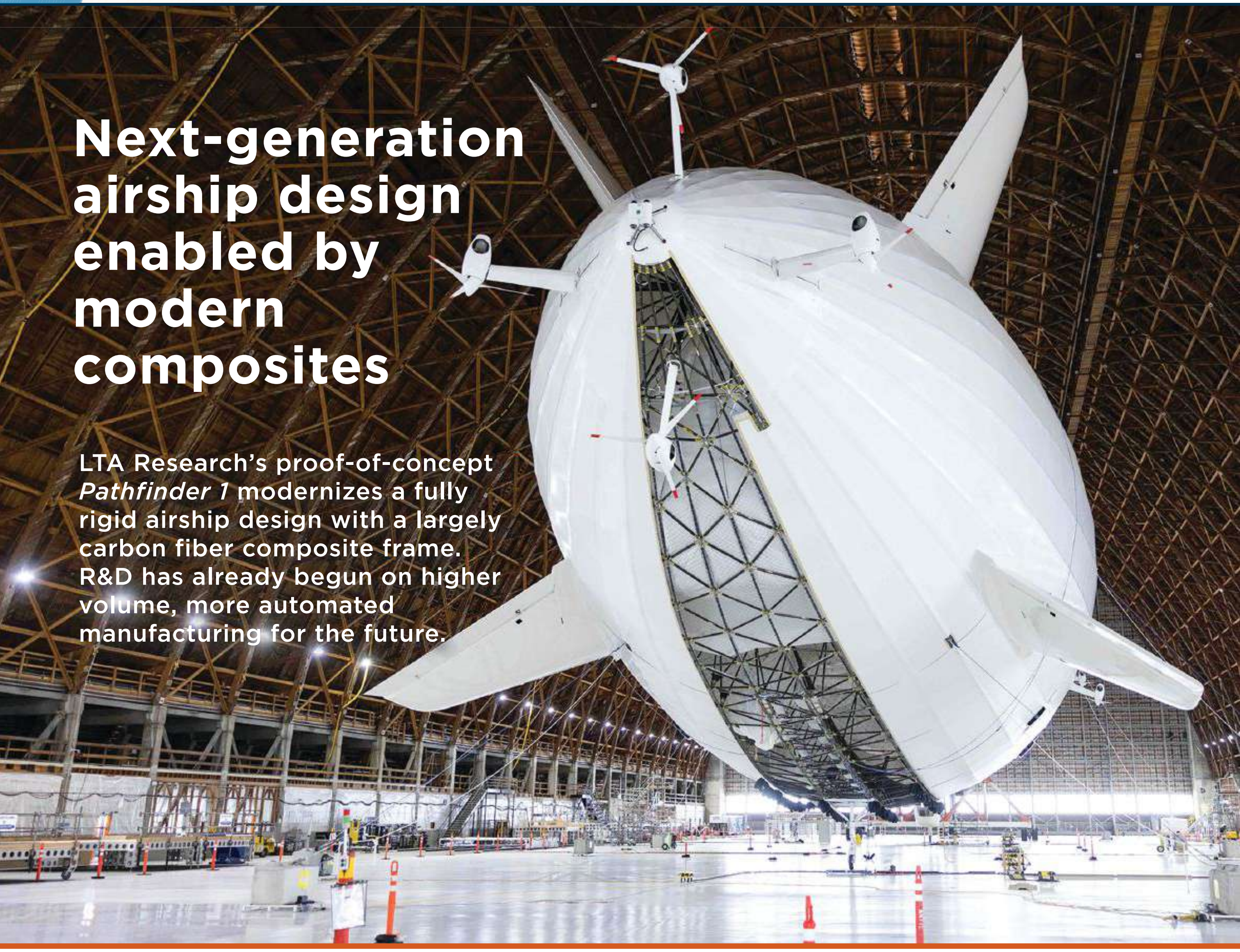
Source | Composites UK

The information within the document is backed up by case studies from the Advanced Manufacturing Research Centre, Airtech Advanced Materials, Alan Harper Composites, Composite Integration, Haydale Composites Solutions, Norco Composites & GRP, Plyable, Surface Generation and 11th Hour Racing.

The guide is free of charge at www.compositesuk.co.uk/industry-support/good-practice-guides. **compositesuk.co.uk**

Next-generation airship design enabled by modern composites

LTA Research's proof-of-concept *Pathfinder 1* modernizes a fully rigid airship design with a largely carbon fiber composite frame. R&D has already begun on higher volume, more automated manufacturing for the future.



Composites enable next-generation rigid airship design

LTA Research's *Pathfinder 1*, its first full-scale, electric-powered prototype airship, is shown here during construction in Mountain View, Calif., U.S. Composites are used for many of the airship's structures, including the carbon fiber composite frame that can be seen through the partially open airship envelope. Source (all images) | LTA Research

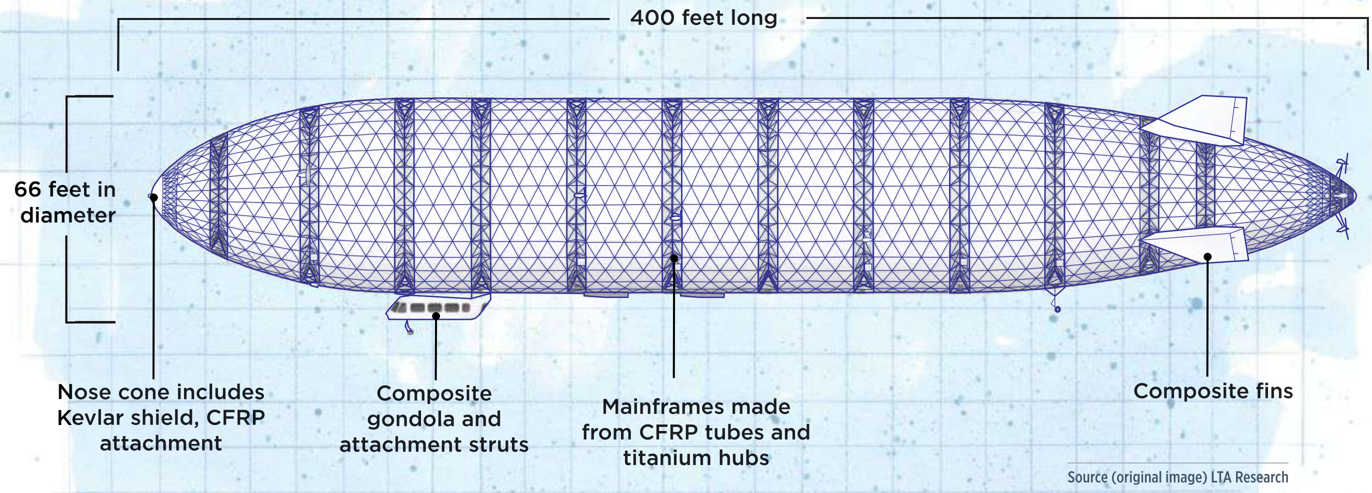
By Hannah Mason / Technical Editor

»Today, large, rigid-framed airships are usually viewed only in black-and-white photos from the first half of the 20th century, popularized at the time by the zeppelins of Luftschiffbau Zeppelin GmbH (Friedrichshafen, Germany) and military airships like the *U.S.S. Akron* and the *U.S.S. Macon*. Tragic accidents to both of these airships, the German *Hindenburg* and others led to the eventual end of the rigid airship era both for passengers and cargo and, eventually, for militaries. Since the 1960s, today's airships are mostly in the form of non-rigid blimps.

However, several companies are working toward a *new* generation of rigid, structured airships, working alongside Federal Aviation Administration (FAA) regulations and using contemporary technologies and materials to ensure safer manufacturing and operation.

One of these is airship company Lighter Than Air (LTA) Research (Mountain View, Calif., U.S.), which aims to create a new generation of airships that are inherently safer and faster than those previously built.

LTA's CEO Alan Weston, who worked previously at the Air Force Research Laboratory (AFRL), NASA Ames Research Center and the Florida Space Institute at the University of Central Florida, started the company with the goal of reducing carbon emissions in air transportation. He decided to focus on modernization of electric or alternatively powered airships as a potential low- or zero-emissions air transport option.



Source (original image) LTA Research

DESIGN RESULTS | **Composites-intensive *Pathfinder 1***

- Rigid airship design includes almost 3,000 titanium hubs and 10,000 CFRP tubes.
- Frame tubes are roll-wrapped and oven-cured for *Pathfinder 1*, with more automated processes investigated for the future.
- Composite materials like carbon fiber, Kevlar, and fiberglass are used throughout the airship.

Susan Kraus / Illustration

In 2014, Weston began a deep dive into research on airship designs, starting with historians and researchers at the University of Akron and talks with airship designers from companies like Luftschiffbau Zeppelin GmbH and Goodyear Tire and Rubber Co.

As the research work progressed, Weston recognized that the airships he was developing had potential to augment humanitarian relief efforts, such as transport of supplies to natural disaster-stricken areas. Airships can dock virtually anywhere and do not rely on availability of intact airstrips or landing zones, can hover for a long period of time to pick up people or drop off goods and can be designed to carry large payloads, all qualities that could lend themselves well in relief efforts.

The company was officially founded in 2015 and backed by Google cofounder Sergey Brin. By 2016, LTA Research had two locations: an R&D lab in Akron, Ohio, U.S., to test design and manufacturing techniques, and a hangar in Mountain View, Calif., U.S. That year, LTA constructed and flew its first small-scale airship models in Mountain View and soon after began production of its first full-scale airship, *Pathfinder 1*.

Designing *Pathfinder 1*

Pathfinder 1 is LTA's proof-of-concept (POC) airship, paving the way for iterations to come, but it is no small-scale model, measuring just under 400 feet long and 66 feet in diameter, and powered by electric motors. Following qualification guidelines by the FAA, the goal is to prove out materials and manufacturing technologies, and to take any learnings into development of the next, even larger *Pathfinder* airships.

Daniel Morgan, VP of engineering at LTA Research, explains that the initial goals for *Pathfinder 1*'s overall design were safety and a simplified assembly process.

From the beginning, the company decided to target a rigid airship design, as opposed to a balloon-like blimp or a semi-rigid design. In a fully rigid design, helium bags still provide the airship's lift but live inside a skeleton-like interior frame of interconnected tubes, in this case covered by a Tedlar (by DuPont, Wilmington, Del., U.S.) skin, called an envelope, which supports the gondola underneath the ship for holding passengers and cargo.

A rigid design provides the most strength to carry cargo and modern navigational and safety systems, *but* more structural components also mean more added weight to the overall airship, potentially reducing range or payload capacity.

Therefore, LTA recognized that composites would likely be used in some capacity to keep the airship's weight as low as possible at maximum strength.

Morgan explains that LTA used early 20th century airship designs as a foundation, modernized with today's materials, manufacturing techniques, and propulsion and navigation technologies, "and composites fall into that category of modern materials. Legacy airships were often built using aluminum or even wood in at least one case, but when you compare stiffness and weight, composites are the clear solution for our application." »

Modernizing the rigid airship frame

LTA Research based its airframe on rigid airships from the 20th century, but with contemporary materials and new, safer assembly techniques. The frame for *Pathfinder 1* is composed of more than 10,000 hollow carbon fiber composite tubes connected to titanium hubs.

Siemens (Alpharetta, Ga., U.S.) Femap finite element analysis (FEA) software and Ansys (Canonsburg, Pa., U.S.) simulation software were used to design each of the airship's structures.

"Composites were used in a number of places where lightweight structure is needed," Morgan says. Carbon fiber, Kevlar and fiberglass are all used depending on the required weight, stiffness and impact resistance properties.

Composite components include the gondola, built by partner Zeppelin; gondola attachment struts; the multi-component, multi-material nose cone, also built in partnership with Zeppelin, which includes a Kevlar shield and a carbon fiber-reinforced polymer (CFRP) attachment mechanism; fins; fiberglass composite motor covers; a roll-wrapped, out-of-autoclave (OOA) cured composite motor pylon; hand laid and press-cured gangway planks; and external air intake vents and mounts fabricated via a mix of autoclave and OOA hand laid composites.

For a rigid airship like *Pathfinder 1*, arguably the most important structural elements — certainly the largest, besides the envelope — are the 13 tube-shaped mainframes. For these, Morgan says carbon fiber composites were the top contender from the beginning. "From out of the gate, we were interested in something that was going to be extremely safe and extremely strong."

Manufacturing and assembling the *Pathfinder 1* frame

"The frame is designed with today's materials in mind," Morgan explains. "Carbon fiber's compressive strength versus aluminum or wood automatically changes the overall structure that you develop, because it carries the load differently." At the same time, he says that LTA didn't want to completely reinvent the wheel. "If you look at the old designs of airships, they use a similar geodesic pattern much like we do, although many of those were truss-based systems," meaning, in a semi-rigid airship design, a keel or truss along the bottom of the structure supporting the helium-inflated envelope above.

For LTA's frame, high strength and low weight were the top considerations; in addition, to simplify the qualification process, LTA decided to lean on existing aerospace-qualified materials. These goals led to a design featuring hollow tubes made from aerospace-grade carbon fiber prepreg, connected by a series of specially designed, welded titanium hubs. The overall *Pathfinder 1* frame is composed of almost 3,000 welded titanium hubs connecting 10,000 multi-ply CFRP tubes.

To simplify assembly, LTA decided on two tube configurations,

Miles of CFRP tubes

New Zealand-based Kilwell Fibrelab used a roll-wrapping and oven cure process to produce the tubes assembled onto *Pathfinder 1*.

Composites-intensive design

In addition to the CFRP frame, a variety of composites were used on the *Pathfinder 1* by LTA and its manufacturing partners. These include the fins (pictured), gondola, motor covers and more.

approximately 3 and 4 inches in diameter, respectively, which are cut to a variety of lengths of up to 12 feet. After testing samples from several suppliers, the company partnered with Kilwell Fibrelab (Rotorua, New Zealand), which specializes in composite tubes for a variety of applications.

For *Pathfinder 1*, the tubes are manufactured via a roll-wrapping process, where the prepreg sheets are cut to a specific size, then laid up in specified layers around a mandrel by hand. A heated shrink tape layer is added to the tubes for compaction, followed by an oven cure cycle. Aerospace-qualified carbon fiber prepregs from Toray (Tokyo, Japan) are used, both a spread-tow plain weave intermediate modulus (IM) prepreg and a unidirectional high modulus (HM) prepreg, with a proprietary resin.

Craig Wilson, CEO at Kilwell, explains that roll-wrapped composite tubes are the company's "bread and butter," but upgrades were needed to Kilwell's facility and process to meet LTA's and the FAA's quality standards, including temperature, humidity and particle management systems to the facility, and a new process for barcoding and data tracking for each process step for each part.

"We developed a more specialized cure cycle compared to some of our other projects, requiring a higher temperature and longer cure cycle to meet the requirements, and all data is monitored and tracked," adds Jason Daniels, production manager at Kilwell.

> The frame is composed of ~3,000 welded titanium hubs connecting 10,000 multi-ply CFRP tubes.

Wilson notes that since the first sample tubes were fabricated in late 2016, as of late summer 2023, Kilwell has produced 24,840 tubes with a total length of more than 25 miles in support of LTA's *Pathfinder* program.

Beyond the tubes themselves, another challenge to the frame structure was assembly. In the past, airships were very labor-intensive to assemble, Morgan says, requiring hundreds of people from dozens of specialized disciplines, many of whom had to work rather perilously from scaffolds. "Today, we can use modern techniques to front-load the process, using more in the way of engineers and automation and greatly reducing touch labor," he says.

In fact, LTA has patented a number of apparatuses designed to facilitate faster, safer construction. Essentially, mainframe tube and hub components are attached to a circular, universal mainframe jig built to the same diameter as the airship, suspended from the ground by support structures. Components are attached to the jig by technicians on the ground, and then the entire apparatus is rotated to lift that section of the mainframe to the required height.

This assembly method, and the tubes and hubs themselves, are all designed to be easily scalable, as LTA begins to look beyond *Pathfinder 1* to even larger airships in the future. "That's what's really a game changer with the architecture we're using," Morgan says, "that scalability. If we want to build an airship of a different size, we can use the same techniques, using the same tools and analysis techniques to design the airship and build it relatively quickly using the same or similar carbon fiber tubes."

Future *Pathfinders*: Larger airships, higher volumes

Right now, the focus is getting *Pathfinder 1* in the air, but the airship ultimately serves as a POC for more, even larger airships to come.

To support an increase in airship size, LTA needed a larger manufacturing space. In 2022, the company acquired the 1,175-foot-long, 325-foot-wide and 211-foot-high Akron Air Dock in Akron, Ohio, U.S., a massive, historical structure built in the 1920s by the Goodyear Zeppelin Corp. (a joint company at the time between Goodyear and Zeppelin) that has been the build site for many blimps, airships and other aircraft. Morgan says, "When we were looking at building a larger ship, we knew that we needed to find another home for it, and Akron is the origin of the airship industry. There's so much historical knowledge."

Currently on the drawing board is the next airship in the *Pathfinder* series, similar in design to *Pathfinder 1* but significantly larger — more than 600 feet long and 98 feet in diameter.

Morgan says the next *Pathfinder* "will largely follow in the footsteps of *Pathfinder 1* in terms of design, using large amounts of composites where they can be used on the airship. It's a design evolution, not a revolution." He notes that changes to materials and manufacturing decisions may be made, as lessons are learned from ongoing tests for *Pathfinder 1*, especially as the company »

■ **Flight-ready**

As of late summer 2023, *Pathfinder 1* is fully built and ready for flight tests in California. LTA plans to take design, manufacturing and operation knowledge from the airship into its next generation of larger, production-targeted airships to be built in Akron, Ohio, U.S.

seeks to accommodate larger part sizes and looks toward commercial production in future, higher manufacturing volumes.

The CFRP frame components are a prime example of this. "Going into the next iteration, we're looking for the same strain-to-weight ratios, the same performance for the frame components, but we need a high-volume manufacturing method," Morgan explains.

About three years ago, when looking into processes that would enable more efficient and scalable manufacturing of frame components, LTA connected with Exel Composites (Vantaa, Finland), which specializes in pultrusion and pull-winding of composite tubes and profiles. Morgan explains, "Exel's expertise in bulk manufacturing and automated manufacturing was the reason we selected them."

The main goals were repeatability and volume, while meeting strength, endurance, toughness and stiffness requirements. It was decided that Exel's pull-winding process was the best fit. Pull-winding essentially combines filament winding and pultrusion: like in pultrusion, carbon fiber tows are guided through a resin bath and then into a heated die to be shaped into the final part. In the pull-winding process, however, some of the tows are not pulled straight through in a linear fashion but are wound helically around a mandrel, which allows for fibers of various alignments for added strength and design flexibility. Like pultrusion, the process is continuous and profiles are subsequently cut to length.

"It's much more automated than a manual wrapping process, and consistency is very high. It's a continuous process that precisely places every fiber exactly where it needs to be," explains Marc Tagher, area sales manager – U.S., at Exel Composites.

"The pull-winding technique allows us a little more flexibility," Morgan adds, "and because the process uses tows instead of fabric, we're able to schedule laydown of the windings specifically to meet our needs." For example, winding the fibers around a mandrel adds hoop strength to the tube even with a relatively thin wall. In addition, "compared to hand layup roll wrapping, pull-winding is roughly an order of magnitude faster, and even offers cost savings with a large enough manufacturing run."

Switching from the current prepreg roll-wrapping process to pull-winding also involves new material selection. Exel's tubes are made from a mix of HM and IM carbon fibers, and a proprietary resin said to be selected for a combination of high performance and compatibility with the pull-winding process.

Exel's R&D teams in Finland have been working on optimizing various iterations of the tubes, which are then sent to LTA for mechanical testing. Once mass production of these tubes begins, Exel plans to move production to its facility in Erlanger, Ken., U.S.

Flight tests and future airships

Currently, the success of *Pathfinder 1* is LTA's top priority. The first airship was completed in early 2023 in Mountain View and as of mid-2023 has completed several indoor flight tests. Through the rest of this year, LTA says its goal is to move into the next phases of outdoor flight testing, as well as continued training for its team of certified pilots and experienced flight crew.

Following the successful rollout of *Pathfinder 1*, LTA's goal is to ultimately manufacture a series of airships out of the hangar in Akron, Ohio, U.S. CW

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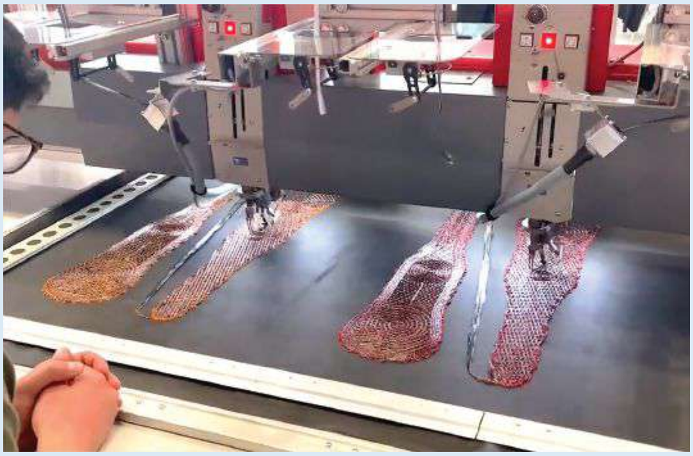
Post Cure

Highlighting the behind-the-scenes of composites manufacturing

Rapid, precision-targeted induction heating

At JEC World 2023, Corebon AB (Malmö, Sweden) demonstrated the ways in which induction heating enables fast, stable and targeted heating with less energy use and short production cycles for composite materials and parts manufacture. On the show floor, material was laid up in a 5-millimeter-thick steel tool, backed by an induction heating system with water cooling. Application of vacuum, heating and cooling were completed in 4-5 minutes, producing a high-quality commingled glass fiber-reinforced polypropylene part was achieved (top).

Corebon is also collaborating with ZSK/Unwind3D (Krefeld, Germany) for layups produced via embroidery and tailored fiber placement (TFP) (bottom). ZSK's equipment enables optimized fiber layups — including logos — that can then be placed directly into the mold to produce parts, resulting in optimized or tailored products. Being stitched here is a commingled glass or carbon fiber-reinforced polypropylene preform; the carbon fiber makes it susceptible to inducting heating, useful for welding.



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