CompositesWorld.com

CW CompositesWorld

Composite T-boom: ACCELERATING INDUSTRIAL AUTOMATION

APRIL 2020

The evolution of composites in NASCAR / 32

Revolutionizing the composites cost paradigm / 36

Composites in space / 46

A property of Gardner Business Media

VOL 6 No 4

APRIL 2020 / Vol: 6 №: 4

COLUMNS

4 From the Editor

6 Past, Present and Future
Several recent IACMI partner projects focus on technology innovation related to challenges in multimaterial joining for the wind and automotive sectors.

8 Design & Testing
After several years of research and development, the Single Cantilever Beam test method is in the process of standardization within ASTM's Committee D30 on Composites.

10 Perspectives & Provocations
Columnist Dale Brosius examines how public opinion on plastics will sharpen the focus on sustainability in composites manufacturing.

12 Gardner Business Index

FEATURES

32 The evolution of composites in NASCAR
The growing role of carbon fiber in stock car racing.
By Scott Francis

36 Revolutionizing the composites cost paradigm, Part 1: Feedstock
Highly-aligned, short-fiber Tailorable Universal Feedstock for Forming achieves aerospace properties, metal-like formability in zero-waste, fiber-to-parts pilot plant.
By Ginger Gardiner

46 Composites in the race to space
Advanced materials use in current and upcoming NASA missions.
By Scott Francis

» DEPARTMENTS

14 Trends
58 Applications
60 New Products
66 Marketplace
66 Ad Index
67 Showcase

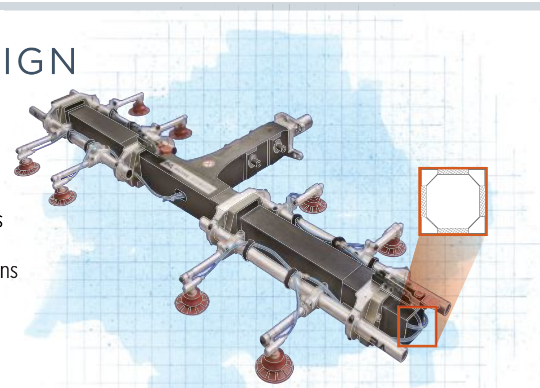
» ON THE COVER

The light weight and vibration damping capability of carbon fiber/epoxy composite material makes it a highly suitable choice for moving components in industrial applications. The pictured composite T-boom supports the transfer of a metal panel on a manufacturing production line. See p. 68.

Source / Bilsing Automation

FOCUS ON DESIGN

68 Composite T-boom accelerates industrial automation
A manufacturing method that integrates filament winding with axial winding of 0-degree fibers opens new design options in industrial automated equipment.
By Karen Mason



CompositesWorld (ISSN 2376-5232) is published monthly and copyright © 2020 by Gardner Business Media Inc. 6915 Valley Ave., Cincinnati, OH 45244-3029. Telephone: (513) 527-8800. Printed in U.S.A. Periodicals postage paid at Cincinnati, OH and additional mailing offices. All rights reserved. POSTMASTER: Send address changes to *CompositesWorld* Magazine, 6915 Valley Ave., Cincinnati, OH 45244-3029. If undeliverable, send Form 3579. CANADA POST: Canada Returns to be sent to IMEX Global Solutions, PO Box 25542, London, ON N6C 6B2 Canada. Publications Mail Agreement #40612608.

CW CompositesWorld

@CompositesWrld

PUBLISHER Ryan Delahanty rdelahanty@gardnerweb.com
EDITOR-IN-CHIEF Jeff Sloan jeff@compositesworld.com
SENIOR EDITOR Ginger Gardiner ggardiner@compositesworld.com
SENIOR EDITOR Scott Francis sfrancis@compositesworld.com
EUROPEAN CONTRIBUTOR Eric Culp eculp@gardnerweb.com
ASSOCIATE EDITOR Hannah Mason hmason@compositesworld.com
DIRECTOR, STRATEGIC INITIATIVES AND EVENTS Scott Stephenson sstephenson@compositesworld.com
ADVERTISING PRODUCTION MANAGER Becky Taggert btaggert@gardnerweb.com
GRAPHIC DESIGNER Susan Kraus skraus@gardnerweb.com
MARKETING MANAGER Chris Saulnier csaulnier@gardnerweb.com

CW CONTRIBUTING WRITERS

Dale Brosius dale@compositesworld.com
Michael LeGault mlegault@compositesworld.com
Peggy Malnati peggy@compositesworld.com
Karen Mason kmason@compositesworld.com
Amanda Jacob ajacob@compositesworld.com

CW SALES GROUP

MIDWESTERN US & INTERNATIONAL Dale Jackman / REGIONAL MANAGER djackman@gardnerweb.com
EASTERN US SALES OFFICE Barbara Businger / REGIONAL MANAGER barb@compositesworld.com
MOUNTAIN, WEST Michael Schwartz / REGIONAL MANAGER mschwartz@gardnerweb.com
EUROPEAN SALES OFFICE Eddie Kania / EUROPEAN SALES MGR. ekania@btopenworld.com

COMPOSITESWORLD IS A PROPERTY OF

GARDNER Business Media, Inc.

HEADQUARTERS

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

CHAIRMAN Richard G. Kline
PRESIDENT Richard G. Kline, Jr.
CHIEF MARKETING OFFICER Melissa Kline Skavlem
CHIEF DATA OFFICER Steve Kline, Jr.
CHIEF FINANCIAL OFFICER Ernest Brubaker
CHIEF TECHNOLOGY OFFICER Phil Louis
DIRECTOR OF CUSTOM CONTENT Tom Beard
ADVERTISING AND PRODUCTION DIRECTOR Bill Caldwell
DIRECTOR OF CONTENT AND WEB Kate Hand
DIRECTOR OF EVENTS Allison Miller
DIRECTOR OF STRATEGIC ENGAGEMENT Dave Necessary
MARKETING AND CREATIVE DIRECTOR Jeff Norgord
DIRECTOR OF MARKET RESEARCH Jan Schafer
AUDIENCE DEVELOPMENT MANAGER Julie Ball

GARDNER BUSINESS MEDIA ALSO PUBLISHES

Modern Machine Shop   Moldmaking Technology
Plastics Technology   Automotive Design & Production   Production Machining
Products Finishing   PF Mexico   Additive Manufacturing

» It's March 11 as I write this. One year and one day ago, on March 10, 2019, the world was hit by what turned out to be the first in a series of black swan events. Ethiopian Airlines flight 302 crashed shortly after take-off from Addis Ababa Bole International Airport in Addis Ababa, Ethiopia. Everyone onboard died.

> No one knows how long it will be until normal returns.

The plane, of course, was a 737 MAX. As we all know, the crash precipitated the grounding of the entire global 737 MAX fleet of 387 aircraft, followed by the slowing and then stopping of 737 MAX production altogether in December 2019 (black swan #2). The aerospace supply chain, in the meantime, was thrown in disarray, with about 400 manufactured-but-not-delivered aircraft in storage by Boeing. Spirit AeroSystems (Wichita, Kan., U.S.), which makes the aluminum fuselage for the entire 737 product line, was forced to lay off 2,800 employees in January 2020. Hundreds of other Tier 2 and Tier 3 suppliers have been similarly impacted.

The harm done to the composites industry by the 737 MAX grounding has been, for the most part, indirect. Although there are some composites on the 737, they are mostly in the engines. The disruption we have felt is caused by 737 MAX ripples, as Boeing has committed vast resources to fixing the aircraft and getting it re-certified for flight, limiting Boeing's ability to focus on other projects.

Consider, for example, that prior to March 10, 2019, Boeing was on a path to announce sometime in 2019 the New Midsize Aircraft (NMA), a new twin-aisle, 200-270-seat, 4,000-5,000-nautical-miles range plane that would fit between the 737 MAX 10 and the 787-8 in the company's lineup. The NMA, the thinking was, would provide a technological stepping stone for composite materials and process maturation, en route to development of a single-aisle replacement for the 737, Boeing's most popular and most profitable aircraft. The NMA would have entered service around 2025, followed by a single-aisle replacement around 2030.

That plan, apparently, is on hold — at least until the 737 MAX is back in service. And the NMA may not come to fruition at all. Airbus, at the 2019 Paris Air Show, announced the A321XLR, a long-range version of the A321 that is designed to allow longer city-pair flights (i.e., Madrid-Dubai) in a single-aisle configuration. Boeing, seeing the popularity of the A321XLR, is rethinking the NMA and might . . . what? Morph the NMA into an XLR derivation? Skip right to the single-aisle replacement? And if that occurs, what happens to the composites technology maturation we'd hoped for?

Airbus, for its part, is happy to watch Boeing struggle to bring the 737 MAX back to life and figure out next steps for the NMA/single-aisle replacement. It is assumed that Airbus will also develop a single-aisle replacement for the A320 (circa 2030 service date), depending in part on what path Boeing chooses. Airbus is pursuing, for a new single-aisle, several high-profile composites M&P development efforts, including an infused wing (Wing of Tomorrow) a thermoplastic fuselage (Clean Sky 2) and more.

The aerospace composites supply chain is, of course, watching all of this anxiously. There is a great desire among raw material suppliers (carbon fiber, glass fiber, fabrics, resins, etc.), intermediates producers (weavers, braiders, prepreggers) and fabricators of finished parts and structures to be a part of the supply chain for next-generation aircraft. Now is the time to prove the material capability, production capacity and technological aptitude required for next-generation aircraft.

And then, of course, the black swan that is COVID-19 arrived in January. Even as I write this, the virus has introduced such uncertainty into the global marketplace that air travel is depressed, schools have been closed, events (like JEC World 2020) have been postponed or canceled and the stock market has struggled. Some air travel analysts suggest that the world could see a *9%* drop in passenger air travel, which will put even more pressure on the economy in general and the aerospace supply chain in particular. And no one knows how long it will be before normal returns.

But, normal *will* return. The 737 MAX will, gradually, return to service. COVID-19 will fade, or at least become a part of the human health landscape. New aircraft programs will be announced. And even with future black swans the composites industry is still well-positioned for long-term growth.

JEFF SLOAN — Editor-In-Chief

Developing new solutions to multimaterial joining

»The IACMI — The Composites Institute (Knoxville, Tenn., U.S.) project model focuses research and development on technology innovation considered within the most likely path for deployment and impact. IACMI and its partners are creating new materials and processes for addressing key industry challenges, including multimaterial joining. The ability to join composites to other materials is a crucial manufacturing-enabling technology for the integration of advanced composites into wind turbine blades, vehicles and other high-value applications. Benefits are numerous:

IACMI supports development of novel non-adhesive joining methods.

- *Lightweighting — via mixed-material product design — improves the energy efficiency and sustainability of end-use applications.* Automotive manufacturers regularly use mixed-material design approaches as a strategy to reduce mass without imposing significant technology implementation risk. Lighter vehicles enable reductions in fuel consumption and greenhouse gas emissions.
- *Multimaterial joining techniques can improve manufacturing process flexibility and reduce production costs.* Longer wind turbine blades are difficult to transport from factory to installation site. As highway transportation for wind turbine blades becomes increasingly impractical, novel multimaterial joining techniques could enable larger and more efficient blades via jointed designs that provide for on-site manufacture and assembly.
- *Improved assembly/disassembly characteristics can enhance product lifecycle characteristics and satisfy end-of-life (EOL) recyclability or circularity goals.* Automakers are increasingly designing vehicles for easy and economic disassembly, due in part to a global shift in favor of sustainability initiatives such as the European Union's End-of-Life-Vehicle Directive, which requires that 85% (by weight) of materials used in passenger vehicles be reusable or recyclable. Improved assembly/disassembly characteristics can enable life-extending refurbishment and replacement of parts as well as the recovery and reuse of EOL products.

IACMI's technology roadmap includes project topic areas that prioritize project focus and will advance the state of multimaterial joining technologies across the composites manufacturing industry in the following ways:

- Novel multimaterial joining techniques including mechanical, adhesive and welding-based approaches are increasingly attractive as the cost of carbon fiber continues to decline.
- Robust sensing and inspection methods are essential to assessing the integrity, repairability and producibility of multimaterial composite joints in key lightweighting applications.
- Reliable design tools and test methods help ensure that novel multimaterial joining techniques are sufficiently cost-effective and dependable to achieve design compliance, serviceability and EOL requirements of key applications.

To address these topic areas, IACMI is supporting the development of novel nonadhesive multimaterial joining methods. For example, one project team is validating a nonadhesive thermal welding approach for joining wind turbine components. The project team consists of Arkema (King of Prussia, Pa., U.S.), Nippon Electric Glass (Otsu, Japan), Saertex (Saerbeck, Germany), General Electric (Boston, Mass., U.S.), TPI Composites (Scottsdale, Ariz., U.S.), the University of Tennessee (UT, Knoxville, Tenn., U.S.) and the National Renewable Energy Laboratory (NREL, Golden, Colo., U.S.).

Adhesive joining is a multi-step method that, if not properly executed, can cause manufacturing defects and subsequent failures in the blade structure. The novelty of Arkema's thermal welding approach is its use of thermoplastic resins to replace incumbent thermosetting epoxies. Thermoplastics can be bonded at room temperature and do not require heat input like thermosetting bonds, thus reducing energy requirements and manufacturing costs.

Unlike thermosets, bonding thermoplastics via thermal welding may eliminate highly stressed bond lines and the need for additional adhesive bonding materials between blade components, which reduces costs and blade manufacturing cycle time. Thermoplastic resins are also easier to recycle, as both manufacturing scrap and EOL components can be heated, recovered and reused for new wind turbines or other composites applications. Additionally, IACMI is demonstrating surface treatment techniques to enhance bond integrity/uniformity.

Surface conditioning technologies, such as ultraviolet ozone (UVO) and oxygen plasma, are often used to clean composite substrates and increase surface energy to ensure strong, durable bonding of fiber-reinforced composite joints. IACMI has commissioned two plasma-based surface treatment technologies to support member projects: one at the U.S. Department of Energy's Manufacturing Demonstration Facility at Oak Ridge National Laboratory (ORNL, Knoxville, Tenn., U.S.), and another at IACMI's Scale-Up Research Facility (SURF) in Detroit, Mich., U.S., which is managed by Michigan State University (East Lansing).

For this project, PPG Industries (Chestwick, Pa., U.S.) and Michigan State University studied new adhesives and coatings that allow OEMs to use their existing automotive assembly lines to integrate structural carbon fiber-reinforced polymers (CFRPs) into mixed-material designs. In this process, structural vehicle bodies are assembled on existing assembly lines and passed through a paint shop, where they are electrocoated and baked in an oven to improve the strength, corrosion resistance and durability of the finish. High oven temperatures — especially for mixed-material designs — can induce stresses and failures due to thermal expansion between coatings and substrate materials and between joined components. The team's investigation of new prototype adhesives established a deeper understanding of the importance of surface treatment technologies for ensuring proper structural adhesive bonding of composites to dissimilar materials. CW

ABOUT THE AUTHOR

Uday Vaidya serves as director of the University of Tennessee's Fibers and Composites Manufacturing Facility (FCMF), IACMI's chief technology officer, and is the University of Tennessee-Oak Ridge National Laboratory governor's chair in advanced composites manufacturing. Vaidya is an expert in manufacturing and product development of fiber-reinforced polymer composites. Vaidya serves as the editor-in-chief for Elsevier's Composites B: Engineering journal. He engages a broad range of undergraduate and graduate students in experiential learning with composites technologies.

The Single Cantilever Beam test for sandwich composites

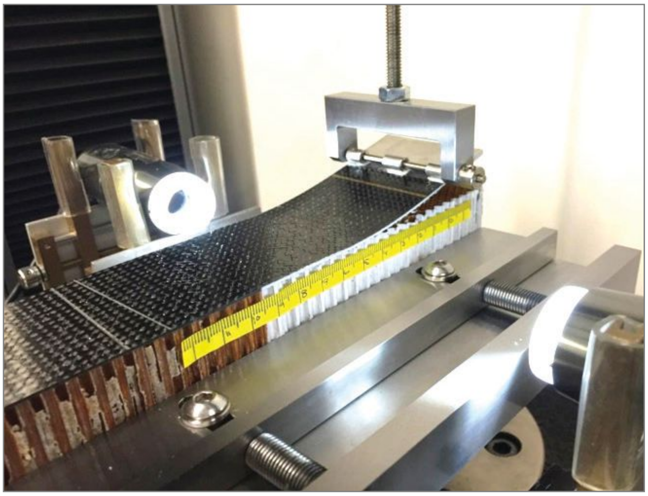


FIG. 1 Single Cantilever Beam (SCB) test configuration

Source | Wyoming Test Fixtures

» In recent years, there's been increasing interest in the development and standardization of new test methods for sandwich composites, including fracture mechanics, notch sensitivity and damage tolerance tests. This recent trend for sandwich composites resembles the period of development (and later standardization) of the same test methods for polymer matrix composites (PMC) in the 1980s and 1990s. In both cases, these developments were driven by new applications for which these properties were important design considerations. In this column, we focus on a Mode I fracture mechanics test for sandwich composites that's approaching ASTM standardization — the Single Cantilever Beam (SCB) test.

For starters, fracture mechanics test methods are used to measure a material's resistance to growth of an existing crack. For PMCs, the Mode I fracture mechanics test method is the Double Cantilever Beam (DCB) test, standardized as ASTM D5528[1] in 1994. This test is used to measure the resistance to growth, or *fracture toughness*, for an existing delamination within a unidirectional laminate under an opening-mode (Mode I) loading.

Similarly for sandwich composites, the SCB test is used to measure the Mode I fracture toughness of an existing disbond in the facesheet/core interface region. A vertical tensile force is applied using a piano hinge or loading block that's bonded to the end of the upper facesheet (Fig. 1). The debonded end of the upper facesheet functions as a cantilever beam, and thus the name — single cantilever beam test. The lower facesheet of the sandwich specimen is secured to the base fixture using an edge-clamping mechanism.

Unlike the DCB test, in which the measured fracture toughness is considered a *material* property of the PMC, the fracture toughness produced using the SCB test is considered a *structural* property. The reason? The measured fracture toughness depends on the sandwich configuration tested — including the facesheet material and thickness, the core material, the adhesive and the manufacturing method. Additionally, changes to the sandwich configuration may result in the disbond propagating at different through-thickness locations within the facesheet/core interface region.

This concept of a structural property has been observed when testing a series of SCB test specimens from the same sandwich panel but with different facesheet thicknesses, produced by bonding two thicknesses of glass/epoxy doublers to the outer surface of the facesheet prior to testing (Fig. 2, p. 9). As the total thickness of the facesheet (and thus the flexural rigidity) increases, the measured Mode I fracture toughness, G_{Ic}, increases. This increase is associated with the disbond migrating away from the adhesive layer adjacent to the facesheet and into the neighboring core material — in this case, a Nomex honeycomb. Detailed finite element analyses show that shear stresses exist in front of the crack tip, producing a small Mode II (shearing) component of the fracture toughness. While small relative to the through-thickness tensile stress, these shear stresses change in sign (positive or negative) and in magnitude depending on distance from the facesheet, and produce the observed differences in the measured fracture toughness and the through-thickness disbond locations. Due to this small Mode II component that may be present, the SCB test is referred to as a *Mode I-dominant* test.

Similar to the DCB test for unidirectional laminates, both *initiation* and *propagation* fracture toughness properties may be obtained using the same SCB test specimen. The *initiation* fracture toughness is a measure of the resistance to initial growth of a disbond with a prescribed crack front and at a designated through-thickness location. When used to investigate initial disbond growth from a sharp crack tip, an extremely thin (~10 microns) non-adhesive PTFE film is inserted into the facesheet/core bondline during sandwich panel manufacturing. However, other types of crack fronts may be of interest, such as those produced by foreign object debris (FOD) present at the facesheet/core interface. When performing the test, force and displacement values are recorded at multiple disbond lengths until the disbond has propagated 10-15 millimeters. The initiation fracture toughness is calculated using a modified beam theory method similar to that used in the ASTM D5528 DCB test method. Since linear elastic behavior is assumed when calculating the initiation values of G_{Ic}, a suitable initial disbond length must be determined to

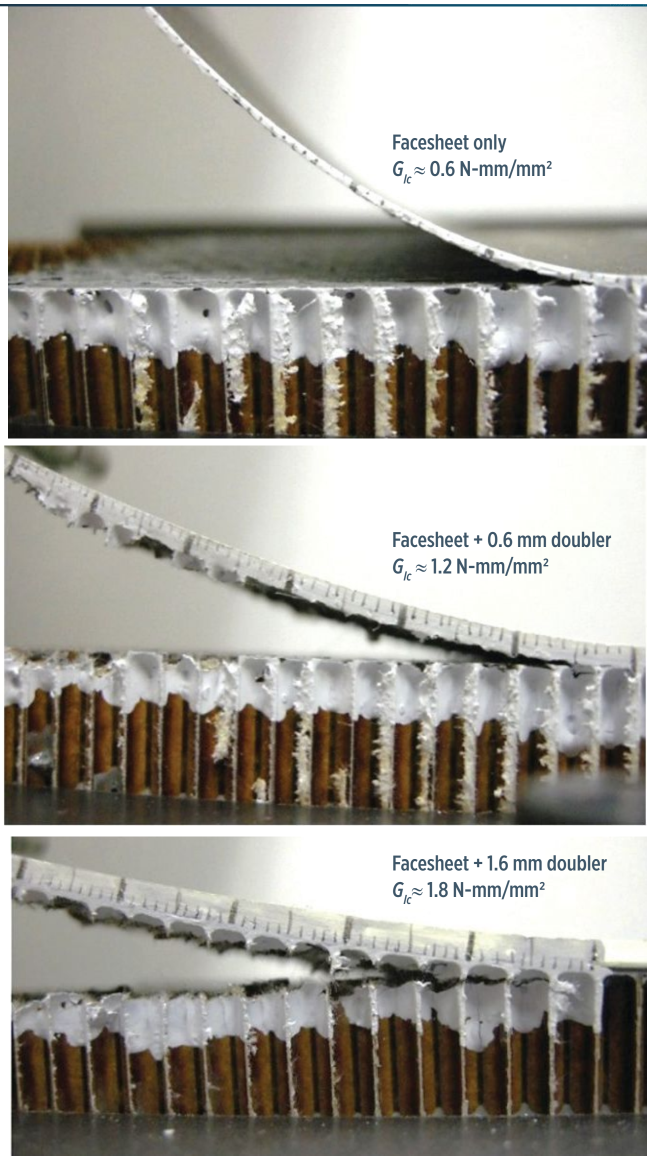


FIG. 2 Through-thickness disbond location and resulting G_{Ic} values for increasing facesheet thickness Source | Dan Adams

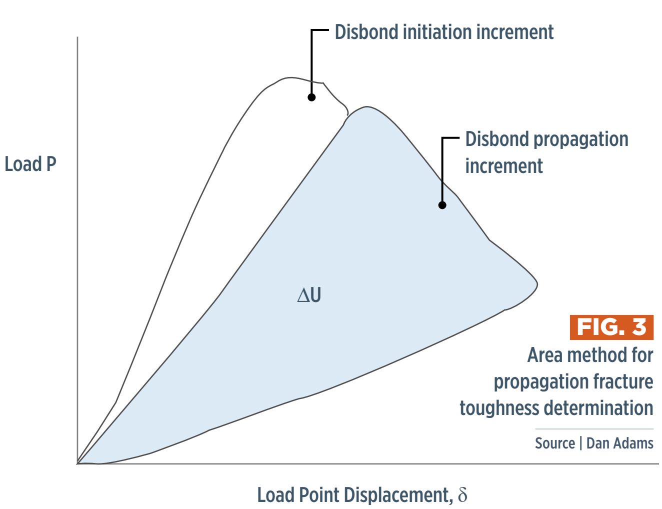


FIG. 3 Area method for propagation fracture toughness determination

Source | Dan Adams

avoid both large rotations and flexural failure of the disbonded facesheet during testing[2].

The *propagation* fracture toughness is associated with the resistance to growth of a naturally propagated disbond that has stabilized at its preferred through-thickness location. Thus, prior to measurement, an initial disbond must be propagated a moderate distance, typically 10-15 millimeters, to allow for the through-thickness location of the natural crack tip to stabilize. If initiation fracture toughness testing has been performed, the resulting 10-15-millimeter disbond propagation is typically sufficient. Otherwise, the initial disbond may be produced using a razor blade or fine-tooth sawblade, keeping as close to the facesheet/core interface as possible. A 10-15-millimeter length of disbond propagation is typically sufficient to produce the through-thickness, stabilized, naturally propagated disbond.

The propagation fracture toughness is calculated using an area method, in which the enclosed area produced in the applied force versus crosshead displacement plot during loading and unloading is used. Since this method does not require linear elastic behavior, large rotations of the disbonded facesheet are permissible. The specimen is loaded at a constant crosshead rate and the force and the displacement values are recorded at regular intervals so that the loading and unloading curves can be properly generated (Fig. 3). The disbond is propagated 30-40 millimeters, and the test is paused to mark the final position of the disbond tip prior to unloading. The propagation fracture toughness is calculated as

$$G_{Ic} = \frac{\Delta U}{\Delta A}$$

where U is the loss in strain energy corresponding to the area of disbond growth, A. The value of U is calculated as the shaded area shown in Fig. 3 using a computer-generated numerical integration method such as the trapezoidal method.

After several years of research and development, the Single Cantilever Beam test method is in the process of standardization within ASTM's Committee D30 on Composites. Further information may be obtained by contacting the author. CW

REFERENCES

1 ASTM D5528 13, Standard Test Method for Mode I Interlaminar Fracture Toughness of Unidirectional Fiber-Reinforced Polymer Matrix Composites, ASTM International (W. Conshohocken, PA, US), 2013 (first issued in 1994).

2 Ratcliffe, J.G. and Reeder, J.R. Sizing a Single Cantilever Beam Specimen for Characterizing Facesheet Core Debonding in Sandwich Structure, Journal of Composite Materials, Vol. 45, No. 25, 2011.

ABOUT THE AUTHOR

Dr. Daniel O. Adams is vice president of Wyoming Test Fixtures Inc. (Salt Lake City, Utah, U.S.) and emeritus professor of mechanical engineering at the University of Utah, where for 22 years he directed the Composite Mechanics Laboratory. He holds a B.S. in mechanical engineering and an M.S. and Ph.D. in engineering mechanics. Adams has a combined 40 years of academic/industry experience in the composite materials field. He has published more than 120 technical papers, is vice-chair of ASTM Committee D30 on Composite Materials and co-chair of the Testing Working Group for the Composite Materials Handbook (CMH-17). He regularly provides testing seminars and consulting services to the composites industry. **Dan@WyomingTestFixtures.com**

Sustainability matters: Now, not just in the future

» Over the past several years, we've seen increasing opposition to things made of polymers, or plastics. Driven by real concerns with ocean and ground pollution, municipalities, states and countries are enacting bans on single-use plastic bags, straws and other items, including packaging.

It's a proven fact that plastics provide exceptional benefits such as extending the shelf lives of food and pharmaceuticals, protecting against bacterial infection and being more durable than paper or glass against damage. However, because of this durability, unless properly disposed of or recycled, they risk winding up in places they shouldn't, like the ocean and other waterways. There's no question we need to do better, but banning plastics will just bring back the problems they have solved.

As part of the "plastics community" (I have been a member of the Society of Plastics Engineers [SPE, Danbury, Conn., U.S.] since 1992), the increasing amount of negative press and efforts to ban plastics certainly draws my attention. And it leads to some interesting consumer behavior. I recently read an article written by someone attempting to remove all plastic from their lives — not just single-use packaging such as toothpaste tubes and shampoo bottles, but also reusable plastic dinnerware and storage containers. I know I have Tupperware that is more than 20 years old and still functioning perfectly — and much more durable than china plates and glass jars. I'll keep using them until I'm gone, I figure. Given the quantity of polymers in the fibers we have in our clothing, the aesthetic interiors in our cars and the housings of our televisions and other electronics, it seems far-fetched to move back to materials used 50 years ago.

For those of us in the composites industry, we've had it relatively easy, with only minimal pressure to recover and reuse manufacturing waste and end-of-life products. Sure, we've seen certain legislation enacted or proposed, but the effects haven't really hit home yet. We know our products enable reduced fuel consumption due to the ability to lightweight transportation and protect against fuel leaks in underground storage tanks. Composites in infrastructure extend the lives of roads, bridges and buildings, reducing long-term concrete production, which uses lots of water and emits large amounts of carbon dioxide. And the largest user of composite materials, the wind energy industry, overcomes the total embodied energy to construct a turbine in the first month of operation, then produces emission-free electricity for another 20 years. In so many ways, composites are more environmentally friendly than traditional materials.

In so many ways, composites are more environmentally friendly than traditional materials.

Our time "flying under the radar" with the public at large when it comes to disposal and recycling may be over. Last month, in my column about the seemingly unstoppable growth of the wind industry, I mentioned end-of-life disposal as a looming issue not only for decommissioned blades, but also for end-of-life composite aircraft and automobiles. A week after filing that column with *CW* (and several weeks before publication), a Feb. 5 article from *Bloomberg* featured a photo of a large pile of used wind blades covered with dirt in a Wyoming landfill, highlighting this particular issue. The article cited how difficult it is to recycle the blades, a true testament to the strength and durability attributes that make them ideal for the application. Since then, other publications and newspapers have picked up on the story — and now the public is much more aware due to this negative press.

Which makes all the efforts our industry has undertaken the last five to 10 years to develop ways to recycle composites even more important. While I don't need to go into the various technologies that have emerged to recycle composite waste and composite parts — there has been significant coverage of that in recent issues of *CompositesWorld*, including an overview of projects funded under the IACMI umbrella — it is important to stress the urgency to do more than just R&D in this topic, or to produce pilot quantities for evaluation. We must scale these solutions not only to accommodate the forthcoming volumes of materials, but also to achieve the needed economies to produce recycled products that are cost-effective to use in other products.

This will take considerable investment, and it will take commitment not only from suppliers of the materials into these recycling facilities, but also innovators finding ways to employ the recovered products, which has been a problem to date. It will also take a collective effort to shout these successes to the press outside of our composites community. By doing so, we can assure the public that composites are indeed the most sustainable solution. CW

ABOUT THE AUTHOR

Dale Brosius is the chief commercialization officer for the Institute for Advanced Composites Manufacturing Innovation (IACMI), a DOE-sponsored public-private partnership targeting high-volume applications of composites in energy-related industries including vehicles and wind. He is also head of his own consulting company, which serves clients in the global composites industry. His career has included positions at US-based firms Dow Chemical Co. (Midland, MI), Fiberite (Tempe, AZ) and successor Cytec Industries Inc. (Woodland Park, NJ), and Bankstown Airport, NSW, Australia-based Quickstep Holdings. He served as chair of the Society of Plastics Engineers Composites and Thermoset Divisions. Brosius has a BS in chemical engineering from Texas A&M University and an MBA.


FIELD-PROVEN ADHESIVES FOR DEMANDING VACUUM MOLDING INFUSION APPLICATIONS.
NEWSTAR ADHESIVES
STICK WITH THE BEST
Specifically formulated for a stronger, more flexible matrix.
NewStar 900 Series Adhesives are formulated to cross-link with resins to create an integrated matrix and not interfere with polymer matrix integrity.
• Low shrinkage during cure
• CA & OTC Compliant
• High tack, hold fast bonds
• Fully integrates into matrix
• Low VOCs, No HAPS
• Repositionable
• Available in Canisters and Aerosols
• Polyester & Vinyl Ester compatible
NEWSTARADHESIVESUSA.COM | 855-497-0700
3rd party testing confirms the N900 line delivers superior performance in vacuum infusion applications when compared to the other competitive infusion adhesives.
N900 EVERHOLD N900
Exclusively Distributed by North American Composites
NAC
NORTH AMERICAN COMPOSITES

Composites Index contracts on weak backlogs

February 2020 — 49.7

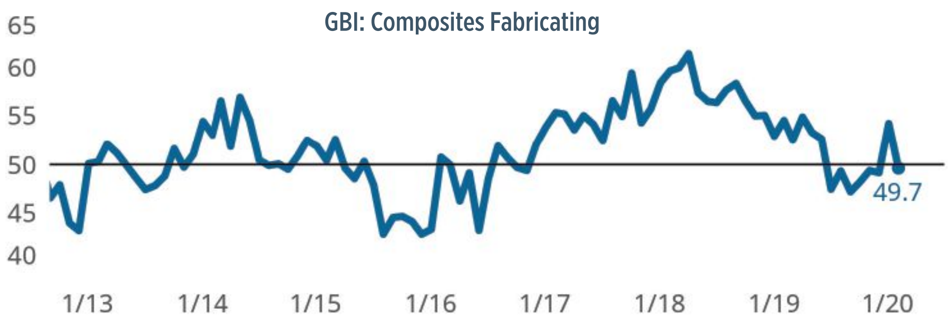
» After January's expansionary reading — the first since mid-2019 — the Composites Index contracted slightly in February to register 49.7. Gardner Intelligence's review of the underlying components observed that the Index reported little new expansionary activity in production and new orders after both registered recent highs the month prior. The fastest-expanding component was supplier deliveries, while the Index was pulled lower by a sharp contraction in backlogs and a continuing contraction in export activity.

In addition, the impact of the COVID-19 virus is expected to have an adverse effect on the Composites Index in the coming months. Though necessary, the efforts of Asian governments in January and February — and by a widening collection of nations in February and March — to combat the spread of COVID-19 through quarantine measures is having a detrimental impact on the world's supply chain. Most immediately, this will restrict the normal flow of upstream and sub-component goods that are necessary for the proper functioning of the manufacturing sector.

This Index is unique in its ability to meticulously measure business conditions specific to the composites industry on a monthly basis, so this Index will be able to quantify both the initial shock from the virus along with the timing and strength of the composites industry's eventual recovery. It is particularly important for our readers to complete the GBI survey sent to them each month. Your participation will enable the best and most accurate reporting of the true magnitude and duration of COVID-19 and will allow you and your peers to make data-driven decisions at a time when the temptation to make impulsive decisions can be strong. CW

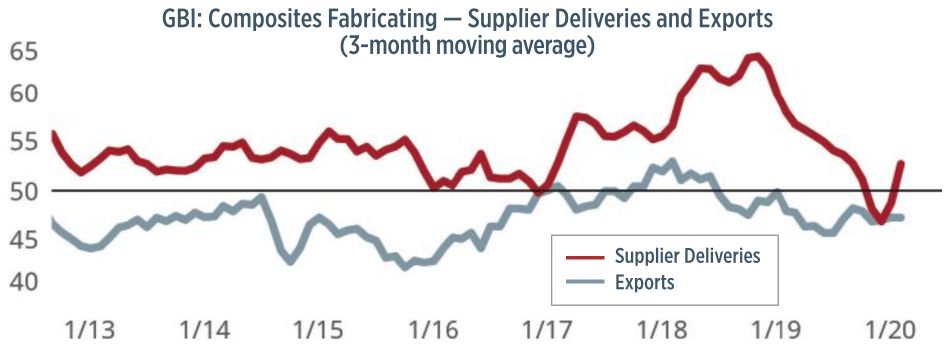
ABOUT THE AUTHOR

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



Slight contraction for February

The Composites Index contracted slightly in February as backlog activity contracted amid a sharply slowing growth in production and new orders activity.



COVID-19 expected to impair supplier chains, export demand and increase costs

Gardner Intelligence expects that most — if not all — of its indicators will be subjected to shocks from COVID-19. That the virus originated in Asia suggests that American manufacturers in the immediate future should pay particular attention to their supply chains and expect increased volatility in export orders and material prices.

PRESENTED BY

GARDNER BUSINESS INDEX

Stay ahead of the curve with Gardner Intelligence.
Visit the blog at gardnerintelligence.com or e-mail mguckes@gardnerweb.com

This month's composites industry trends include an interview with Rhode Island Commerce director of business development John Riendeau from the *CW* Talks podcast, the latest digital technologies from the National Composites Centre and more.

Q&A with John Riendeau, Rhode Island Commerce

CW senior editor Scott Francis talks to John Riendeau, director of business development at Rhode Island Commerce. Riendeau discusses how the state of Rhode Island has leveraged centuries of local boatbuilding experience to transition into the world of advanced composites. He highlights local companies including Clear Carbon and Components (C3, Bristol, R.I., U.S.) and Goetz Composites (Bristol, R.I., U.S.), which have evolved from boatbuilding roots to use composites to shape countless industries.

To listen to the full interview, go to compositesworld.com/podcast or download CW Talks on Google Play or iTunes.

***CW*: Let's look at a couple of Rhode Island-based companies, Clear Carbon and Components (C3) and Goetz Composites. Can we examine those two companies as a little bit of an example of the shift from boatbuilding to new composites-related markets? Can you tell us a bit about what these two companies are doing?**

JR: I'll start with Clear Carbon and Components. Matt Dunham, who's the founder of the company, in his youth as a boatbuilder learned the skills for setting fiberglass and resin in a mold to build a boat. When he created his own company, he wanted to experiment and do things his own way. He has done that with all types of different components, getting into carbon fiber, Kevlar and other materials … On behalf of the military he [manufactures] a [carbon fiber] enclosure that is portable and foldable. … you pull it apart into a 20-foot box, which could be used for housing [or] a military command post, etc.

He also does unique vessels [such as] tow vessels for the U.S. Navy [and] undersea unmanned vehicles. He's doing pretty unique things like [musical instruments] that he evolved through a friend. He experimented [and] did a lot of prototype development … and now he's one of the premier stringed instrument manufacturers in the country, [manufacturing] violins, cellos, violas … along those lines. A totally different customer base from the U.S. military.

He also does a portable matting system. Again, all carbon fiber that you unroll — picture this thing at about 10 feet wide, that unrolls and lays over wet, muddy ground so that vehicles can transit over it. And you just roll it back up and you take it with you. That's for the military and other users that want to get over this kind of terrain.

He [also] does some very exotic furniture — very high-end, very durable. It can withstand the elements and it can accept color, because the color is infused into the product itself. He's a very unique builder and designer of various composite components.

Goetz Composites is the other company you talked about. Eric Goetz has been around since the 1970s playing with this stuff, and it was around 1984 that he built, on behalf of a German customer, a custom carbon fiber racing yacht called the *Frers 54*. That was 36 years ago. At that time, that was novel — that was a novel boat, a novel vessel and a lot of it caught a lot of attention. It was lighter, more durable, faster. When people see that, they want the same materials in their boats.

Goetz has gotten into the architectural field and [has created] very unique pieces. For example, for Universal Studios in Orlando, he worked extensively with the Wizarding World of Harry Potter, doing very unique pieces that are on the exterior of those buildings. He did a piece for the Miami design district called the Fly's Eye Dome.

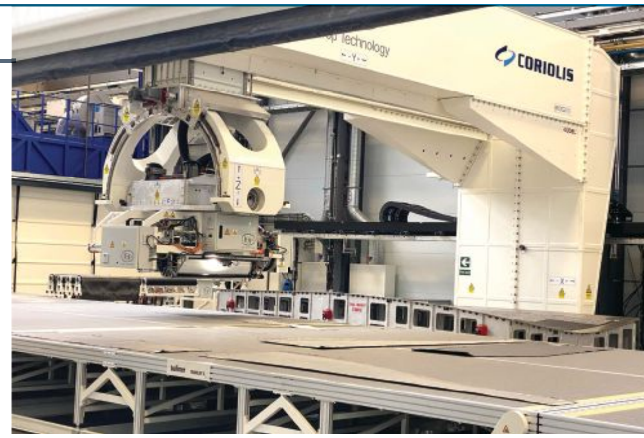
And it's not just these companies. It's Rhode Island that stands out — lots of companies here have that capability and have been able to work with these kind of exotic materials and resins, and are able to produce. That's why so many people want to see their products built by Rhode Island builders.

BIZ BRIEF

Earlier this year, **Spirit AeroSystems** (Wichita, Kan., U.S.) acquired **Fiber Materials Inc.** (FMI, Biddeford, Maine, U.S.) for $120 million. FMI is an industry-leading technology company specializing in high-temperature materials and composites for defense. The company's main operations focus on multidirectional reinforced composites that enable high-temperature applications such as thermal protection systems, reentry vehicle nose tips and more.

AEROSPACE

National Composites Centre unveils digital composites technologies



NCC's new Coriolis automated fiber placement system. *CW* photo | Scott Francis

The U.K.'s National Composites Centre (NCC, Bristol, U.K.) held an event in February celebrating the center's investment in an additional 9,948 square meters of space and 10 state-of-the-art digital manufacturing technologies.

The investment is part of a digital capability acquisition program known as iCAP, a £36.7 million investment in 10 technologies tailor-made for the NCC with the goal of speeding development of composites manufacturing for a range of markets. The iCAP program is funded by the Aerospace Technology Institute (Cranfield, U.K.), Local Enterprise Partnership and the High Value Manufacturing Catapult (Solihull, U.K.).

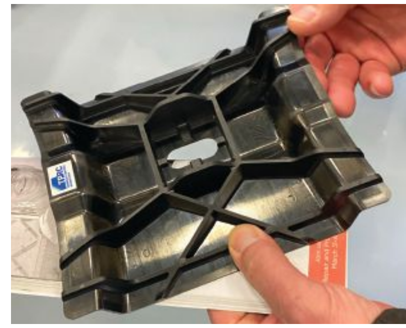
"Our mission is to mature composites technology out of the academic research area into a production-ready environment," says Rich Hooper, director of engineering and manufacture at NCC. To that end, for the past two years, a team of NCC engineers, researchers, software architects, roboticists and textile experts have been exploring how digital technologies can make composite parts easier to design and improve the speed and cost of manufacture.

The aerospace sector is a significant driver of the demand for high-rate composites manufacturing. According to the NCC, using current, labor-intensive techniques, manufacturers can only make six pairs of wings per month — the likely rate of production needed for a future single aisle aircraft is 100 pairs per month. The NCC is a partner in the Airbus Wing of Tomorrow Programme, which has a goal of developing a high-rate commercial aircraft wing structure manufacturing process involving more automation, fewer parts, better parts integration, faster cycle time, faster NDI and faster assembly.

The NCC's new equipment includes a new pilot line that will be used for the Wing of Tomorrow. The high-rate deposition system comprises two huge industrial robots that automate the wing production process. Weighing 45 tonnes and *(continued to p. 18)*


OSG
EXPECT THE BEST
OUTPERFORM THE REST
Patented Geometries
Reduces uncut fibers & delamination
Multiple Designs
For milling in composites & metal stack materials
OSG Diamond Coating
Excellent durability & up to 50x longer tool life
EXOPRO® AERO Composite Routers
EXOPRO® AERO products represent OSG's highest performance tooling for composite and composite/metal stack applications. Featuring our patented ultra-fine diamond coating and unique geometries for unparalleled performance and tool life. Standard or special tooling, OSG designs new and innovative products specifically to shape our customers' dreams.
800-837-2223 • osgtool.com

(continued from p. 16)



An overmolded carbon fiber part produced using the NCC's new overmolding cell.

CW photo | Scott Francis

24 tonnes respectively, the robots measure, cut, lift and place pieces of carbon fiber plies with millimeter accuracy. Five-meter-wide strips of composite material, up to 20 meters long, can be laid in one precise movement, potentially cutting the number of fabric components required from around 100,000 to just 150, and reducing wing-build time from one week to one day.

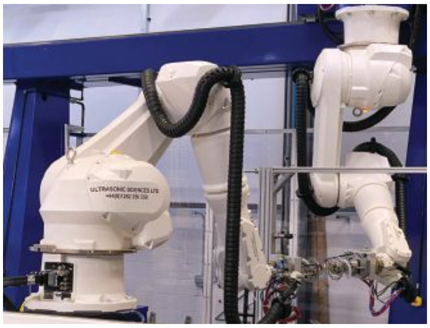
Once the plies are laid, the wing is vacuum bagged and moves into a new 20-meter-long oven equipped with large-scale resin infusion tanks. The wing is cured in the oven at 180°C within 8 hours.

The new technologies at the NCC are not only helping to rethink how aircraft wings are made, but are also helping to bridge the gap between academic research and industrialization in a range of markets from construction to oil and gas.

"[This] investment in 10 new world-leading composites capabilities will enable us to develop the wings and engines for the aircraft of the future, work on technologies that will define the way we produce and store energy and transform the way we build infrastructure," says Richard Oldfield, CEO of the NCC.

"Membership has doubled in the last year, but has doubled out of the non-traditional sectors," he adds. "That's really exciting and really does open up fantastic opportunities."

Other technologies include a circular braider from Eurocarbon (Sittard, Netherlands), the largest of its kind in Europe, which automatically weaves up to 288 individual strands of high-strength carbon fiber to



Ultrasonic NDI is conducted by two robots working in unison.

CW photo | Scott Francis

create hollow 3D shapes (or geometries), for products such as pipes or aircraft propellers.

A new overmolding cell supplied by Engel (Schwertberg, Austria) features a horizontal 1,700-tonne press, injection barrel temperatures/pressures up to 420°C and 2,000 bar with a shot volume up to 6,400 cubic meters. The goal of the overmolding system is to enable the mass-production of composite components.

"Composite overmolding technology specifically allows for the rapid manufacture of net-shape structural thermoplastic composites," says Enrique Garcia, chief technology officer at the NCC. "It combines both laminate thermoforming and polymer injection molding in one automated process, thus structural components with a valuable combination of high strength and integrated complex design features can be manufactured with a very low cycle time."

For nondestructive inspection (NDI) of parts, the NCC has commissioned two, 3-meter-high robots that work in unison to scan the component by beaming ultrasound through high-pressure water jets. The system then measures the time taken for sound to travel through the part, alerting operators to any anomalies.

New technologies at the NCC also include an automated preforming cell, a Coriolis Composites (Quéven, France) C5 automated fiber placement (AFP) robotic gantry system and an Electroimpact (Mukilteo, Wash., U.S.) AFP/ATL machine.

AUTOMOTIVE

Sustainable composite materials support Toyota EV concept


Source | Covestro

Sustainability and electric vehicles combine in a new car concept featuring composites.

Material solutions provider Covestro (Leverkusen, Germany) has been chosen by Toyota Boshoku Corp. (a car component manufacturer of the Toyota Group, Kariya City, Japan) to jointly develop a new polyurethane composite material for use on the Toyota Motor Corp.'s electric concept car *LQ*.

The lightweight, sustainable material is based on a combination of Covestro's advanced Baypreg F NF technology and Toyota Boshoku's expertise in using kenaf fibers. This new kenaf fiber-reinforced polyurethane foam composite material will be used on the *LQ*'s door trims.

Kenaf is a member of the hibiscus genus and is growing in regions such as Southeast Asia, Bangladesh, India and Africa. The fiber is obtained from bast fibers of the kenaf plant and has recently attracted increasing attention as a cost-effective raw material with good mechanical properties, Covestro says. In the automotive industry, the plant fiber is also said to be attracting increasing interest as an alternative raw material.

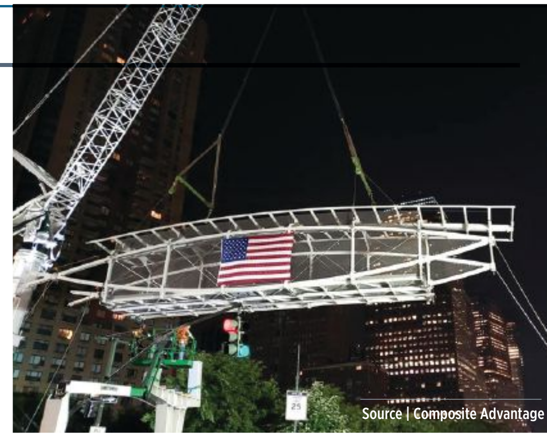
Covestro and Toyota Boshoku's kenaf fiber-reinforced polyurethane foam composite is characterized by a very low density of less than 1 kilogram per square meter, as well as high strength. The door trim made from this material is said to be 30% lighter than that produced from conventional materials. Lightweight materials also enable the car to travel farther on one tank of gas or a single battery charge.

The new composite material was developed in close cooperation between Toyota Boshoku and Covestro's recently renovated Japanese Innovation Center.

"Our joint development makes an important contribution to the design of particularly lightweight and sustainable vehicles," says Hiroaki Ido, head of Polyurethanes Application Development for Transportation at Covestro's Japanese Innovation Center. "It is also a good example of our company's focus on using alternative raw materials and establishing a circular economy."

INFRASTRUCTURE

FRP chosen for New York pedestrian bridge as part of 9/11 rebuild project


Source | Composite Advantage

Manhattan has an estimated 1.63 million people living in 23 square miles, making the New York borough one of the most crowded places in the U.S. Pedestrian bridges across roadways help connect people to various sections of the city.

The West Thames pedestrian bridge to Battery Park City has been more than a decade in the making. After the terrorist attacks on September 11, 2001, a temporary pedestrian bridge was installed on Rector Street, but in 2017, the Lower Manhattan Development Corp. and the Battery Park City Authority chose Composite Advantage's (Dayton, Ohio, U.S.) FiberSPAN fiber-reinforced polymer (FRP) pedestrian bridge system for the permanent structure.

The FRP West Thames Street crossing, which opened to the public in late 2019, spans 230 feet over six-lane West Street and Hudson River Greenway, giving pedestrians a direct connection to Battery Park City from the Financial District.

According to Composite Advantage, the FRP pedestrian bridge is the first of its type in New York Cit. The 16 panels of FRP decking are supported by a two-span steel lenticular truss bridge.

Composite Advantage designed the structure to meet performance requirements that included a 90-psf live load and a deflection rating of L/360. The deck area totaled 3,482 square feet, with deck panel dimensions of 12.9 by 12.9 feet, a deck depth of 4 inches and a deck weight of 8.4 psf.

"We're seeing an uptick in use of FRP on signature pedestrian bridges," says Scott Reeve, president of Composite Advantage. "Corrosion resistance, light weight and the design flexibility of FRP make it an attractive option. But we're also finding that our FRP bridge products are being adopted because they are becoming a robust conduit for helping people make connections in congested urban areas."

FiberSPAN bridge deck features included curbs, access to utilities underneath, and a long-lasting, non-slip overlay of quartz aggregate polymer.

The prefabricated FRP decking was installed on the bridge in Red Hook, Brooklyn, and then the fully assembled structure traveled by barge to Battery Park City, where it was installed overnight.

CARBON FIBER

NASA, OceanGate collaborate on manufacture of carbon fiber pressure vessels


Source | OceanGate

OceanGate (Everett, Wash., U.S.) and NASA are working together on the development of a carbon fiber pressure vessel for use in OceanGate's composites-intensive deep-sea submersibles.

NASA's Marshall Space Flight Center in Huntsville, Ala., U.S., will serve as the facility where the development and manufacture of a new aerospace-grade hull is completed. This design effort is key to OceanGate completing its latest Cyclops-class submersible that is designed to dive to 6,000 meters (19,800 feet) with five crewmembers on board.

"We continue to receive more demand for Titanic, deep-sea research and environmental supervision of deep-sea mining missions that very few submersibles in the world have the capability of supporting. NASA's advanced composite manufacturing capability is ideally suited for the high-precision and high-quality requirements of our latest hull design," explains OceanGate CEO and founder, Stockton Rush.

"OceanGate's primary goal is to open the oceans and make exploring, researching and documenting deep ocean sights safer and more accessible to not only researchers and governmental agencies, but also to citizen explorers. We look forward to working with NASA to do just that," Rush adds.

"NASA is committed to cutting-edge composites research and development that will not only further our deep space exploration goals, but will also improve materials and manufacturing for American industry," says John Vickers, principal technologist for advanced manufacturing technology at NASA. "This Space Act Agreement with OceanGate is a great example of how NASA partners with companies to bring space technology back down to Earth."

Researchers explore biomimetic approach for making adhesives tougher

How do you make adhesives for electronics, vehicles and construction tougher? By making them weaker. That's the proposed solution from a Purdue University (West Lafayette, Ind., U.S.) research team — well-known for its adhesive technology.

Using inspiration from mussels and oysters, the Purdue team added bonds that are broken easily throughout the material. When pressure or stress is applied to the material, these sacrificial bonds are designed to absorb energy and break apart. Meanwhile, the rest of the larger adhesive system remains intact. The Purdue team's work is published in the *Journal of the American Chemical Society*.

"We added weak bonds within the adhesive so that mechanical forces and growing cracks lose energy by breaking these bonds instead of having the whole, larger material fracture. The idea is to manage how energy moves through the material. The overall adhesive system can become tougher and less likely to break apart when placed under mechanical stress," says Jonathan Wilker, a Purdue professor of chemistry and materials engineering, who helps lead the research team

Wilker's team tested this idea with several types of bonds, with potential for various applications. Read more at short.compositesworld.com/PUadhesive.

CARBON FIBER

"Green" carbon fiber: Renewable energy powers fiber production

Source | Zoltek

Zoltek Companies Inc. (St. Louis, Missouri, U.S.) claims to be the first carbon fiber producer to use green energy — electricity produced from renewable resources such as wind turbines — to manufacture a portion of its global carbon fiber production.

At the start of the year, Zoltek's facility in Nyergesújfalu, Hungary, began using electricity from renewable resources to power everything from precursor production to ovens used to carbonize precursor on the way to producing carbon fiber, to intermediate products made from the carbon fiber.

"The green electricity is being used for every step of the process, from the moment our raw material enters our facility until the moment the finished carbon fiber leaves as part of a shipment to a customer," explains Tobias Potyra, Zoltek global automotive director.

This switch in energy sources — at a cost premium that will be borne by Zoltek and not passed on to customers — is estimated to save 5,000 metric tons of carbon dioxide (CO_2) annually versus electricity generated by burning coal or natural gas. The plant's local electricity supplier will issue CO_2 certificates to Zoltek based on actual consumption at year's end.

The significance of this step becomes clearer when the size of the Nyergesújfalu facility it considered. It has an annual capacity of 15,000 metric tons of carbon fiber and is said to be the world's largest fully integrated carbon fiber plant where polyacrylonitrile (PAN) precursor, carbon fiber itself, and downstream, value-added carbon fiber-based intermediates like fabrics and pultruded goods are produced at a single site. Given how energy-intensive carbon fiber production is, hopefully other carbon fiber producers follow suit.

Although it still looks black, a portion of Zoltek's total global output of industrial-grade (heavy-tow) carbon fiber has just become greener thanks to use of electricity produced from renewable resources that helps offset the greenhouse gases normally (continued on p. 26)

(continued from p. 25)

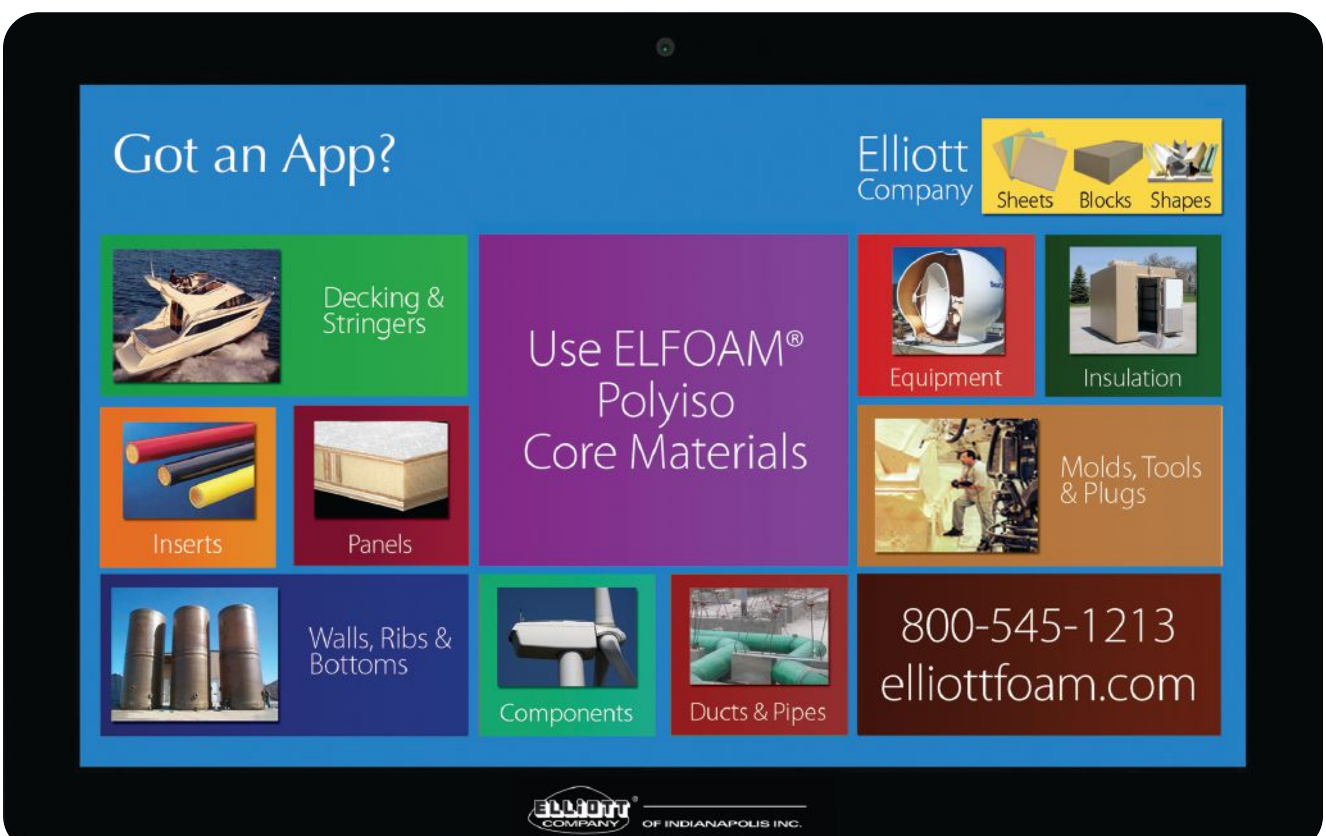
generated when electricity is produced by burning coal or natural gas.

Reportedly, the change is being made as part of Zoltek's internal efforts to focus on sustainability in all areas of its business.

"Our carbon fibers enable wind energy to compete with fossil fuels, automobiles to be lighter weight, and batteries to be more efficient, so the shift to renewables to power our own precursor and carbon fiber manufacturing was the next logical step," explains David Purcell, Zoltek executive vice president. "The proactive use of renewable energy aligns with both our own corporate philosophy as well as the philosophies of many of the industries we serve across the globe whose products already benefit the environment."

"At Zoltek, we focus every day on ways to make life better for future generations," adds Nobuya Ando, Zoltek CEO and president. "Using green energy is our responsibility to our customers, our shareholders and everyone in our communities."

Zoltek is the global producer of low-cost, industrial-grade (heavy-tow) carbon fiber and carbon fiber-based intermediates for automotive, wind energy, thermoplastic compounding, offshore drilling, civil engineering, marine and other industrial segments. Zoltek was acquired by Toray Group (Tokyo, Japan) in 2014.



AEROSPACE

AMRC, NCC, Dowty Propellers to develop lightweight composite propeller blades


Source | AMRC

Composite researchers at the University of Sheffield Advanced Manufacturing Research Centre (AMRC, Sheffield, U.K.), along with industry partners from the High Value Manufacturing Catapult, are carrying out a £20 million (more than $25 million USD) project to develop lightweight composite propeller blades, aimed at reducing the U.K. aviation sector's carbon footprint and noise emissions at airports.

The AMRC, along with the National Composites Centre (Bristol, U.K.) and the Manufacturing Technology Centre (Coventry, U.K.), is supporting private sector partner Dowty Propellers (part of GE Aviation Systems) for the Innovate UK-funded Digital Propulsion project.

Alongside the NCC, the AMRC is exploring innovative ways to design and manufacture various types and sizes of propeller blades, including the load-bearing structure, the cores, the blade roots and relevant hub connections. The researchers are also collaborating to form a new braid that fits various shapes, using equipment purchased by the AMRC with funding from the Aerospace Technology Institute (ATI).

"Our portfolio of cutting-edge equipment means we're able to access a wide range of advanced technologies to do this work including finite element analysis, braiding, tailored fiber placement, resin transfer molding and press forming," says Elaine Arnold, automation technical lead for the AMRC Composite Centre. "The next steps will be to look at the braiding of multiple parts of the blade and then the thermoforming of the foam that sits on the inside of the blade. Excellent progress has been made so far and the goal is for us to make a section of the full blade," Arnold adds.

The three-year program has allowed Dowty (continued on p. 28)

(continued from p. 27)

to investigate multiple technologies to design the next generation of composite propeller blades, incorporating new and novel geometries beyond current capabilities offered by existing manufacturing techniques.

"This program paves the way for new business opportunities within Dowty. The technology development led by the Catapults is allowing us to explore both current and emerging markets and create offerings for prospective customers which are both innovative and cost-effective.

The cross-Catapult collaborative effort is enabling detailed technology development to occur at a fast pace due to the sharing of resource and expertise, all of which benefits Dowty and, ultimately, its customers," says Jonathan Chestney, Dowty Propellers' engineering leader.

The AMRC is working with Catapult colleagues in the Bristol based National Composites Centre and the Coventry based Manufacturing Technology Centre in the ATI-funded program. They are also investigating the shift from manual to automated blade manufacturing processes.

CARBON FIBER

4M reveals progress with plasma oxidation for carbon fiber production


Source | ORNL

4M Carbon Fiber Corp. (Knoxville, Tenn., U.S.) has completed a carbon fiber manufacturing demonstration program that it says proves the viability of a process that uses the company's atmospheric plasma oxidation technology to produce 15% stronger carbon fiber while tripling production output. The results, say 4M, demonstrate the ability to produce higher quality carbon fiber while spreading capital and operating costs over three times the production capacity. 4M is exploring options to license this technology to carbon fiber producers.

In collaboration with carbon fiber manufacturer Formosa Plastics Corp. (Kaohsiung City, Taiwan) and the Department of Energy's Carbon Fiber Technology *(continued on p. 30)*

(continued from p. 29)

Facility (CFTF) at Oak Ridge National Laboratory (ORNL, Oak Ridge, Tenn., U.S.), 4M's team oxidized Formosa's polyacrylonitrile (PAN) precursor using the internationally patented atmospheric plasma technology developed by 4M and ORNL. The fiber was then carbonized, surface-treated and sized at the CFTF. The resulting carbon fiber was then tested at the CFTF using industrial testing methodology. The initial trial showed that the fiber produced using 4M's oxidation technology exhibits higher tensile properties than carbon fiber produced using conventional processes with Formosa's precursor.

Dr. Truman Bonds, CTO of 4M, says, "We have yet to optimize our process for this precursor, so we believe that there is still room for processing speed improvement and even better carbon fiber properties. 4M intend to continue technology licensing discussions with several carbon fiber manufacturers and new entrants, and we hope to finalize and announce a strategic partnership soon."

4M's next step in the plasma oxidation commercialization process is to complete a $20 million pilot plant to produce samples requested by automakers, trucking companies, container manufacturers and carbon fiber producers. Mike Agentis, general manager of 4M, says PAN for this pilot plant would likely be sourced from Formosa, but that other suppliers are also being considered. The pilot plant is expected to allow 4M to operate closer to commercial scale and produce quantities large enough for carbon fiber manufacturers to make decisions about licensing the technology.

BIZ BRIEF

Web Industries Inc. (Marlborough, Mass., U.S.), a precision formatter of composite materials, in March opened a European Center of Excellence for Composite Development & Commercialization (CoE) at Omega Systèmes in Nantes, France.

The new CoE offers the European market access to technical teams, a material analysis lab and pilot lines for demonstration, rapid development, testing and qualification of different composite material formats, including thermosets, thermoplastics and other composite types. The facility has high-volume composite formatting lines to transition new materials and processes to commercial-scale production. In addition to speeding new product development, the CoE can help customers devise strategies to enhance productivity and reduce costs for mature product programs, Web says.

Web Industries acquired Omega Systèmes in January 2019 and has been investing in Omega's France-based team, technologies and manufacturing capabilities. The Nantes CoE will collaborate with Web's North American CoEs for composites automation and thermoplastic composite development. The CoE also is an active collaborator and member of many European research institutes, such as the National Composites Centre, Thermoplastic Composites Research Center, Technical University of Dresden and Technical University of Munich.

The evolution of composites in NASCAR

The growing role of carbon fiber in stock car racing.

By **Scott Francis** / Senior Editor

Next Gen prototype

A prototype Next Gen car built by Richard Childress Racing (RCR, Welcome, N.C., U.S.) was test driven by RCR driver Austin Dillon in October 2019 and then by Team Penske driver Joey Logano in December 2019.

Source | NASCAR

» There's something uniquely American about stock car racing. In the U.S., the sport has origins tied to the distribution of bootleg whiskey, known as moonshine, during the 1920s in the Prohibition era. Bootleggers would lighten and modify their vehicles for increased speed and handling in order to evade police. Fascination with these souped-up street vehicles led drivers to begin racing them for prize money and bragging rights. The races became a popular form of entertainment, and the tradition eventually became an organized sport.

The National Association for Stock Car Auto Racing, better known as NASCAR (Charlotte, N.C., U.S.), officially got its start in 1948 when the organization was established to create a standardized set of stock car racing rules and regulations. Today the sanctioning body oversees more than 1,500 races at various tracks in the U.S., Canada, Mexico and Europe.

In the early days of stock car racing, the vehicles were limited to factory model cars. Eventually, NASCAR allowed the cars to be modified to increase durability. Over the years, the number of modifications increased, and the practice wove its way into the culture of the sport. Each season, NASCAR evaluates its rules and regulations, often making changes with the goal of improving safety or making the cars more competitive. NASCAR vehicles are checked prior to each race for compliance with the organization's ever-evolving regulations. NASCAR dictates which materials can be used for the cars, as well as where and how they are employed.

Lightweighting and improving a car's speed go hand-in-hand, so naturally NASCAR vehicles have used composites for their inherent light weight, strength and stiffness for decades. A carbon fiber part manufactured at the same thickness as a steel part offers four times the strength at one-third the weight. NASCAR teams, constantly looking for opportunities to legally remove weight from their vehicles, have increased use of composite materials in the sport over the years.

In addition to lightweighting, composite materials also offer other advantages. Tremendous heat is generated in brakes during racing, and under-the-hood temperatures can reach 300-400°F. Carbon fiber's heat-resistant qualities can help reduce fatigue on engine parts.

In the current Generation 6 vehicle specification (commonly referred to as Gen-6) used in the NASCAR Cup racing series, several body parts are made of composite materials. Gen-6 cars comprise a steel tube frame chassis and a mix of carbon fiber and stamped steel body panels. The car's hood and rear deck lid are made of carbon fiber with Kevlar incorporated to decrease splintering and shattering in the event of a crash. The front and rear fascia also are made of composites. Other examples of composite »

components include cooling hoses, gear cooler housings, brake ducts and battery cases. When it comes to engine components, the emphasis on composite parts is placed on components mounted higher on the engine, which lowers the vehicle's center of gravity. Carbon fiber seats are also often used. The current cars weigh 3,200 pounds (1,451 kilograms) without driver and fuel.

A new seventh-generation vehicle specification is currently in development for NASCAR, and many teams expect the so-called Next Gen car to allow for even more composites, possibly even an all-composite body. There is also speculation that the current body-on-frame construction of NASCAR vehicles might be replaced by a tub that would likely also incorporate carbon fiber.

According to Jeff Andrews, director of engine operations at NASCAR Cup Series team Hendrick Motorsports (Charlotte, N.C., U.S.), the Next Gen car aims to be lighter than the current Gen-6 car and will likely be in the 3,000- to 3,100-pound range. "Implementation of all-composite bodies is in the very near future," said Andrews during a keynote at the Society for the Advancement of Material and Process Engineering (SAMPE) 2019 Conference and Exhibition in May 2019. "The sport could see widespread adoption of composite bodies within 2-4 years." He added that a full composite body system could provide a more consistent surface over the length of the vehicle and possibly allow for more streamlined vehicle build times.

Though not yet introduced into NASCAR's Cup Series, composite bodies are already being tested at other levels of NASCAR competition. An all-composite body was first introduced to NASCAR's national competition level in three races during its Xfinity Series competition in 2017. In 2018, the composite body style was used in all races in the series except for the superspeedway races (Dayton International Speedway and Talladega Superspeedway). The Xfinity composite body is comprised of 13 interlocking composite panels held together by flanges. Essentially, the panels lock and bolt into place, which eases replacement of damaged panels.

LEARN MORE
Read this article online | short.compositesworld.com/NASCAR

According to Brett Bodine, senior director of team efficiencies at NASCAR Research and Development Center, hanging a body comprising pre-fabricated composite panels on a chassis takes considerably less time than what is required to form, shape and weld a steel body — approximately two days compared to nearly two weeks.

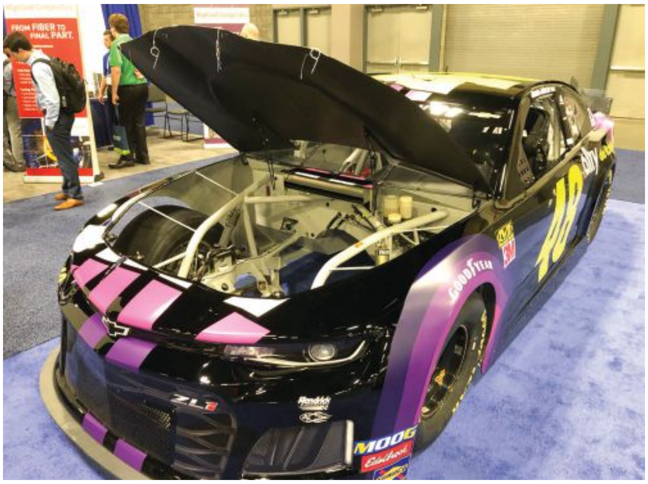
"We feel quite confident that it's going to save every team owner money in the area of hanging bodies on their racecars," he says. "Probably the big savings is going to be in the repair. These panels unbolt from each other and you can bolt a new one right back on. With that reduced repair time we feel that teams will enjoy potentially needing less vehicles to run the entire series."

Another feature of the Xfinity composite body is a raised honeycomb pattern on the panel surfaces in areas where teams may be tempted to illegally modify the car's aerodynamics. Any sanding or massaging of those raised areas would be easily noticeable as an infraction.

Carbon fiber components

This 2019 car built by Hendricks Racing for driver Jimmie Johnson has 35% more carbon fiber than his 2002 car, which had a few carbon ducts but was almost entirely metal. The 2019 car has a carbon fiber hood, part of the nose, trunk, seat, bumpers and some small parts. The largest carbon fiber part is the seat.

CW photo | Scott Francis



Five Star RaceCar Bodies (Twin Lakes, Wis., U.S.) produces the composite panels used in the Xfinity composite body. The company's composite bodies have been used in the NASCAR K&N Pro Series since 2015, which provided a proving ground for NASCAR for the body style before allowing them to run in a national series.

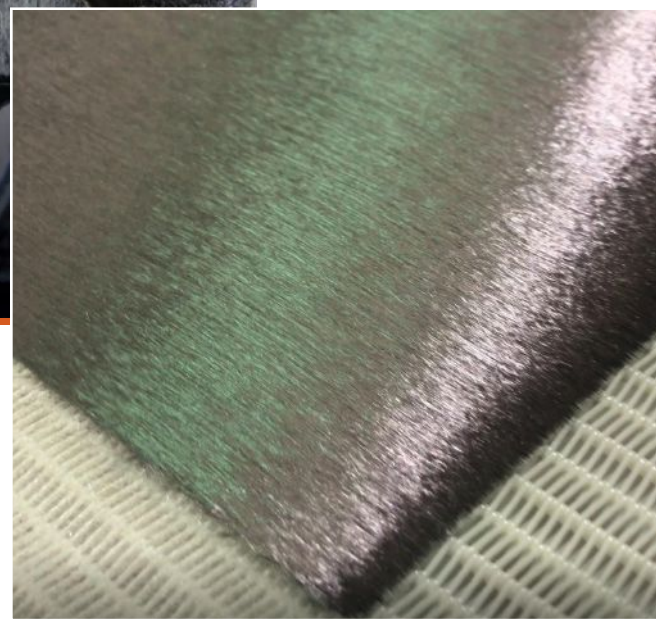
In addition to lightweighting, NASCAR's goal with the Next Gen specification is to reduce the cost of competing in NASCAR, opening the door for vehicle manufacturers beyond the big three — Chevrolet, Ford and Toyota — that dominate the sport. John Probst, NASCAR vice president of innovation and racing development, has said that the Next Gen bodies will likely be constructed from a flange-fit composite material — meaning that the panels are interlocking — as with the cars used for the Xfinity series.

A prototype Next Gen car built by Richard Childress Racing (RCR, Welcome, N.C., U.S.) was test-driven by RCR driver Austin Dillon in October 2019 and then by Team Penske driver Joey Logano in December 2019. While development and testing continues, the Next Gen shell and chassis is expected to debut in 2021. CW

ABOUT THE AUTHOR

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

Revolutionizing the composites cost paradigm, Part 1: Feedstock



■ **TuFF short fiber sheet material for affordable complex-shaped composite parts**

UD-CCM has developed the Tailorable Universal Feedstock for Forming (TuFF), a sheet material that attains UD prepreg-level fiber volume and properties (IM7 fiber shown here) thanks to a high degree of fiber alignment and length control, yet forms readily into complex shapes due to its in-plane stretchability.

Source for all images | University of Delaware CCM

Highly-aligned, short-fiber Tailorable Universal Feedstock for Forming achieves aerospace properties, metal-like formability in zero-waste, fiber-to-parts pilot plant.

By Ginger Gardiner / Senior Editor

» The Tailorable Feedstock and Forming (TFF) program was launched by The Defense Advanced Research Projects Agency (DARPA, Arlington, Va., U.S.) in 2015 to enable rapid, low-cost and agile manufacture of complex geometry composite parts that weigh less than 20 pounds. Composites win against metals for large, stiffened skins made with processes such as automated tape laying and fiber placement (ATL/AFP). However, more than 80% of the parts in a typical tactical military airframe are small with complex geometry. For these, machined aluminum is favored because of the high cost and complexity of composite materials and manufacturing for small parts.

"You can buy a 4- to 6-inch plate of aluminum, throw it in a CNC machining center and hit a button," says composites industry and TFF program consultant Jeff Hendrix. "Although metal parts are cheaper to make, their additional weight and susceptibility to cracking and corrosion leads to sub-optimal performance of the system," explains Mick Maher, the program manager in DARPA's Defense Sciences Office who originated TFF. (Though Maher completed his five-year DARPA term in 2016, his vision for TFF is shared by current DARPA program manager Dr. Jan Vandenbrande.) Hendrix agrees but points out, "No one is going to pay double for the weight savings composites offer in these smaller parts; they must become more cost-competitive with aluminum."

To achieve this vision, TFF is divided into two subprograms — the first for materials (*feedstock*) discussed here in Part 1, and the second for molding (*forming*) explored in next month's Part 2:

- Tailorable Universal Feedstock for Forming (TuFF) led by the University of Delaware (UD) Center for Composite Materials (UD-CCM, Newark, Del., U.S.)
- RApid high-Performance Manufacturing (RAPM, pronounced "wrap-em") led by The Boeing Co. (Chicago, Ill., U.S.).

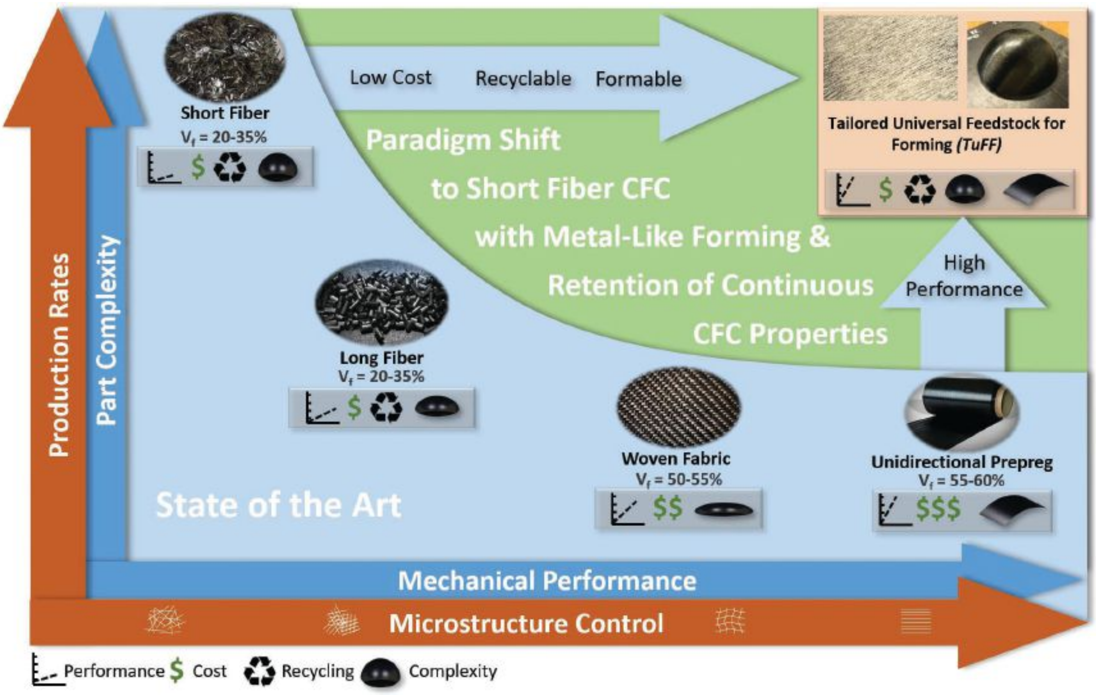


FIG. 1 Short fiber format, long fiber performance and formable for lower part cost

The goal of the DARPA-funded TuFF program is a universal material that can be tailored to meet specific part and program requirements, but still enable composites to win against machined aluminum for small parts (<10 kg) in defense applications, where the market penetration of composites remains small, even with the latest technology advances in commercial aircraft and automotive.

The TuFF feedstock is a highly aligned, discontinuous fiber preform in thin-ply format, which can be combined with thermoplastic (TP) or thermoset (TS) resins for prepreg, or used in dry form for infusion-based processes. A patent-pending, discontinuous fiber alignment and preforming process has been demonstrated in a 5-ton/year pilot facility at UD-CCM comprising:

- Short fiber dispersion and alignment
- Automated layup and stacking
- Prepregging and tailored blank production
- TS/TP forming and liquid molding cell, to be added by the third quarter of 2020.

The alignment process is fiber agnostic, and TuFF preforms have been manufactured with aerospace-grade polyacrylonitrile (PAN) carbon fiber (e.g., IM7, T800), pitch carbon fiber, recycled carbon fiber, glass and ceramic fibers. Laminates with <1% voids and up to 63% fiber volume have demonstrated >40% biaxial in-plane strain capability during forming, enabling metals-like molding of complex geometries *without* darting or complex ply patterns. The pilot process line has also demonstrated closed-loop recycling and reuse of fiber from the TuFF process scrap, with the goal of enabling zero-waste manufacturing. TuFF was recognized at CAMX 2019 by the American Composites Manufacturers Assn. (ACMA; Arlington, Va., U.S.) with the Infinite Possibility for Market Growth Award, as part of its Awards for Composites Excellence (ACE) program.

"The TuFF program was constructed to address several key challenges."

Developing discontinuous fiber feedstock

Continuous carbon fiber reinforcements pose two problems for TFF's objectives: It is expensive and difficult to form into complex shapes. Short fiber offers formability, but current forms and processes, such as injection molding, do not deliver the high-fiber volume properties required (Fig. 1). There is also the issue of how to amortize high tooling and part development costs over an increasingly fragmented DoD market of more mission-specific platforms at lower volumes.

"This makes composite parts expensive for unique part/process/program certification," adds Dr. John W. Gillespie, Jr., director of the UD-CCM and the TuFF principal investigator. The aim for TuFF, then, was to develop a material that demonstrates metal-like formability but can also be tailored to meet a range of DoD application needs and volumes.

"The TuFF program was constructed to address several key challenges, including how to make short carbon fibers with smaller diameters to enable composites with aerospace properties," says Dr. Shridhar Yarlagadda, assistant director for research at UD-CCM and a TuFF project leader. "The idea was to move to low-cost pitch precursors and make the short fiber directly instead of cutting continuous fiber, aiming toward IM [intermediate modulus] carbon fiber properties." The program included Drexel University (Philadelphia, Pa., U.S.), Virginia Polytechnic Institute and State University (Blacksburg, Va., U.S.) and Clemson University (Clemson, S.C., U.S.) as subcontractors, with the latter performing most of the work on pitch fiber. »

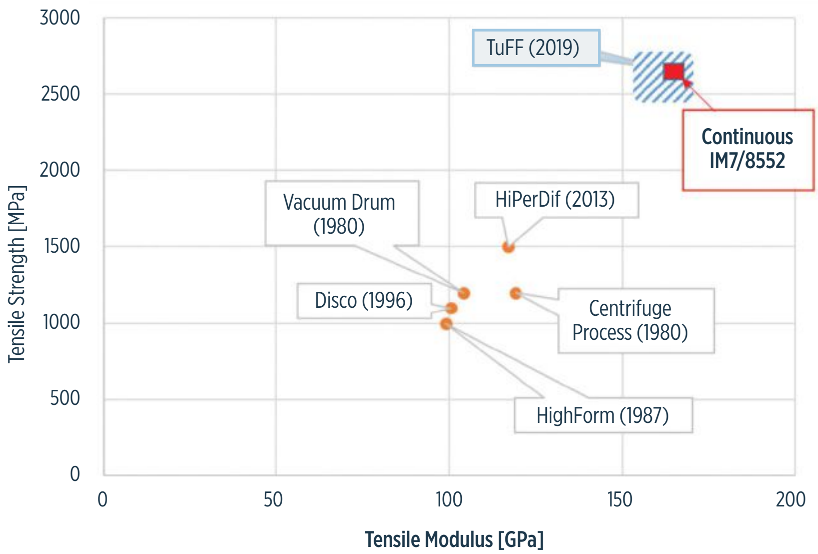


FIG. 2 History of short fiber materials

TuFF finally succeeds where previous efforts have failed due to its ability to tightly control fiber length and alignment with aspect ratios that lie within the sweet spot for formability.

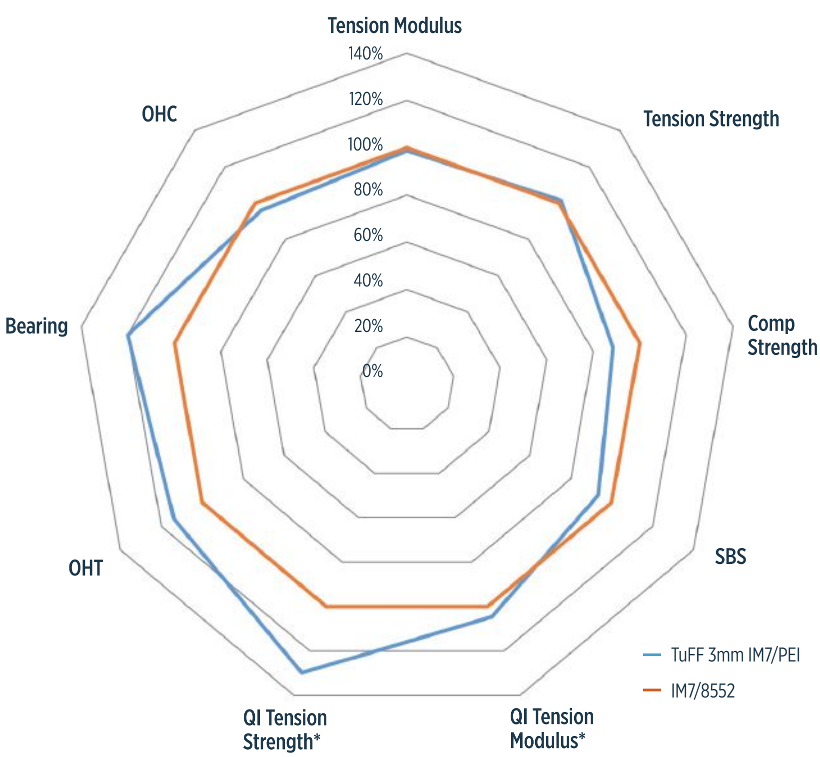


FIG. 3 Attaining UD prepreg properties

TuFF has shown properties equal to UD prepreg and even an increase in certain properties for thin-ply (60 gsm/60-micron thick) IM7/PEI material compared to standard IM7/8552 epoxy prepreg in preliminary testing, thanks to the thin-ply microstructure.

"This is a challenging problem because you're looking at a process very different from what is used to produce continuous fiber," Yarlagadda explains. Although multiple iterations of pitch fiber from Clemson have been evaluated, additional work beyond the DARPA TuFF project will be required to develop and mature the pitch fiber technology. Thus, the TuFF results presented here were achieved using commercial, continuous PAN fibers cut to short lengths. Cost implications are discussed below.

Short carbon fiber solutions for affordable, formable composites have been sought for decades (Fig. 2), including DiscoTex, stretch-broken carbon fiber (SBCF) and HiPerDif (High Performance Discontinuous Fiber). For SBCF, a mechanical process breaks continuous PAN carbon fibers into lengths of 25-50 millimeters or longer (Learn More). For the 0.005-millimeter diameter IM7 carbon fiber (Hexcel, Stamford, Conn., U.S.) used, this gives an aspect ratio of 10,000:1. "An aspect ratio above 10,000 requires high forming forces," Yarlagadda explains, noting the sweet spot for formability is an aspect ratio between 100:1 and 1,000:1. TuFF uses 3-millimeter-long IM7 fibers for an aspect ratio of 600:1.

"Technical papers were published from the late 1990s onward showing that short fibers with an aspect ratio of 100:1 should match the *stiffness* of continuous fibers, and with an aspect ratio of 1,000:1 they should match *strength* as well," Yarlagadda says. "But there were issues with fiber alignment."

HiPerDiF, developed by the University of Bristol (Bristol, U.K.), uses carbon fibers 1-12 millimeters long that are suspended in water and deposited from nozzles onto a substrate to create an aligned fiber preform (Learn More). Thus, they have improved fiber alignment versus SBCF, but report only 67% of the fibers within ±3 degrees from unidirectional. TuFF achieves >95% of fibers aligned within 5 degrees of the desired direction.

Controlled, uniform microstructure

"With this high level of fiber alignment, we can get to the same fiber volume as unidirectional prepreg," explains Dirk Heider, assistant director of UD-CCM and also a TuFF project leader. He notes fiber volume control between 40% and 63% has been demonstrated for TuFF composites using 3-millimeter long IM7 carbon fiber.

The other key factor is fiber length control; 95% of the IM7 fibers in TuFF measure 2.8 to 3.2 millimeters long (nominal 3 ±0.2 millimeters). "You want »

FIG. 4 Complex shapes, thin-ply tapes

TuFF's short fiber and uniform microstructure enables forming aerospace-quality, complex shapes without high pressure or complex temperature control. The material can also be split into continuous tapes for use in AFP processing.

to have very consistent fiber lengths to optimize both mechanical and forming performance to achieve a repeatable process," Gillespie explains. Heider adds that an IM7 fiber length of 3 millimeters is sufficient to give full property translation while reducing forming pressure and tooling cost. "We control the microstructure regardless of fiber type," he observes. Yarlagadda adds, "If you have uniform microstructure, then you have a globally uniform response, resulting in consistent part thickness during forming."

Is tow size a factor? "No," Heider says. "You have to align at the filament level or else you don't get this translation of properties and controlled microstructure. We receive chopped IM7 tows from an outside vendor and then filamentize by dispersing them in water. We then deposit the filaments as a sheet with a very high alignment, putting the fibers back together but in a very controlled way." The patent-pending TuFF process produces thin-ply (8 microns thick) fiber sheets that can then be stacked into tailored layups, cut into blanks or slit into tapes. Thin-ply refers to a tow that is spread — e.g., a 5-millimeter-wide 12K high-strength (HS) carbon fiber tow is commonly spread to a 25-millimeter-wide tape (Learn More). "We have demonstrated a thin-ply tape that has very good steerability, achieving a radius of 1 inch, versus 40-50 inches for continuous fiber tapes," Heider notes.

Heider says that with a *standard* modulus fiber, the diameter is roughly 7 microns (0.007 millimeters), which means a 4- to 5-millimeter fiber length for TuFF's desired aspect ratio of 100-1,000:1. He also points out that composite properties depend not just on the fiber, but also on the resin and the resin-fiber interface. "We have been working with commercial fiber that is surface treated for aerospace thermoplastic and epoxy matrix resins, but not sized," Heider says. "We have shown good bonding between our short fibers and the resin, which was reported in several papers presented at SAMPE 2019."

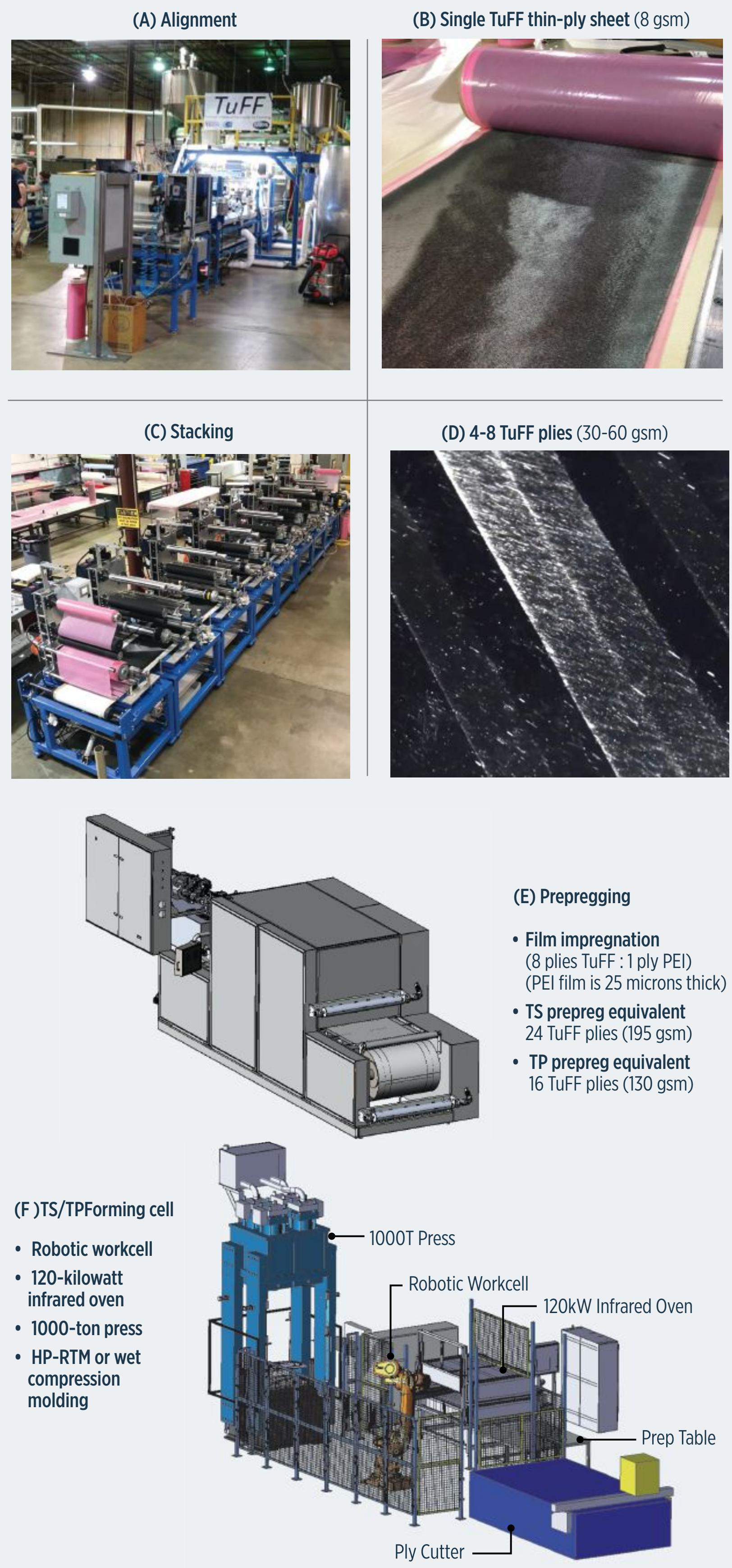
Aerospace properties, metal-like formability

"We are testing the aligned short fiber material with PEI (polyetherimide) and PEKK (polyetherketoneketone) thermoplastics and Hexcel 8552 epoxy [used in HexPly unidirectional prepreg] to demonstrate aerospace-grade composite properties," Gillespie says. Testing with PEI has been completed and shows composite properties that are equal to continuous carbon fiber across the board (Fig. 3, p. 38), including tension, compression and shear as well as notched properties such as open-hole tension and compression (OHT/OHC) and bearing strength. Testing with PEKK and 8552 epoxy is ongoing and will be completed this year.

"We are able to produce composite laminates with less than 1% voids," Yarlagadda says. "We have also demonstrated comparable properties to UD thermoset and thermoplastic prepregs, as well as some preliminary data for thin-ply TuFF formats." Thin-ply reinforcements have been shown to increase load-carrying capacity and reduce crack propagation for higher damage tolerance (see Learn More). "This preliminary data shows tensile strength improvements of up to 30% due to the thin-ply microstructure," Yarlagadda adds.

FIG. 5 Fiber-to-parts pilot plant

UD-CCM has installed a 5 ton/year pilot plant that produces continuous TuFF sheets and prepreg as well as tailored blanks that will be used in its flexible manufacturing cell for complex-shaped parts up to 0.9 by 1.2 meters (3 by 4 feet).



"The material is stretchable in-plane, so it's formable like metal," he adds. TuFF has formed part geometries with >40% biaxial strain. "We hold the boundary and shape it, very much like metal-forming processes." TuFF formability has been demonstrated for a range of layups including 0- and 90-degree unidirectional (UD), 0/90 biaxial and quasi-isotropic layups. Images in Fig. 4 (see Learn More for URL to a video) also demonstrate a range of complex-shaped parts. "We've started with thin parts because you cannot hide defects."

Fiber-to-parts pilot plant

"One of our objectives within this DARPA program was to move beyond a lab-scale system," says Dr. John Tierney, senior scientist at UD-CCM and a TuFF co-inventor. "After several iterations, we currently have two 24-inch-wide lines for making aligned, short-fiber sheets: a standard line and an off-axis line for producing angled fiber orientations (e.g., 45, 30, 60 degrees)." The standard sheet from these lines is a continuous, thin-ply material, 8 microns thick and roughly 8 grams/square meter (Fig. 5). The sheet is wound onto rolls, which are then loaded into an adjacent automated stacking system. Built in-house, this takes the individual rolls and stacks up to eight plies to build the desired fiber areal weight (FAW) and fiber orientation layup, resulting in standard prepregs and blanks that are 30-190 grams/square meter and 30-190 microns thick.

"The third machine, for prepregging and tailored blank fabrication, is mostly off-the-shelf but customized to handle our material," notes Yarlagadda. "Prior to this machine, we have been using a resin film process, layering our stacked sheets with resin film and then applying heat and pressure to consolidate. The semi-continuous indexing press design allows us to either make prepreg or tailored thermoplastic blanks."

He explains that the process for making blanks is not an AFP process where tapes are applied to a rotating table.

"It follows standard composite layup methods, where tailored blank design drives the layup » sequence. What TuFF can do is to simplify blank geometry, eliminating complex darts and ply shapes, because the in-plane stretch capability allows complex shaping." Heider explains that in the subsequent forming cell, which can produce parts up to 0.9 by 1.2 meters, "we're typically using rectangular pre-consolidated blanks of specific layups and then molding those to shape, similar to sheet metal forming. We're also creating dry blanks and molding them into shape for liquid resin infusion." This work is being done with Composites Automation LLC, UD-CCM's small-company incubator, also based in Newark. "The results look very promising," Heider adds. "We can stabilize the material using a thermoplastic veil and then preform it easily, followed by infusion."

LEARN MORE

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

Read more about SBCF and HiPerDif | short.compositesworld.com/SBCF and short.compositesworld.com/HiPerDiF

Watch the TuFF video on YouTube | short.compositesworld.com/TuFFvideo

Read more about thin-ply materials | short.compositesworld.com/SpreadTow

Tierney emphasizes that this pilot plant with integrated automation and a capacity of 5 tons/year demonstrates the industrial scalability of the TuFF technology. "All of the hardware reflects what a full-scale plant looks like," he explains. "It is currently supplying the materials needed for our materials characterization testing and forming demonstrations."

Cost, fiber-to-part conversion, zero waste

TuFF has demonstrated its ability to meet aerospace performance with high formability, but what about low cost? "We are using continuous PAN fiber cut to short lengths," Yarlagadda concedes. "However, there are commercial short fibers on the market from Toray, Hexcel, Teijin and others, as well as short fibers from recycled and waste stream sources. These fibers do not have the certification required for primary aerospace structures, but do have potential to significantly lower material cost for other applications."

"Ultimately, it comes down to your fiber-to-part cost structure," he continues. "With fabric and UD tape, you bear the cost of conversion from fiber to that form and then again to complex-geometry parts, with the latter generating significant scrap and molding risk due to complexity, defects, etc. By starting with continuous, certified fibers with subsequent cutting, we do get a bit of extra cost, but when we convert this to complex shapes, it is so much easier to form. So, there are advantages in avoiding complex patterns and layups, plus formability and lower scrap with TuFF for aerospace parts."

Hendrix acknowledges that UD-CCM can form the kind of deep-draw parts that were a challenge for TFF's RAPM program using continuous fiber materials (see upcoming Part 2). "TuFF enables making these parts using a half-dozen sheets versus 20 different subpreforms, which is key to achieving our cost target. They've also shown they can make geometries that can't be made with traditional materials." Yarlagadda cites the waffle part shown in the »

opening photo: "This is impossible with continuous fiber. How does that affect your value and business case calculations? This requires you to step back and ask how *could* you make parts now and what design freedom could you exploit?"

Heider returns to fiber cost and considers another factor: waste re-use. "If you don't require certified fiber, it may be possible to use lower-cost short or recycled fiber." Most recycled fiber is short fiber, because pyrolysis and some of the other processes require chopping before the resin can be removed from scrap prepreg and cured waste/end-of-life parts. "If you use short fiber forms as a starting point, all of your scrap can be reused, so that you essentially have a zero-waste manufacturing process," Yarlagadda says. "This was not a focus of the DARPA TFF program, but we have shown we can recycle the TuFF material, put that fiber back through the TuFF process and get the same properties. DoD applications require certified aerospace-grade fiber, but we think the cost advantages of short fiber will still make it possible to significantly reduce cost."

Next steps

"We want to finish the PEKK and 8552 epoxy property testing and then publish these results, as well as our work with various parts molding processes," Gillespie says. "We have patents pending and are in the process of licensing the technology." The DARPA TFF program officially ends in 2020, with all of the testing and results disseminated.

"When TFF was originally set up, the program was looking at why aren't composites used more in defense and in automotive," Gillespie says. "For automotive, it's because they have invested in metals shaping and must re-invest for composites. But what happens when composites can be shaped like metal? Then it becomes easier to reconfigure existing production processes and leverage existing equipment."

For Hendrix, the pressing issue is not high-volume production but how to achieve affordable weight savings at low volumes. "I don't expect 10,000 aluminum parts to be replaced with 10,000 composite parts," he acknowledges, "but I'll take a couple hundred." For that to happen, the next step is to take a handful of example parts and walk them through using these materials and processes, capable of aerospace quality, and validate the economics against machined aluminum.

In Part 2, *CW* will review the RAPM program, which is exploring a variety of processes in a reconfigurable manufacturing cell, featuring modular tooling and rapid heating/cooling with pixelated temperature control. CW

ABOUT THE AUTHOR

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

Composites in the race to space

Advanced materials use in current and upcoming NASA missions.

By **Scott Francis** / Senior Editor

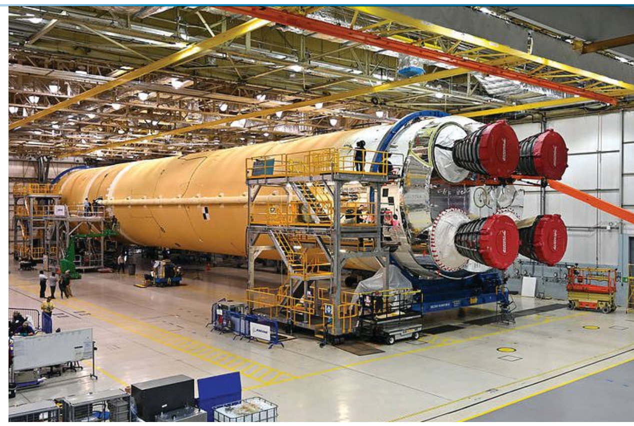
» July 20, 2019, marked the 50-year anniversary of the first *Apollo* moon landing. Though, at the time the *Apollo* capsule was built, the composites industry was still in its infancy and the materials were not yet in widespread use, the *Apollo* capsule used early composites technology in the form of an ablative heat shield made from Avcoat, an epoxy novolac resin with silica fibers in a fiberglass-phenolic honeycomb structure. A fiberglass honeycomb was bonded to the primary structure and the paste-like material was injected into each cell individually. Since *Apollo*, advanced composites have evolved by leaps and bounds, and have played a significant role in space programs with use in launch vehicles, the space shuttle, satellites, space telescopes and the International Space Station.

Today, the human race finds itself poised for some exciting new steps in space exploration. President Trump and the current NASA leadership has called for a return to the moon by U.S. astronauts by 2024 and has announced a 2021 budget of more than $25 billion for the National Aeronautics and Space Administration's

Old school

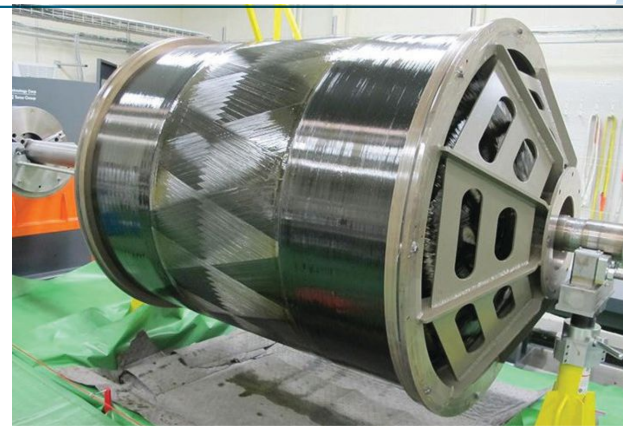
Apollo's heat shield was made of epoxy phenolic novolac resin in a fiberglass honeycomb.

CW photos | Scott Francis



Heavy launcher

SLS Rocket Stage being prepared for shipping. Source | NASA



Solid rocket motor case

Aerojet Rocketdyne is using a new carbon fiber winding machine to produce solid rocket motor cases at its Huntsville, Ala., U.S., Advanced Manufacturing Facility. Source | Aerojet Rocketdyne

Crew module

The *Orion* spacecraft being prepared for thermal testing. Source | NASA

Heat shield

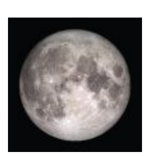
Orion's carbon fiber heat shield is manufactured using an out-of-autoclave prepreg from Toray Advanced Composites. Source | Lockheed Martin

(NASA, Washington, D.C., U.S.) human space exploration program. NASA administrator Jim Bridenstine says the budget is "one of the strongest budgets in NASA history."

In addition to another moon shot, NASA has current and forthcoming missions to study the solar system from the sun to the icy moons of the outermost planets and beyond. Missions to explore the sun are currently underway: at the time of this writing, the *Parker Solar Probe* is monitoring the sun's atmosphere and a *Solar Orbiter* has successfully launched. Efforts are also underway to further the exploration of exoplanets and distant galaxies through the Transiting Exoplanet Survey Satellite (TESS) mission and the James Webb Space Telescope, the latter of which has made strides toward launch-readiness over the past year.

New spacecraft and programs have also resulted in recent years from increased collaboration between national and international space agencies as well as commercial companies. For example, SpaceX (Hawthorne, Calif., U.S.), with its *Crew Dragon* spacecraft, and Boeing Space and Launch (Arlington, Va., U.S.), with its *Starliner* spacecraft, are racing toward the first crewed U.S. spaceflight since the discontinuation of the space shuttle program in July 2011. The two companies have been performing test flights with NASA in hopes of a crewed mission in 2021.

From the increased support of NASA's space program to the explosive growth of commercial space, the human race seems truly poised for the next great space age. Composites and advanced materials play an increasingly larger role in the manufacture of the launchers, spacecraft and instruments that make all of this exploration possible.



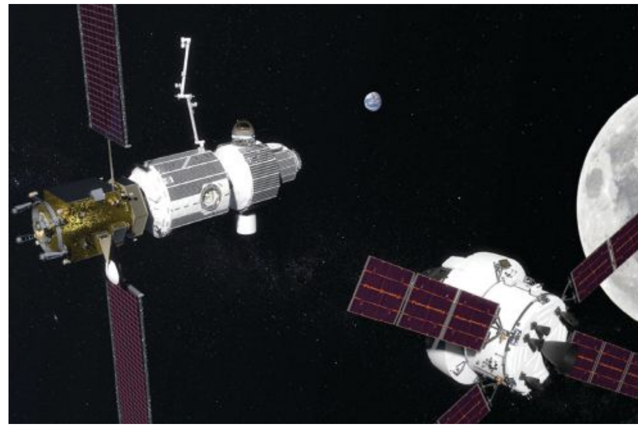
Source | NASA

Moon

The overarching program to return humans to the moon is named after Artemis, the Greek goddess of the moon and the hunt, and the twin sister of Apollo. The scope of the program is vast. *Artemis* »

***Orion* compression pad**

Four compression pads made from a 3D woven quartz material and a cyanate ester resin attach to *Orion's* heatshield. Source | NASA



Gateway

This artist's rendering shows *Orion* in the process of docking with the *Gateway* lunar orbital platform/space station. Source | NASA

will establish a lunar-orbit base, allowing astronauts to not only further explore the moon, but also use the moon as an outpost for eventual missions to Mars. Several projects make up the *Artemis* program, including a new heavy launch vehicle known as the Space Launch System (SLS), the *Orion* crew vessel, a lunar orbit space station known as *Gateway* and a lunar lander. Advanced composite materials factor into all of these components in one way or another.

The Space Launch System (SLS)

NASA's new heavy launch vehicle is aimed at enabling exploration beyond Earth's orbit. In 2015, NASA invested in an Electroimpact (Mukilteo, Wash., U.S.) automated fiber placement (AFP) machine to manufacture large-scale rocket parts comprising sandwich structures more than 8 meters in diameter made of carbon fiber skins with an aluminum honeycomb core. The AFP head holds up to 16 spools of carbon fiber and is positioned at the end of a 21-foot robot arm that places the fibers onto a tooling surface in precise patterns to form structures of varying shapes and sizes.

Similar sandwich structures are created by RUAG Space (Decatur, Ala., U.S.) using hand layup. The company is working with Dynetics (Huntsville, Ala., U.S.) on a Universal Stage Adapter (USA) that will join the upper stage of SLS to the *Orion* crew module. RUAG Space will manufacture the adapter's 8.4-meter-diameter shell, which comprises four composite honeycomb core quarter panels that will be hot-bonded together (See Learn More).

Orion Multi-Purpose Crew Vehicle

Consisting of a command module manufactured by Lockheed Martin (Bethesda, Md., U.S.) and a service module provided by the European Space Agency (ESA, Paris, France) and manufactured by Airbus Defence and Space (Ottobrunn, Germany), *Orion* is the heart of the *Artemis* program and will carry astronauts to space, serve as the exploration vehicle during space travel and return the crew to Earth.

Orion's propulsion system includes numerous components manufactured by Aerojet Rocketdyne (Sacramento, Calif., »

U.S.), including eight 110-pound thrust bipropellant auxiliary engines based on Aerojet Rocketdyne's R-4D engine family. Aerojet Rocketdyne also provides the Launch Abort System (LAS) jettison motor and composite overwrapped pressure vessels for the spacecraft. In early 2020, Aerojet Rocketdyne installed a carbon fiber winding machine to produce its solid rocket motor cases (See Learn More).

For reentry, *Orion* uses a 5-meter diameter carbon fiber heat shield manufactured by Lockheed Martin that is manufactured as a sandwich structure featuring carbon fiber skins and a titanium honeycomb core. The heat shield is then covered in panels of Avcoat — the same ablative material used for the *Apollo* missions (See Learn More).

Four compression pads of ablative material are attached to the heat shield with titanium bolts at points where the command module attaches to the service module. The compression pads must resist structural loads during launch and ascent, as well as pyro-shock (from explosive bolts) during separation of the two modules. They must also meet reentry demands for high-temperature resistance and ablation. Carbon fiber/phenolic pads were used on the first flight of the *Orion* test vehicle, but showed evidence of interlaminar cracks post-flight and were replaced with a 3D woven solution known as 3D Multifunctional Ablative TPS (3D-MAT). This uses a 3D woven quartz material from Bally Ribbon Mills (Bally, Pa., U.S.) and a cyanate ester resin system from Toray Advanced Composites (Morgan Hill, Calif., U.S.). (See Learn More)

Artemis xEMU

NASA's new EVA suit provides improved range of mobility. Source | NASA

The Lunar Orbital Platform-*Gateway* (LOP-G)

Gateway is a lunar orbit space station being developed by NASA along with international partners including Russian, Canadian, Japanese and European space agencies. *Gateway's* role is to support exploration of the moon and to serve as an outpost for eventual missions to Mars. The various modules for the station are in development and will likely employ composite materials in some fashion.

A Roll-Out Solar Array (ROSA) developed by the Air Force Research Laboratory (AFRL; Dayton, Ohio, U.S.) and Deployable Space Systems using high-strain composites (HSC) will be used in the *Gateway* program. HSCs are thin, lightweight composite materials engineered to fit into small packages and deploy by unfurling. The ROSA system uses two carbon fiber HSC booms to roll out and tension a large solar array blanket. (See Learn More)

Another potential contribution to *Gateway* is the Canadarm-3. Proposed by the Canadian Space Agency (Longueuil, Quebec, Canada), the device is an 8.5-meter robotic arm built from carbon fiber composites. Previous Canadarm systems have been used on the space shuttle and the International Space Station (ISS).

Lunar landers

Numerous companies are working on lunar landing system concepts for *Artemis*, all of which include potential for composite materials. For example, Blue Origin (Kent, Wash., U.S.) is partnering with Lockheed Martin, Northrop Grumman (Falls Church, Va., U.S.) and Draper (Cambridge, Mass., U.S.) on a proposed three-vehicle lunar landing system. It will comprise Blue Origin's *Blue Moon* lunar lander, a "Transfer Element" vehicle provided by Northrop Grumman that will position the landing system in lunar orbit, and an "Ascent Element" vehicle by Lockheed Martin that will return astronauts from the moon's surface to lunar orbit. Several other companies working on lunar lander concepts include Boeing, Dynetics, SpaceX and Sierra Nevada Corp. (Louisville, Colo. and Madison, Wis., U.S.).

In addition to crewed lunar landers, NASA anticipates the need for both small and mid-size lunar landers to enable a variety of science investigations and large technology demonstration payloads.

Artemis suits

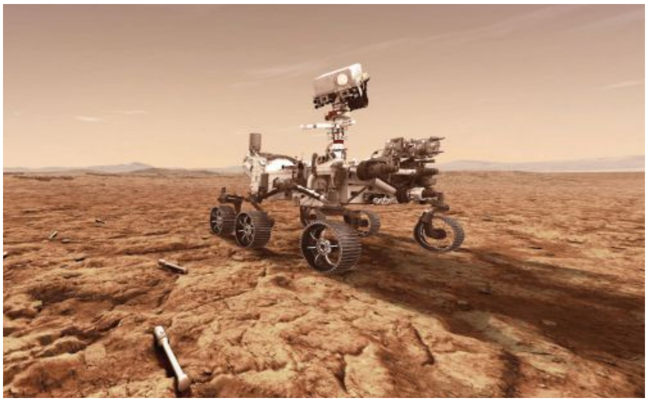
In October 2019, NASA unveiled two new spacesuit designs — a new Exploration Extravehicular Mobility Unit (xEMU) and the Orion Crew Survival System (OCSS) suit — both of which will be used for the *Artemis* program moon missions.

The xEMU suit is reported to offer a much improved range of mobility over suits currently in use for extravehicular activity (EVA). According to ILC Dover (Frederica, Del., U.S.), which has a longstanding relationship with NASA for the manufacture of space suits, the xEMU suit is an update of an advance walking suit delivered to NASA in 2016 known as the Z-2.

"Since 2016, ILC Dover has continued to improve the design of walking suits, as well as zero-G suits and launch entry suits," says Dan Klopp, product marketing for ILC Dover.

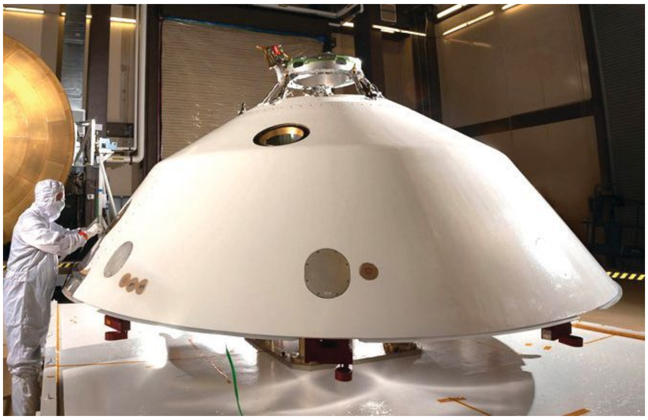
The Z-2 spacesuit prototype features a carbon/epoxy torso and hip elements in the design.

NASA's OCSS spacesuit is designed as a pressurized launch and entry suit for *Orion* crew members. While NASA has not »



■ Rover

The Mars 2020 Rover will weigh less than the average compact car. Source | NASA



■ Aeroshell

The aeroshell is designed to protect the Mars Rover during atmospheric entry and landing. Source | Lockheed Martin

■ Mars Helicopter

More than 1,500 individual pieces of carbon fiber were used in the construction of the Mars Helicopter. Source | NASA

released details on the materials in the new design, it's a safe bet that a fair amount composites are involved. Shuttle-era launch and entry suits featured an outer layer of DuPont's (Richmond, Va., U.S.) flame-resistant meta-aramid Nomex. Previous Extravehicular Mobility Units (EMUs) have used combinations of Nomex, the para-aramid Kevlar (also developed by DuPont) and Gore-Tex, a waterproof, breathable fabric membrane manufactured by W.L. Gore & Assoc. (Newark, Del., U.S.) (See Learn More).

Source | NASA

Mars

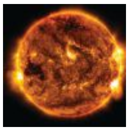
A large part of the *Artemis* initiative is to set the stage to send humans to Mars. In the meantime, NASA also is working toward an unmanned mission to Mars this summer that will establish a new robotic rover and a robotic exploratory helicopter on the red planet.

A capsule-shaped aeroshell will protect the Mars 2020 Rover during entry into Mars' atmosphere and landing. The aeroshell is made of an aluminum honeycomb with carbon fiber skins. The heat shield uses a tiled phenolic-impregnated carbon ablator (PICA) thermal protection system.

The Mars 2020 Rover itself is approximately 10 feet long, 9 feet wide and 7 feet tall (3 meters long, 2.7 meters wide, 2.2 meters tall). While NASA hasn't released details about the materials used to construct the rover, it is known that Advanced Composites Training (ACT, London, Ontario, Canada) served as a consultant to NASA's Jet Propulsion Laboratory (JPL, Pasadena, Calif., U.S.) on the use of composite materials for the rover's construction (See Learn More).

At 2,314 pounds (1,050 kilograms), the rover will weigh less than the average compact car. It needs to be both lightweight and durable for the journey to the red planet, and also needs to be strong enough to carry cameras and scientific instruments, as well as the Mars Helicopter — another composites-intensive craft that will be used to explore the planet.

The Mars Helicopter is constructed of more than 1,500 individual pieces of carbon fiber, flight-grade aluminum, silicon, copper, foil and foam and weighs no more than 4 pounds (1.8 kilograms) (See Learn More).



Source | NASA

Sun

Two missions are currently underway to improve our understanding of the sun and its behaviors, with the ultimate goal of forecasting solar storms that can affect terrestrial electrical systems, satellite communications and GPS.

Parker Solar Probe

Launched in August 2018, the *Parker Solar Probe* performs in-situ measurements and imaging to study the corona of the sun and solar wind. In order to endure the extreme temperatures in this region, the probe uses a 4.5-inch-thick lightweight reflective shield. This thermal protection system (TPS) is made from carbon fiber composite foam sandwiched between two carbon laminates and coated with white ceramic paint on the sun-facing surface. »


fives
Industry can do it
For you, In-Process Inspection increases Performance.
The Fives, real-time, composite, inspection system with advanced surface profilometry, developed with the National Research Council of Canada, will ensure manufacturers meet strict standards by providing superior measurements without limiting the layup process. This responsive, quality control, feedback loop will both speed up the overall production process and reduce its variability enabling manufacturers to become more competitive.
HIGH PRECISION MACHINES
www.fivesgroup.com
Booth A33
SAMPE 2020
May 5-6 | Seattle, WA

Solar probe

Parker Solar Probe's carbon fiber composite foam TPS is designed to withstand the heat of the sun's corona. Source | NASA

Solar shield

A carbon fiber composite/titanium layered solar shield protects the *Solar Orbiter* from the heat of the sun. Source | ESA

The shield was designed by Johns Hopkins Applied Physics Laboratory (Laurel, Md., U.S.) and built at Carbon-Carbon Advanced Technologies (Kennedale, Texas, U.S.).

Most of the probe's instruments are tucked behind the TPS, and sensors along the edge of the heat shield keep the spacecraft positioned correctly. Solar arrays that are used to power the craft can be retracted into the heat shield's shadow for protection. A simple cooling system that operates by circulating about a gallon of water is also employed to keep the solar arrays and instruments cool.

In January 2019, NASA reported that *Parker Solar Probe* was operating as designed following its fourth close approach to the sun, known as a perihelion. The craft's TPS reached a new record temperature of 1,134°F (612°C), though the spacecraft and instruments behind this protective heat shield remained at a temperature of about 85°F (30°C). During the spacecraft's closest three perihelia in 2024-25, the TPS will see temperatures around 2,500°F (1,370°C).

Solar Orbiter

Solar Orbiter, a collaborative mission between the European Space Agency (ESA) and NASA, launched in February 2020. The orbiter is on a unique trajectory that will allow its comprehensive set of instruments to provide the first-ever images of the sun's poles.

The spacecraft is protected by a carbon fiber composite/titanium layered solar shield with apertures for various instruments. The 324-pound heat shield can withstand temperatures up to 970°F (521°C) and uses a 0.05-millimeter-thick layer of titanium foil to reflect heat. The shield is supported by a 2.94-by-2.56-meter support panel that is about 5 centimeters thick and made of lightweight aluminum honeycomb with two high thermal conductivity carbon fiber skins. Further protection is provided by multi-layer insulation capable of withstanding 572°F (300°C). *Solar Orbiter*'s heat shield is coated with a thin, black layer of calcium phosphate.

Beyond the solar system

In August 2019, engineers at Northrop Grumman's facilities in Redondo Beach, Calif., U.S., mechanically connected the James Webb Space Telescope's (JWST) Optical Telescope Element, which includes mirrors and scientific instruments, and the Space Craft Element, which combines JWST's sunshield and spacecraft, for the first time. Although both components of the telescope have been tested individually, this marks the first time the two halves have been combined into a single observatory. The milestone was an important one for Webb as the telescope inches toward its planned launch in 2021.

JWST is the most powerful and complex space telescope ever built — 100 times more powerful than the Hubble telescope. Designed to explore the cosmos using infrared light, the telescope will allow astronomers to observe the most distant objects in the universe, providing images of distant stars, exoplanets and the first galaxies formed. The telescope is also an exciting example of how composites enable satellites and spacecraft.

Space telescope

Using infrared light, the James Webb Space Telescope will allow astronomers to observe the most distant objects in the universe. Source | NASA

The telescope platform is made up of three major components — the Optical Telescope Element (OTE), the Integrated Science Instrument Module (ISIM) and the Space Craft Element (SCE), which includes the spacecraft bus and the tennis-court sized sunshield.

JWST employs a carbon fiber backplane to support the telescope's mirrors, instruments and other elements — a total of more than 2,400 kilograms (2.5 tons) of hardware. The structure is also responsible for keeping the telescope steady during long periods of light collection. The backplane cannot vary more than 38 nanometers despite extreme temperatures ranging from -406°F to -343°F (-243°C to -208°C).

The backplane is made from prepreg comprising carbon fiber provided by Toray Advanced Composites and cyanate ester resin from Hexcel (Stamford, Conn., U.S.). The structure includes more than 10,000 lightweight carbon fiber composite parts. The entire backplane structure includes the center section, the wing assemblies and the backplane support fixture (BSF), and measures approximately 24 feet long by 19.5 feet wide by more than 11 feet deep (7.3 by 5.9 by 3.4 meters) when fully deployed. It weighs only 2,180 pounds (989 kilograms), but will support »

LEARN MORE

Read this article online | short.compositesworld.com/space2020

CW's RUAG Space plant tour | short.compositesworld.com/RUAGSpace

Aerojet Rocketdyne's role in Orion | short.compositesworld.com/AR_Orion

Composites displace metal in Orion's re-entry system | short.compositesworld.com/OOA_Orion

3D woven composites used by NASA | short.compositesworld.com/NASA3DMAT

High strain composites for satellite applications | short.compositesworld.com/satellites

Spacesuits for the next generation | short.compositesworld.com/spacesuits

Composites training for the Mars rover | short.compositesworld.com/ACT_Mars

Flight tests for the Mars rover | short.compositesworld.com/Marsflight

Composites stabilize the JWST | short.compositesworld.com/JWST_CFRP

instruments that weight more than 7,300 pounds (3,311 kilograms) — a payload of more than 300% its own weight.

In addition to the primary mirror and backplane structure, JWST's OTE includes its Deployable Tower Assembly (DTA), the secondary mirror support structure and the ISIM framework that houses the telescope's scientific instruments and cooling systems. These structures are made with a prepreg of ultra-high modulus carbon fiber and cyanate ester resin from Toray Advanced Composites.

"These materials are very good optical bench materials," says Sean Johnson, product manager, thermosets for Toray. "The high stiffness of the UHM fiber provides a very stable structure [and] provides a certain amount of damping. It's very good at the low temperatures [JWST] is going to see."

The SCE, or spacecraft bus, is also made of Toray's carbon fiber composites and houses the spacecraft's propulsion, observatory support systems, solar power, active cooling systems and communications. The bus must simultaneously be lightweight yet capable of withstanding a force equivalent to 45 tons while supporting the observatory during launch.

In October 2019, JWST successfully passed its sunshield deployment testing and is currently scheduled to launch in 2021. (See Learn More).

A giant leap

The next few years will set the stage for a whole new age of space exploration. As the spacecraft and systems needed for this new golden age continue to evolve, composites suppliers and fabricators will be constantly challenged to push the materials and technologies to new limits. CW

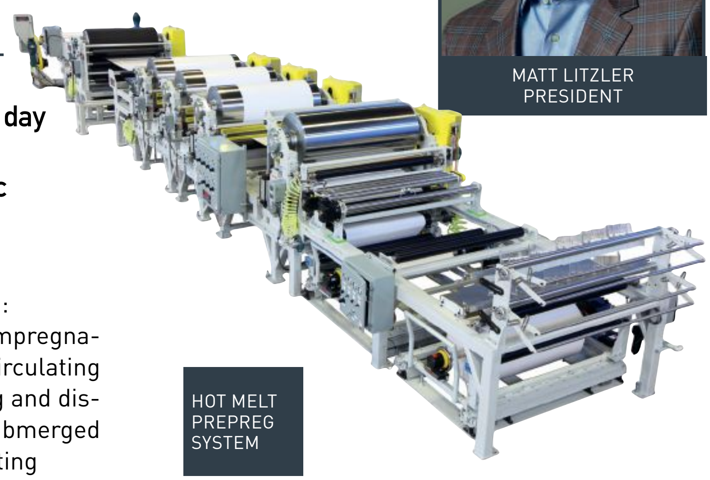
ABOUT THE AUTHOR

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

Litzler Designs Equipment for the Composite Industry Worldwide

MATT LITZLER
PRESIDENT

DRIVEN BY RIGHT is the commitment we make every day at Litzler. We engineer and deliver custom continuous process machinery that meets each customer's specific needs and fuels their business success.



HOT MELT PREPREG SYSTEM

C. A. Litzler Co., Inc. manufactures Oxidation Ovens used in carbon fiber production and Prepreg machines for structural composites. Litzler manufactures all major types of Prepreg machinery: Solution, Hot Melt and Thermoplastic Systems. Components include: OPTI-FLOW ovens, unwinds, precision metering rolls and filmers, compaction roll sets, winders, and accumulators. COM-PREG™ pilot machines for Solution, Hot Melt and Thermoplastic applications.

Thermoplastics PrePreg :

■ Fiber Saturation and Impregnation • Stainless steel, recirculating slurry dip tanks • Mixing and distribution manifolds • Submerged rollers to encourage wetting

■ Water/solvent removal and resin pre-heating • Infrared ovens are used because they do not disturb the resin distribution

■ Heated Die • Precision machined to maintain/improve resin distribution • Uniform temperature distribution across and along the web for uniform penetration and wetting.

> Industry is moving to Thermoplastic Tape for new applications. Litzler Tape Lines are proven across multiple sectors including aerospace and sporting goods. ”

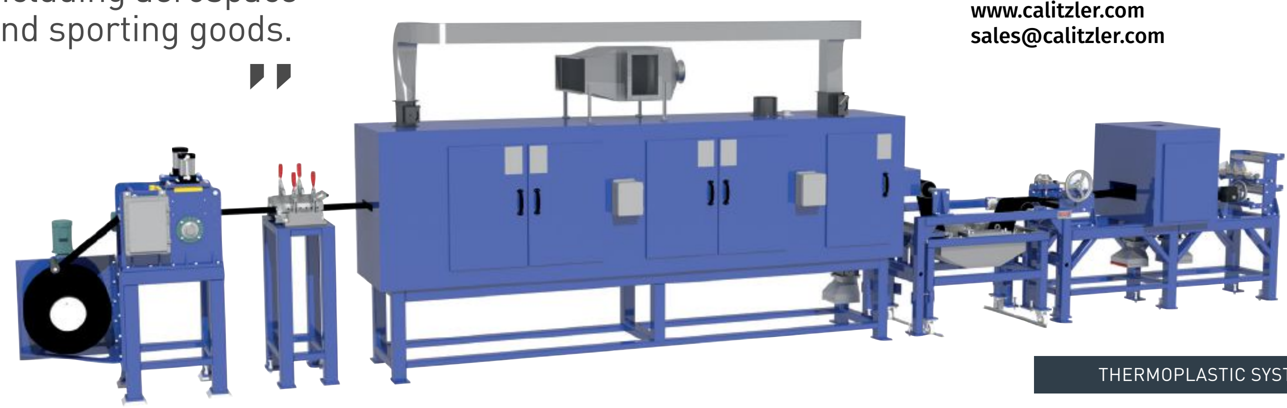
LITZLER
DRIVEN BY RIGHT

Carben Fiber Lines :

As part of a complete carbon fiber line, Litzler supplies highly engineered Roll Stands with large diameter rolls to minimize deflection, Sizing Stations and Dryers, Tension Stands, Litzler Automation Control Systems and the Computreater CF for development and testing of new fibers. Litzler also integrates furnaces, pollution control, surface treatment, creels and winders.

Visit www.calitzler.com to learn more about Litzler and our 67 years of experience designing and building equipment for the composite industry.

Contact: 216-267-8020
C. A. Litzler Co., Inc.
4800 W. 160th Street Cleveland, OH 44135 USA
www.calitzler.com
sales@calitzler.com



PHOTOS DR

THERMOPLASTIC SYSTEM

Carbon fiber tapes enhance performance of cross-country skis

Madshus Skis uses dry carbon fiber tapes to increase cross-country ski performance, manufacturing efficiency and surface finish.

Source | Hexcel

Madshus Skis (Seattle, Wash., U.S.) has been building skis since 1906, with its cross-country racing skis appearing regularly in Olympic, World Championship and World Cup races around the world. An early adopter of composites technology for sporting goods, the company first began building fiberglass skis in 1974, and, in a recent collaboration with Hexcel (Stamford, Conn., U.S.), is evolving its ski construction to include the latest developments in epoxy and carbon fiber composites.

One of Madshus' specifications was that the composite materials for its skis needed to be suitable for the automated production processes it uses to ensure quality, precision and consistency in its skis. The company also needed a competitively priced product that produced less "fuzz" than the company experienced when trying to slit wider tape rolls, and that met tight tolerances for aerial weight and width.

Hexcel's HiTape products are a range of dry unidirectional (UD) carbon fiber tapes developed originally for use with automated tape laying (ATL) and automated fiber placement (AFP) for out-of-autoclave (OOA) manufacturing of aircraft primary structures. HiTape is manufactured with industrial-grade carbon fiber with aerial weights of 120-250 gsm and widths of 38-47 millimeters. The tapes are constructed from dry fiber tows sandwiched between lightweight thermoplastic veils, which add additional toughness to the finished laminate.

Especially useful for this application, the tapes are also designed to be free of fiber splices and cut filaments, enabling clean, fuzz-free edges suited to automated production processes. Further, HiTape's formability and permeability enable rapid material placement and infusion. Hexcel says it is presently delivering nearly 500,000 meters of HiTape per year, with plans to boost volumes in the near future to meet increasing customer demand.

After initial testing in 2016, Hexcel now supplies Madshus with three HiTape products based on the design parameters of each cross-country ski type. The fibers are said to improve ski performance, manufacturing efficiency and surface finish.

"HiTape gives us exactly what we need for our automated production processes — consistency and quality," affirms Bjørn Ivar Austrem, technical director of Madshus. "In particular, the exceptionally clean edges of the tapes really makes a difference in our molding process and enhances the surface finish of the finished ski."

Madshus uses resin transfer molding (RTM) to produce its skis. HiTape and a layer of woven glass fiber fabric are lightly fixed to precision-shaped polyurethane (PU) cores before a glass fiber braided sock is passed over the top to secure the reinforcements. This dry fiber ski "blank" is then positioned in an aluminum mold, with the ski's digitally printed topsheet and low-friction running base, before the mold is closed and the resin is injected.

According to Hexcel, this application demonstrates that HiTape's benefits can also transfer to high-volume industrial applications and resin transfer molding (RTM) processes. Beyond skis, Hexcel notes that its HiTape products are suited to meet automated production needs in a range of industrial, sporting goods and automotive applications. CW

New Products

» PREPREG MATERIALS

Roving applicator technology simplifies prepreg tape placement

Voith GmbH's (Heidenheim, Germany) second-generation Voith Roving Applicator technology (VRA NextGen) reportedly has been improved to enable direct deposition of prepreg tapes.

Previously, this was only possible with dry material, the company says. Instead of applying a binder, the resin is impregnated directly into the fibers. According to Voith, this further streamlines the process chain and facilitates handling of the workpiece, especially if they are processed within the same production line. The technology is also suitable for series production of carbon fiber-reinforced plastic components.

Both the basic VRA technology and the further development VRA NextGen are said to optimize fiber placement when paired with Voith's innovations in fiber conditioning and tape handling. The result is customized stacks that are said to reduce waste and increase cost efficiency.

voith-composites.com

» ADHESIVES & BONDING

Rubber adhesive spray designed for temporary bonds

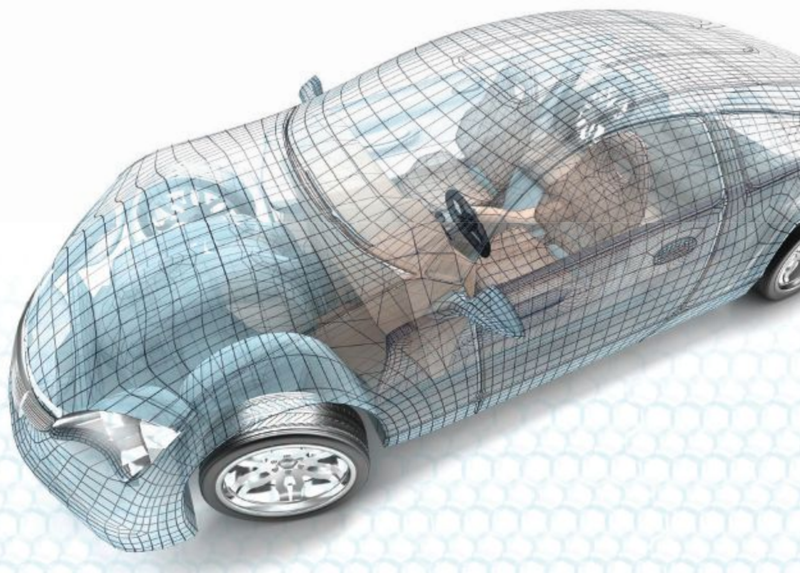
Airtech Advanced Materials Group's (Huntington Beach, Calif., U.S.) Airtac 2 Improved is a mist spray rubber adhesive designed for temporary bonds. According to Airtech, it can be used on materials that need extra tack for placement on vertical or difficult surface areas, and is ideally suited for applications such as temporary placement of details or pattern fabrication.

Benefits are said to include excellent tack in order to hold dry materials for faster vacuum bagging, accurate material placement for infusion setups and low toxicity for safer application.

The company says that Airtac 2 Improved meets many restrictions that U.S. states have in place for low volatile organic compound (VOC) levels in aerosol products. Currently, this product is only available in the U.S., Mexico and China.

airtechonline.com

Source | Airtech



» PREPREG MATERIALS

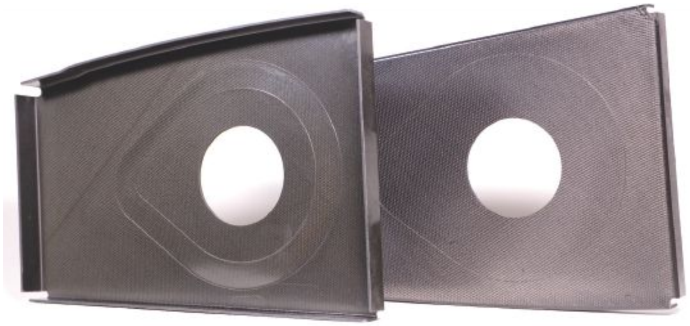
Epoxy prepreg targets aerostructures compression molding

Solvay Composite Materials' (Alpharetta, Ga., U.S.) CYCOM EP2750 is a highly drapable epoxy prepreg designed specifically for the compression molding of high-quality, high-rate, cost-effective primary and secondary aerostructures. The resin can be processed via compression molding only, compression molding with freestanding post-cure, or autoclave cure and offers takt times as short at 15 minutes.

Solvay officials say development of CYCOM EP2750 was stimulated by demand for an epoxy prepreg that allows fabricators to provide high-rate, reliable, cost-effective parts manufacture at aerospace quality. The goal of the prepreg is to enable manufacture of composite parts that are cost- and performance-competitive with machined aluminum.

Solvay points to two aerospace market trends that are likely to benefit significantly from CYCOM EP2750. First, single-aisle replacements for the Boeing 737 and the Airbus A320 aircraft are each expected to be manufactured at or close to 100 units per month. Second is the burgeoning urban air mobility (UAM) market, comprised of small, point-to-point, manned and unmanned aircraft. These likely will be manufactured at rates numbering 3,000-5,000 units per year and, like larger commercial aircraft, will require materials and processes qualified for aerospace application.

For commercial aircraft, CYCOM EP2750 is targeted toward use in access panels, blocker doors, brackets and clips. For UAM and UAV applications, the prepreg is targeted toward use in bulkheads, ribs, fuselage sections, brackets and clips.



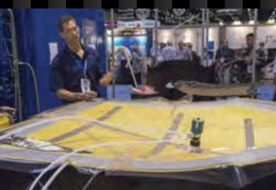
Rib-like parts fabricated with Solvay's CYCOM EP2750 epoxy prepreg. Source | Luchini, T., Rodriguez, A., Rogers S., Bras A., Whysall, A., Russell, R., Lucas, S., Hahn, G. "Spring Frame Press Fabrication of Aerospace Production Components," SAMPE 2019.

Representatives of Solvay anticipate that the preferred process for CYCOM EP2750 will be isothermal press cure, in which the layup is preheated, inserted into the mold, pressed, removed from the mold and then trimmed. This "hot in/hot out" process offers a 95% degree of cure at part removal and has a takt time of 60 minutes at 170°C, or 30 minutes at 190°C. The resin is said to offer low risk of exotherm even at high process temperatures.

Alternatively, CYCOM EP2750 can be pressed to 80% degree of cure, and then post-cured (freestanding) outside *(continued on page 64)*

COMPOSITES ONE, IACMI, AND THE CLOSED MOLD ALLIANCE

WORKSHOP SCHEDULE




2020


MARCH
31-APR 1

National Wind Technology Center
Boulder, CO
Focus: Advanced Composites / Wind Energy and Repair

JUNE
23-24

Davis Technical College - Freeport West Campus (D5)
Salt Lake City, UT
Focus: Advanced Composites / Aerospace

AUGUST
4-5

Gulf State Community College
Panama City, FL
Focus: Advanced Composites / Aerospace

OCTOBER
27-28

Dayton Composites Center
Dayton, OH
Focus: Advanced Composites / Emerging Markets

For More Information visit compositesone.com or email rachel.menges@compositesone.com.

Composites One®

ClosedMold Alliance
Composites One • MVP
RTM North Technologies

The Composites iacmi Institute

MVP
Magnum Venus Products

(continued from page 62)

Source | Solvay

the mold. Using this process, parts can be removed from the mold after 15-45 minutes, depending on the cure temperature. For autoclave cure, the prepreg must be ramped up to 177°C for a 30-minute dwell, followed by cool-down. Total takt time for this process is 120-180 minutes. Finally, CYCOM EP2750 is compatible with Solvay's new Double Diaphragm Forming (DDF) process.

Mechanical properties of CYCOM EP2750 include a service temperature of 132°C, a dry T_g of 197°C and a wet T_g of 168°C. Hot/wet open hole compression strength is 40.5 ksi; room temperature open hole compression strength is 50.5 ksi. Solvay says the National Center for Advanced Materials Performance (NCAMP) at Wichita State University (Wichita, Kan., U.S.) has begun qualification of CYCOM EP2750 that is expected to be completed before the end of 2020.

CYCOM EP2750 is currently being prepregged with Solvay's 3K-tow, 8-harness Thornel T650 carbon fiber reinforcement. Under development and scale-up are product versions using a 2×2 carbon fiber twill and a unidirectional carbon fiber tape. **solvay.com**

MANUFACTURING SUPPLIERS

RECRUITMENT/HELP WANTED

ADVERTISING INDEX

A&P Technology Inc. . . . . Inside Front Cover
Abaris Training Resources Inc. 24
ACMA - American Composites Manufacturers Association 61
Adapt Laser Systems LLC 28
Airtech International 39
Anderson America Corp. 45
Ascent Aerospace 29
Beckwood Press Co. 48
C.A. Litzler Co. Inc. 57
CAMX - The Composites and Advanced Materials Expo 65
CGTech 25
Chem-Trend L.P. 43
Cincinnati Testing Labs 44
Click Bond 2
Coastal Enterprises Co. 20
Composites One LLC 35
DeltaWing Manufacturing 7
Eastman Machine Co. 51
Elliott Co. of Indianapolis Inc. 26
Engineering Technology Corp. 21
Fives Machining Systems Inc. 53
General Plastics Manufacturing Co. Inc. 14
Gurit 58
Hexcel Composites 33
Industrial Technologies 44
Institute for Advanced Composites Manufacturing Innovation (IACMI) 63
IPCO US LLC 26
LEWCO Inc. 31
Magnolia Advanced Materials Inc. . . Inside Back Cover
Matec Instrument Companies 29

SHOWCASE

Newstar Adhesives 11
OMAX Corp. 27
OSG USA Inc. 17
Pacific Coast Composites . . . . . Back Cover
PPG Engineering Materials/Dexmet 40
Precision Fabrics Group - Nexus 18
Precision Fabrics Group - Peel Ply 19
Pro-Set Inc. 7
Renegade Materials Corp. 5
Revchem Composites 31
SAMPE 42
Smart Tooling 28
Smartech International 30
Society of Plastics Engineers Automotive Division . . 72
Society of Plastics Engineers Thermoset Division . . 30
Specialty Materials Inc. 55
Technical Fibre Products Inc. 15
Teijin Ltd. 13
Thermwood Corp. 49
Tinius Olsen Testing Machine Co. Inc. 21
TMP 51
Toray Advanced Composites USA Inc. 3
Torr Technologies Inc. 55
U.S. Polychemical Corp. 50
Vectorply Corp. 22
Verisurf Software Inc. 20
Victrex USA Inc. 64
Weber Manufacturing Technologies Inc. 24
Wisconsin Oven Corp. 16
Wyoming Test Fixtures Inc. 23

Composite T-boom accelerates industrial automation

A manufacturing method that integrates filament winding with axial winding of 0-degree fibers opens new design options in industrial automated equipment.

By Karen Mason / Contributing Writer

■ **Industrial transfer**

The light weight and vibration damping capability of carbon fiber/epoxy composite material makes it a highly suitable choice for moving components in industrial applications. A composite T-boom here supports the transfer of a metal panel on a manufacturing production line. Source | Bilsing Automation

» Across much of the manufacturing world, companies address intensifying market pressures by finding innovative ways to reduce production time and cost, while maximizing production throughput. An emerging outcome of this ever-growing "need for speed" is that high-performance composite industrial components are finding their way onto factory floors to rapidly move materials and unfinished products through the manufacturing process.

Such applications represent a departure from the more common industrial applications of composites: brackets, fixtures, ductwork, pallets, tanks and other manufacturing facility components that demand the corrosion resistance and durability of non-high-performance composite materials. In contrast to these relatively stationary applications, high-performance composite applications demand a combination of light weight and vibration damping to help manufacturers accelerate high-speed transfers, and to handle the rapid starts and stops of booms, gantries, shafts, beams and other moving components — all with a high degree of stability, accuracy and repeatability.

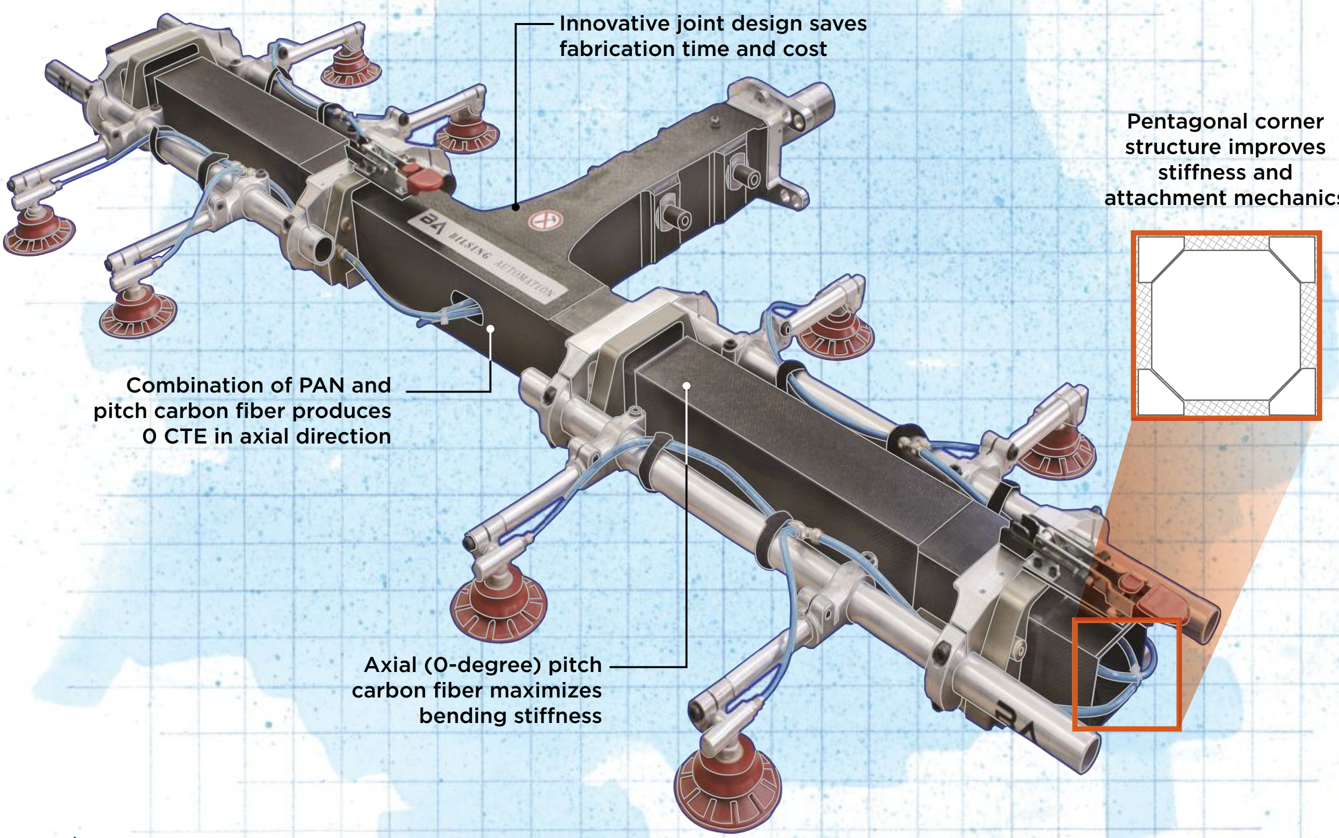
Interest in designing and producing long, rapidly moving machine components from high-performance composites has brought together two companies in the Czech Republic. The first, CompoTech (Sušice, Czech Republic), is a full-service composites design and manufacturing firm focused on advanced and hybrid filament winding applications. The company integrated into its filament winding systems a fiber placement technology that enables axial winding of 0-degree fibers, a combination that adds axial strength and stiffness to CompoTech's designs.

The second company is Bilsing Automation (Attendorn, Germany), a company focused on innovative modular tooling systems for numerous industries. Bilsing boasts a leading position in the development of industrial tooling made from carbon fiber-reinforced polymer (CFRP) composites, which it began incorporating into its tooling systems in 2006. Serendipitously, Bilsing's manufacturing headquarters are in the Czech Republic near CompoTech's facility. CompoTech supplies all of Bilsing's CFRP components — which are, specifically, carbon fiber/epoxy.

"We have a tight relationship with Bilsing," notes Zdeněk Pošvář, CompoTech Bilsing account manager. "We know all the details for their carbon fiber tools and perform the FEA [finite element analysis] to determine optimal wall thickness, torsional and bending stiffness, layup and winding sequence as well as final sizing of components." CompoTech uses Ansys (Canonsburg, Penn., U.S.) FEA software.

Many of the applications the two companies create involve the replacement of steel and/or aluminum machine components. For example, a 2019 CFRP project for a Bilsing industrial customer required a robot arm to move a 500-kilogram payload. This payload and the existing steel/aluminum tool together weighed 1,000 kilograms, but the biggest robot, from KUKA Robotics Corp. (Augsburg, Germany), can handle a maximum of 650 kilograms. An all-aluminum replacement was still too heavy, creating a payload/tool mass of 700 kilograms. "So no other solution but CFRP could work," Pošvář reports. The CFRP tooling reduced the total mass to 640 kilograms, making the robot application feasible.

"CFRP is a little more expensive than metal components," notes Thomas Garant, general manager of Bilsing Automation North America, "but we've proven with the assistance of customers that assembling a successful business case justifies this. CFRP also provides a lighter as well as a more robust solution that also lengthens the life of automation equipment. The strength, stiffness and light weight of the CFRP components (10% stiffer, 40% lighter) allows them to pick up heavier payloads and maintain, if not increase, production output."



DESIGN RESULTS | **CFRP T-boom**

- Up to 20% increase in machine productivity compared to machines with metal transfer components
- 10% stiffer and 40% lighter than metal version
- 8% weight reduction and 85% improvement in long bending stiffness compared to previous composite design

Susan Kraus / Illustration

Pošvář adds, "In some cases, CFRP enables customers to buy a smaller robot or machine, which saves a lot of money."

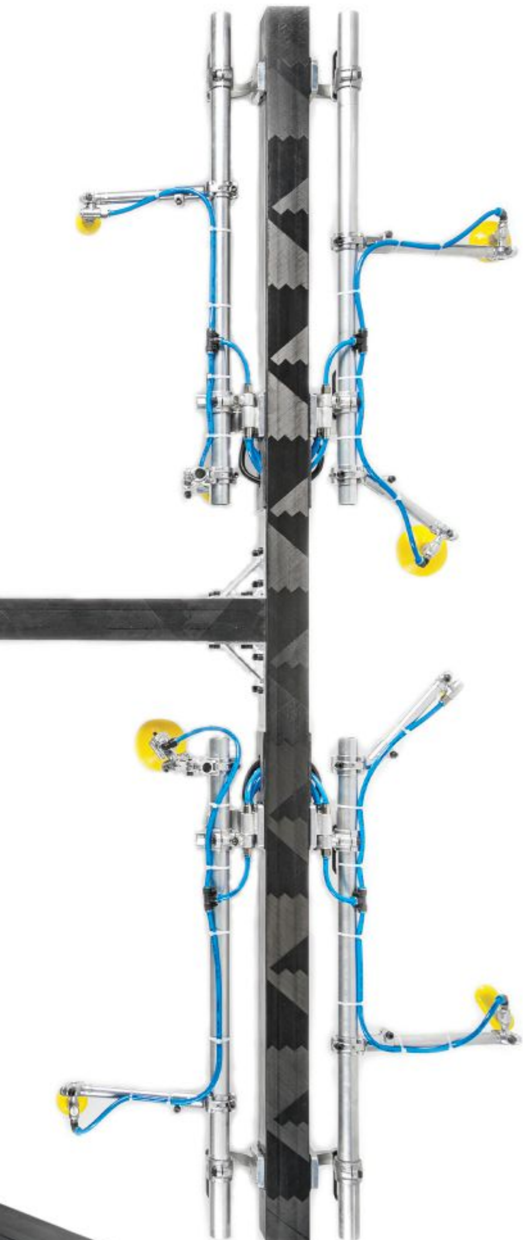
One CFRP component that CompoTech has been supplying to Bilsing since 2006 is the T-boom, a T-shaped beam with a square profile. The T-boom is a common component of automation equipment and historically is made from steel and/or aluminum. It is used to transfer components from one manufacturing step to another (for example, from a press to a punch cutter). The T-boom connects to machinery at the stem of the T and uses the arms to move materials or unfinished parts. Recent manufacturing and design advancements have improved the performance of CFRP T-booms in terms of critical functional characteristics — vibration, deflection and distortion being chief among them.

Minimizing problematic characteristics

Vibration is the nemesis of many automated manufacturing machines. It tends to set manufacturing quality and speed against each other: waiting for vibrations to die down increases machine accuracy, but slows the production cycle. Conversely, faster machine operation compromises machine accuracy, and oftentimes, the quality of the finished product. Alternatively, if the components of a machine can be made to vibrate less, this enables the manufacturer to increase machine speed while maintaining (or improving) product quality.

This is where high-performance composites can be leveraged to improve the performance of automated manufacturing equipment. Reducing the mass and/or increasing the stiffness of a moving machine component results in a higher natural frequency in that component — the frequency at which an operational vibration causes the component to resonate and amplify that vibration. A metal component may have a natural frequency close to the operating frequencies of the machine, while a component made from high-performance composites possesses a high enough natural frequency that it does not resonate with the vibrations created by machine movement.

In addition to preventing resonance, a composite machine component can also damp the vibrations that occur. The composite materials themselves have better damping »



T-boom design

This composite T-boom replaces steel and/or aluminum T-booms, which are commonly used to transfer components in industrial automation systems. The stem of the T connects to the robot or other transfer machinery, and the arms support the load to be transferred. Attachments like the ones shown here provide vacuum or other gripper mechanisms to hold and release the part being transferred. Source | Bilsing Automation

performance than metals. Additionally, CompoTech designs incorporate other materials that are effective at damping (such as rubber) into the CFRP structures. The result is a part that offers damping performance 12-20 times better than that provided by steel.

Placing fibers along the longitudinal (0-degree) axis helps to optimize the automation component's bending performance, minimizing its deflection under load. Unlike filament-wound fibers, axial fibers do not bend around the component's profile; the straight 0-degree fibers thus lend maximal mechanical characteristics to the finished beam. In fact, CompoTech estimates that its combined filament winding and axial fiber placement technology produces beams 10-15% stiffer in the axial direction, with 50% greater bending strength, compared to conventional filament-wound beams.

Geometric distortion can also negatively affect the performance of T-booms and similar components, which often operate in settings where wide temperature fluctuations are common, both from ambient temperature changes and from machine-generated heat. Because of this, the coefficient of thermal expansion (CTE) of machine components becomes critical: along the length of these components, distortion due to thermal expansion/contraction may be significant enough to compromise accuracy and stability. CompoTech designs account for CTE with a strategic combination of both polyacrylonitrile (PAN) and pitch carbon fibers. The composite can be designed to create a machine component with zero CTE axially and/or radially (e.g., spindles), making thermal distortion and its impact on production negligible.

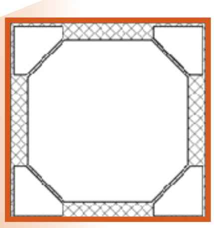
Reducing vibration, deflection and distortion in industrial machinery contributes to improved performance both of the component itself and of the machinery with which it is working, points out CompoTech business development director Humphrey Carter. "When the transfer component can be inserted into a smaller opening in a press, for example, this cuts the time and energy required to open it wider prior to transfer." Though the decreased time and energy may be small for each individual transfer, the savings accumulate rapidly when the press is making hundreds of parts each day.

T-boom improvements

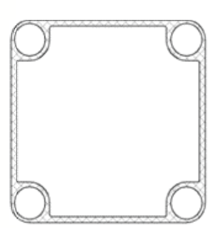
Vibration and deflection reductions compared to metal T-booms represent a benefit of any CFRP T-boom, but CompoTech's latest design innovations are improving vibration and deflection performance even more. One could characterize the CompoTech innovation approach as "manufacture for design." Carter explains, "We develop the process technology bespoke to the design criteria and can make this available for our technology partners as well as composite designers and producers." One of the first examples of this

New corner design

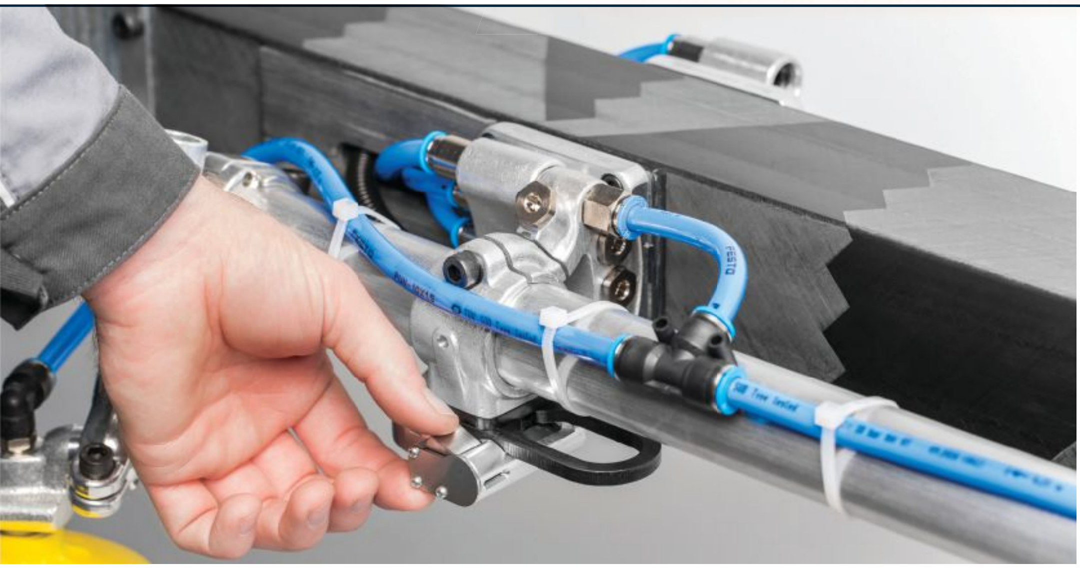
Compared to previous cylindrical corner elements, the pentagonal corner design (visible here at the end of the beam) has reduced weight and increased stiffness of the beam, both of which improve beam performance. Source | Bilsing Automation/CompoTech



The new pentagonal corner design, shown here in cross section.



Previous T-boom designs featured cylindrical corner elements (shown here in cross section).



Robust attachments

The new pentagonal corner design that runs the length of the beam, along with the tolerance that pressing achieves in the beam's shape, handles attachments more efficiently than the previous design. The new design requires little surface preparation or secondary bonding for the attachments.

Source | Bilsing Automation

approach is CompoTech's inclusion of high-modulus pitch fibers in the T-boom design. Strategically placed pitch fiber reinforcement in the T-boom enables CompoTech to offer optimized stiffness. But fine-tuning of the fiber placement and winding system is required to work with pitch fiber, which breaks more easily than PAN fiber. CompoTech has made the manufacturing advancements necessary to make this design option feasible.

To further reduce vibration, the CompoTech T-boom design also includes a damping material that consists of a proprietary combination of cork and rubber. "Positioning of the damping material is the challenging part of the profile design process," Pošvář notes. The current design includes four layers of the damping material (one layer for each side), put in place between carbon layers during the winding process.

The design of the beam profile's corner pieces is the most significant upgrade in the current T-boom design. In the older design, cylindrical openings in the beam's corner structure run the length of the beam. A metal rod is placed inside these corner structures at the points at which Bilsing affixes attachments, providing the strength needed at those points for bonding or bolting. These attachments may also require a metal plate (with its attendant weight penalty) to be placed on the outside of the beam to provide adequate strength at the attachment point.

The new design incorporates pentagonal openings in the corners, again running the length of the beam. These corner configurations are produced individually by winding on separate mandrels. They are then placed in the main body tooling and the fiber placement and winding of the square beam section is performed. Once complete, the beam goes into a press.

The new pentagonal corners have proven beneficial: testing has shown a 20% improvement in torsional stiffness and as much as 85% in long bending stiffness, and an 8% reduction in total beam/fastener weight compared to the cylindrical elements in the old beam profile.

"It is the functionality of the corners and the tolerance achieved with the pressing that allows efficient joining by fixing bolts and supports without a large amount of surface prep or secondary bonding," says Carter. To achieve the same joint strength as a steel weld, previous designs would laminate over the joint, which adds a manufacturing step and increases cost. The Bilsing-CompoTech approach first joins the elements with a minimum amount of adhesive and then provides a simple reinforcement with steel bolts through the corner elements.

Extending industrial applications

CompoTech builds each T-boom according to Bilsing's needs (which in turn are determined by Bilsing's manufacturing customers), resulting in a range of T-boom specifications. T-boom stems are typically 700 millimeters long, while the beam making up the arms extends 1.6-2 meters. Wall thickness varies by the demands of the application but is typically about 10 millimeters. Fiber volume is 50-60%.

Carter says CompoTech uses a variety of carbon fiber suppliers, with most of the pitch fiber coming from Nippon Graphite Fiber Corp. (Hirohata, Japan) and Mitsubishi Chemical Carbon Fiber & Composites (Tokyo, Japan). Epoxy resin is supplied for all CompoTech T-booms by GRM Systems (Olomouc, Czech Republic).

Bilsing's carbon fiber product line is a growing sector of the company's business, and the lightweight, stiff, low-vibration components are also expanding the range of motion feasible in T-booms. Recent machine innovations incorporate swiveling, rocking and rotational movement that enables the transfer of components to maneuver around other equipment along the most efficient path possible. Such innovations add to the productivity levels possible with CFRP T-booms, and therefore, to the attractiveness of CFRP as an industrial machinery material of choice. CW

ABOUT THE AUTHOR

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


PACIFIC COAST
COMPOSITES
The right materials.
The right quantities.
The right time.
PACIFIC COAST
COMPOSITES
SOLVAY
asking more from chemistry®
HEXCEL
Official Distributor
3M
Authorized Distributor
and Repackager
Automotive and Aerospace Solutions Division