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NOVEMBER 2019

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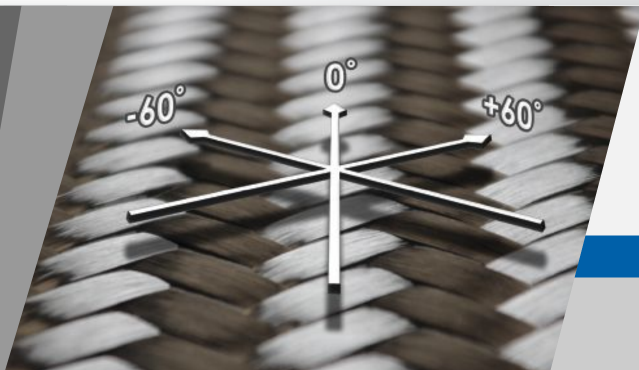

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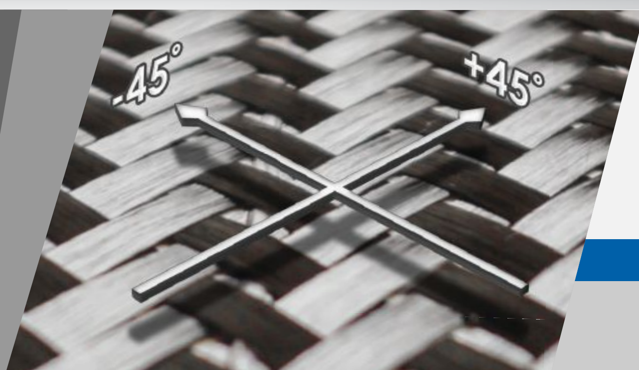

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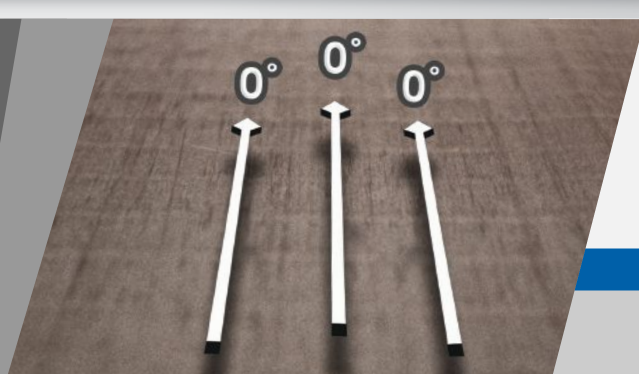

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Arris Composites' Additive Molding process combines additive manufacturing technology with high-speed compression molding to produce high-performance thermoplastic composite parts. Shown here, the company's demonstration truss is expected to outperform a conventional pultruded truss of the same cross-section because of its optimally aligned fiber reinforcement. See p. 22.

Source / Arris Composites

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I have an uncle who earned his degree in electrical engineering in the 1960s and went on to enjoy a profitable career as an engineer and then data analyst. He is, by nature, highly data oriented and enjoys making and maintaining databases of all types — golf scores, bowling scores, batting averages, etc.

The most famous database my uncle developed was one that he maintained over a period of 15 years, 1985-1999. In this dataset he recorded found coins. That is, every time he found a coin in a public place, he noted the denomination of the coin, the year it was minted, where it was found (city, state, country) and the date and time at which it was found.

> How does one facility put all of its data into context?

He doggedly recorded this information in an Excel spreadsheet and then, each year, issued to everyone in our family a report of his findings, which used a variety of pivot tables to slice and dice the data to reveal interesting observations about the coins he'd discovered. As the years went on, my uncle compared coin data from the current year to previous years, revealing trends and even more hidden informational gems.

I looked forward to my uncle's coin report each year and admired the systematic determination its creation required. I was also struck by a couple of things about my uncle's coin database. First, he found a lot of coins — more than 17,000 over that 15 years. I figured that his desire to build a database of found coins likely made my uncle uncommonly aware of coins to be found. Second, although his annual reports were intensely interesting, I often found myself wondering what the data meant. My uncle poured a great deal of time and energy into developing and maintaining this database, but to what end? What is the value of such data?

If you are a manufacturer of composite parts and structures, this question of the value of data is not a trivial one. Any composites manufacturing operation generates an immense amount of data that has various levels of potential utility. On a typical manufacturing floor, the most obvious display of data surrounds operations efficiency, quality control and safety. Often, bulletin boards, television monitors and other visual devices are used to signal to workers and supervisors how well certain manufacturing processes are conforming to the standard.

Such data, however, are baseline only. There is additional information — sometimes unseen — surrounding material quality, material expiration, material waste rate, machine performance, equipment utilization, order lead time, delivery performance, customer reject rate, customer retention rate and much more. The question is, what does it mean? How does one facility put all of this data into context?

That is the question that the CW Top Shops survey attempts to answer. Launched earlier this year, the CW Top Shops survey was sent to thousands of composites fabricators, asking them to provide metrics about their operations, ranging from facility size and markets served to machine utilization and profit margin. The value of the CW Top Shops data is simple: It allows you to compare your composites manufacturing operations to other composites manufacturing operations. It helps you see strengths and weaknesses — where you excel and where you can improve.

We received 110 responses to the survey this year, and you will find on p. 20 of this issue samples of some of the data we received. You will also find the list of 31 companies that scored highest in the survey and earned the CW Top Shops award. If you participated in the 2019 survey, you received a customized report that showed you your facility's data and compared it to other survey respondents. If you did not participate this year, you can still purchase the CW Top Shops report, which includes all respondent data. You can also look forward to the CW Top Shops survey returning in 2020.

As you very likely know, the amount of data emerging from your manufacturing operations is increasing exponentially. It is no longer acceptable to simply gather and store that data. One of your jobs as a fabricator will be to organize it, put it in context and give it meaning. We hope that CW Top Shops becomes a valuable tool in that effort.

JEFF SLOAN — Editor-In-Chief

Urban air mobility: The action heats up

» I'm just back from CAMX 2019, which was replete with exciting innovations, presentations and displays across the spectrum of composites. While at the show, I took the pulse of the industry and caught up with hundreds of colleagues and acquaintances acquired over the years. One thing I really like about CAMX is that it goes well beyond the typical format for a trade show and technical conference. Beyond extras like tutorials and workforce development activities, there are numerous opportunities for special interest groups to congregate, and there are a number of side meetings covering specific topics.

A series of these meetings was organized by the American Composites Manufacturers Assn. (ACMA, Arlington, Va., U.S.) under the organization's Composites Growth Initiative. These meetings, largely consisting of industry participants and led by ACMA staff, delved into ways to expand composites use in markets like automotive, infrastructure, construction and corrosion resistance. Due to other obligations, I was only able to attend two meetings, one on automotive and the second on a relatively new and exciting topic: urban air mobility (UAM). I had previously written about this topic in September 2018, asking whether there really is a market for flying cars and air taxis, and if a true business case can be made for them. To my surprise, more than 50 people attended the CAMX meeting, and it is clear there is great enthusiasm in the composites community for the potential of this yet-to-be-commercialized application.

> Can flying taxis be profitable, and will there be enough demand?

The meeting was organized by ACMA and Danielle McLean of HappyTakeOff, a Wichita, Kan.-based consultancy focused on the aircraft and infrastructure needs of the UAM market. McLean believes "the need for composites expertise is huge," not only for airframes, but for lightweight infrastructure that will go atop parking garages and other large-surface-area-buildings to serve as "vertiports." Dr. Anita Sengupta, chief product officer for Airspace Experience Technologies (ASX), one of many aspiring suppliers of electric vertical take off and landing (eVTOL) vehicles, believes that being based in Detroit enables the company to have an automotive production mindset to keep aircraft costs low (less than $1 million per vehicle) to make the business case work. ASX has tested subscale models and is working toward a full-scale prototype. John Geriguis, with California-based Joby Aviation, noted that his company continues flight testing of full-scale versions of its aircraft and is actively adding staff across multiple disciplines, including composites engineers. Andy Bridge of Janicki Industries (Sedro-Woolley, Wash., U.S.) emphasized that the fabrication volumes for UAM aircraft fall well above the typical 10 per week reference point for aircraft such as the 737 and A320, and well below high-volume automotive's reference point of more than 100,000 per annum. A target of 50-100 UAM vehicles per day may be needed to meet demand and amortize fixed costs to be competitive. This falls into the range of production of BMW's composites-intensive *i3*, so processes such as high-pressure resin transfer molding (HP-RTM), thermoplastic stamping and pultrusion could play key roles.

And what about the economics? Can flying taxis be profitable, and will there be enough demand? Michael Dyment, founder of NEXA Capital Partners (McLean, Va., U.S.) has no doubt. Dyment spoke at the ACMA event and also in a longer session during the conference, noting that by 2050, more than 6 billion people worldwide will live in urban areas, with increasing congestion for people, goods and services. UAM provides a fundamental change in lifestyle, much like the automobile, passenger aircraft, personal computers and mobile telephones have in the past. He notes that there are more than 100 eVTOL manufacturers working to develop, fly and certify aircraft for the UAM market. "There is a market today," he says. "Just not the infrastructure to support it." NEXA studied 74 large cities globally, identifying more than 4,000 heliports, most of which need to be repurposed for UAM, to the tune of more than $30 billion. This presents a real opportunity for composites. In the 2020-2040 timeframe, NEXA estimates the UAM market could generate more than $318 billion in revenues with more than $600 billion in total economic impact in the 74 cities studied. The market for air vehicles in this period will exceed $41 billion.

While attendees at the ACMA meeting were optimistic, everyone knows there are still major hurdles to overcome, including standards, how to regulate the airspace and how to certify the aircraft. NASA and the FAA are working together to develop a UAM "grand challenge" to address these impediments, with a first phase of developmental flights in late 2020, then full field demonstrations with a small number of participants in 2022. A second, broader grand challenge will follow. If all goes well, within five years, we will see UAM roll out, and open up a sizable market for composites. 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.

The challenge of identifying test procedures for recycled carbon fiber composites

The increase in the global demand for carbon fiber products — and the waste associated with their consumption — raises a lot of sustainability issues. Carbon fiber has an embodied energy as high as that of aluminum, which is widely recycled, and the disposal of carbon fiber waste has a serious impact on the circular economy. As a result, recycling techniques such as hydrolysis, solvolysis and pyrolysis have been gaining momentum over the last couple of decades[1].

FIG 1 Carbon fiber recycling process
Source | ELG Carbon Fibre

The major technological challenge with pyrolysis, however, is its inability to recover carbon fiber in the same form as its source. The end product of pyrolysis recycling is a fluffy, entangled mass of discontinuous fibers (Fig. 1). An efficient, cost-effective method for handling recycled carbon fibers (rCF) is conversion of fibers into a textile fabric. Using this method, ELG Carbon Fibre (Coseley, U.K.) converts rCF into randomly distributed, dry laid, needle-punched, nonwoven fabrics. Due to the porous nature of these fabrics, however, the resulting compression-molded laminates typically only achieve around 30% fiber volume fraction.

Because of these material behavior properties, rCF composites are dissimilar to conventional, long and continuous fiber-reinforced virgin carbon fiber (vCF) composites, and likewise exhibit different properties. To understand the capabilities, mechanical behavior and design limits of rCF composites, it is essential to develop a reliable materials dataset, and to characterize them with suitable test methods. Unfortunately, the codes and standards for macro-scale testing were developed with virgin continuous fiber-reinforced composites in mind. In addition, a number of discrepancies at coupon level testing exist in literature and industry even for conventional composites[2]. Adding further complication, some OEMs use their own test protocols to characterize vCF composites[3]. The introduction of rCF materials with their unique reinforcement architecture increases this ambiguity in composites testing protocols. Additionally, there is a wide choice of test methods for the measurement of a single property. Though identification of the most suitable test is time-consuming, it is fundamental for understanding rCF's mechanical behavior. The primary objective of my research was to determine if nonwoven rCF composites would require the development of a specific set of standard testing protocols to evaluate and analyze its use in existing and potential new applications.

However, the guidance for a test method that is seemingly as straightforward as a static tensile test becomes unclear in the case of discontinuous, nonwoven rCF composites. The common practice is to use straight-sided rectangular coupons due to the simplicity of specimen preparation, but for rCF composites, the use of rectangular coupons, as described by ASTM D3039 or ISO 527-4 type 2 or 3, with or without end tabs, has resulted in failures at or near the tabs due to a poor stress transfer into the gauge length of the specimen. From a sample size of 150 rectangular specimens, fewer than 12.5% produced an acceptable gauge failure. Possible causes include poor specimen preparation, load introduction method, grips, test speed, etc. A bow-tie specimen, as trialed by the U.S. Army Materials and Mechanics Research Center for random glass fiber composites, did not yield improved results for rCF composites either[4]. In this trial, the use of dogbone geometry, as described by ASTM D638, resulted in improved performance with more than 80% of the specimens failing within the central gauge region (Fig. 2). This specimen design has a large impact on tensile characteristics, as the rectangular geometry specimens tend to fail prematurely.

My study, using identical rCF composite rectangular and dogbone samples, resulted in a 10% and 20% reduction in tensile strength and stiffness, respectively, for the rectangular samples as compared to the dogbone samples. Improved geometry design in tension load was also evident in cyclic fatigue. At a particular stress level in a tension-tension fatigue loading, a rectangular coupon could fail anywhere between a few hundred cycles to more than 3 million fatigue cycles, whereas the variability in cycles to failure for dogbone coupons was much lower.

A similar pattern was observed when both out-of-plane and in-plane shear were evaluated. Although out-of-plane shear or interlaminar shear is only a quality control test, a number of test methods have been established for its assessment, such as short beam shear (SBS) test methods described by ASTM D2344 and ISO

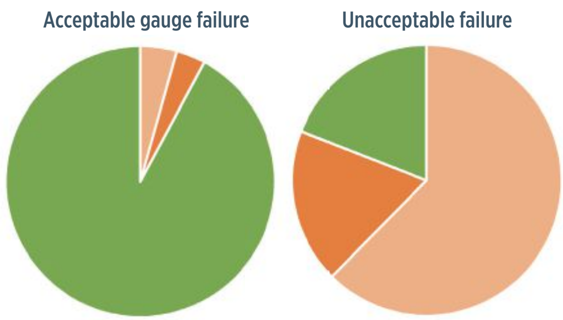

FIG 2 Improvement in stress transfer to sample gauge length in dogbone specimens

Source | Karthik Krishna Kumar

14130, double notch shear (DNS) by ASTM D3846 and the recently developed Double Beam Shear (DBS) by ISO 19927. Unfortunately, none of these tests presented the desired result of a pure interlaminar shear failure with rCF composites. The common tendency was to fail by undesirable modes such as tensile or crushing, rather than a shear-dominated failure in the specimen.

A successful method for subjecting a material to a state of pure shear is the Iosipescu shear test, which uses a V notch geometry specimen. However, for the evaluation of interlaminar shear, ASTM D5379 recommends the use of a 76-millimeter-thick panel that is quite impossible to manufacture without the introduction of defects. The alternative was to bond panels together to 76 millimeters thick, which, if successful specimen, could result in a crushing failure at the grip section of the V notch specimen. A remodified standard specimen design reconstructing only the critical section of the V notch specimen avoided this potential problem and resulted in the generation of a pure interlaminar shear failure in rCF composites.

The Iosipescu shear test was, however, inapplicable for in-plane shear testing in rCF composites. The tendency was to fail by a tensile-dominant failure. A possible alternative could be the plate twist method as described by ISO 15310, generally used for wood composites. It is clear that the nature of the fiber reinforcement architecture has a significant effect on the mechanical behavior and material response for basic static macro-scale coupon level tests. Furthermore, the mechanical behavior of rCF composites in cyclic loading has been found to be quite unlike that in conventional vCF composites or short fiber-reinforced composites.

A number of material processing variables influence mechanical properties of rCF, but the analysis of these parameters is futile and cumbersome without the development of dedicated standard testing practices for a material that has freshly entered the market. The British Standards Institution (BSI) has addressed specifications for unconventional composite systems like textile glass-reinforced plastics, sheet molding compound (SMC) and bulk molding compound (BMC) thermoset composites and more with dedicated standards that identify applicable test methods. Recycled carbon fiber composites now require the same approach. CW

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ABOUT THE AUTHOR

Karthik Krishna Kumar is a Ph.D. student at Oxford Brookes University, U.K. His research entails the development of appropriate test practices for recycled, nonwoven carbon fiber composite systems and assessment of their fatigue behavior and environmental durability, for the safe and sustainable use of carbon fiber in practical applications.

Composites Index contracts for third month

September — 47.3

» The Composites Index experienced its third month of contracting activity in September, registering 47.3. Index readings above 50 indicate expanding activity, while values below 50 indicate contracting activity. The further away a reading is from 50 the greater the change in activity. Gardner Intelligence's review of the underlying data found that the gauge for supplier deliveries was the only expanding component within the Index. Both new orders and backlog activity readings fell sharply to levels last experienced in mid-2016. The remaining components of the Index all registered mildly contracting activity levels.

For a second month, the export reading registered higher than new orders; however, because September's figures were both contractionary — with total new orders reading four points lower — the implication is that both domestic and foreign orders for manufactured composites goods contracted.

The spread between production and new orders activity narrowed in September after significantly widening in the prior month; overall this appears to have done little to support backlog activity, which fell to a multi-year low. In two of the last three months, production activity has contracted while supplier deliveries have experienced stable expansion, a trend that seems destined to change. CW

ABOUT THE AUTHOR

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

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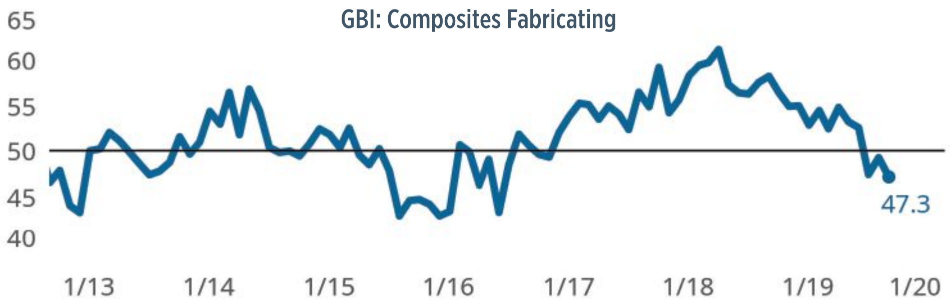
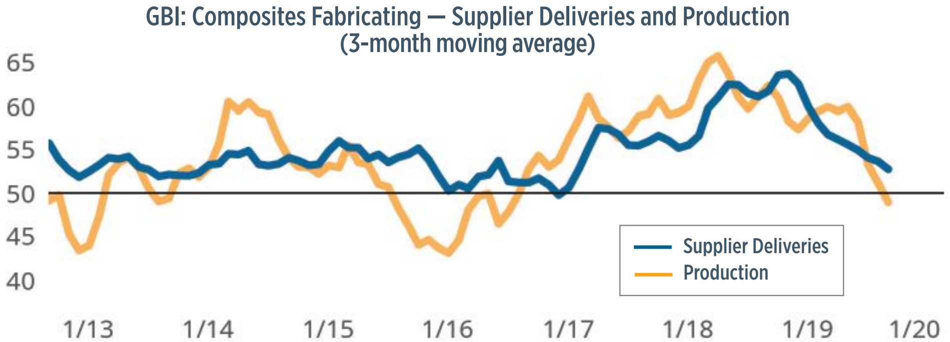


Business activity contracts on new orders and backlogs

A quickening contraction in business activity sent the Composites Index lower in September. A broadening contraction in backlogs and new orders more than offset gains from supplier delivery activity.



Production and supplier delivery activity send contradicting messages

Production activity has reported contracting activity in two of the last three months, while supplier deliveries reported its 30th month of continuously expanding activity. The conflicting messages being sent by these components suggest a reconciliation must eventually occur.

Take a closer look at this year's CAMX Awards and ACE winners, learn about developments in all-composite wheels for electric vehicles and more.

2019 CAMX Awards, ACE winners illustrate industry trends

The CAMX 2019 trade show, held Sept. 23-25 in Anaheim, Calif., U.S., showcased the latest processes, materials and solutions in composites manufacturing, and highlighted new projects and products across a variety of end markets. This year's CAMX Awards and ACMA ACE winners represent some of the best on display at this year's show and what's trending in the industry, with innovations ranging from next-generation aerospace parts and high-volume automotive parts, to greener materials and revolutions in composite 3D printing. Here is a rundown of the winners:

CAMX Awards: CarbonPro box and laser drilling

CAMX gives two awards each year, one in the Unsurpassed Innovation category and one in the Combined Strength category.

General Motors (Detroit, Mich., U.S.) and Continental Structural Plastics (Auburn Hills, Mich., U.S.) were awarded the CAMX Unsurpassed Innovation award for the CarbonPro chopped carbon fiber/polyamide box for the GMC *Sierra Denali* pickup truck (right, top image).

The Institut fur Textiltechnik of RWTH Aachen University (Aachen, Germany) took home the CAMX Combined Strength award for its high-accuracy laser drill for cutting holes in carbon fiber preforms for inserts and fasteners.

ACE winners: from SMC to ASTRA

The American Composites Manufacturers Assn. (ACMA; Arlington, Va., U.S.) Awards for Composites Excellence (ACE) are given for exemplary achievement in materials and processes, equipment and tooling, creative design, growth opportunity and sustainability.

The Innovation in Green Composite Design award went to LyondellBasell (Houston, Texas, U.S.) for its new styrene-free sheet molding compound (SMC) that meets the requirements of California's Proposition 65 law, plus the LEED building quality standard for use of sustainable materials. Proposition 65 requires businesses to provide warnings to Californians about significant exposures to chemicals that cause cancer, birth defects or other reproductive harm.

The Infinite Possibility for Market Growth award was given to the University of Delaware (Newark, Del., U.S.) for the development of its Tailorable Universal Feedstock for Forming (TUFF), a short-fiber composite material engineered for the fabrication of complex-geometry parts.

The Fibers and Composites Manufacturing Facility (FCMF) at the University of Tennessee (Knoxville, Tenn., U.S.) was awarded the Most Creative Application award for its braided, arched beams developed for the International Friendship Bell pavilion in Oak Bridge, Tenn.

The winner of the Equipment and Tooling Innovation award was Fortify (Boston, Mass., U.S.), for its development of a stereolithography 3D printing technology that can magnetically align fibers in a finished composite part (above, middle image).

The Material and Process Innovation award was given to aerospace Tier 1 fabricator Spirit AeroSystems (Wichita, Kan., U.S.) for its development of the Advanced Structures Technology & Revolutionary Architecture (ASTRA) demonstrator, a next-generation fuselage panel that Spirit says can meet the strength, throughput and cost requirements of a single-aisle commercial aircraft (above, bottom image).

Cobra composites enable security robot

Composite shelled robots are being designed to enhance security by patrolling parking areas and communal spaces. Source | Cobra International

Cobra International (Chonburi, Thailand) is collaborating with robotics provider Obodroid (Bangkok, Thailand) to help bring a new building security robot concept to life. With the robotic systems already in place, Cobra will deliver a set of eight composite parts that form the lightweight body shell cladding of the streamlined 1.35-meter high robot.

Having been involved from the outset of the project, from design and engineering through to the prototyping of the composite robot shell parts, Cobra International will start with the production of the first batch of robots in 2020.

By using cameras and sensors integrated into robots, building operators can provide more effective and flexible security monitoring systems, providing a 24/7 autonomous patrol service around the residential area.

The Cobra design and development team selected a glass fiber and epoxy composite laminate for the robot shell parts to provide a stiff, lightweight yet cost-effective cladding for the robot. A combination of woven and stitched multiaxial reinforcements were hand laminated with epoxy resins before curing under vacuum bag consolidation.

Cobra also developed the mold tools for the composite parts, with some molds made in-house and the balance produced by Cobra's network of local tooling partners.

"Cobra takes great pride in providing a design and development service for its clients, especially those who are completely new to the world of possibilities provided by composite materials," says Danu Chotikapanich, CEO of Cobra International. "Taking a client's initial ideas and developing prototypes followed by production-ready parts is a massive part of bringing composites into new product sectors like robotics."

According to Chotikapanich, the composite-shelled robots will soon be patrolling the parking areas and communal spaces of the latest tech-enabled commercial and residential real estate developments.

CW MONTH IN REVIEW

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

Montefibre Carbon awarded €5.6 million from Spanish government
The investment will enable the large-tow PAN precursor manufacturer to expand its production capacity to 33,000 metric tons per year by 2025, the company says.
10/11/19 | short.compositesworld.com/M_C_fund

Virgin Galactic announces milestones in next *SpaceShipTwo* manufacture
The fuselage and cabin have been attached to the wing assembly, moving the ship closer to full assembly.
10/3/19 | short.compositesworld.com/VG_SS2

NASA announces urban air mobility challenge
NASA's UAM Grand Challenge will be a full field demonstration in an urban environment to test the readiness of UAM vehicles and airspace operator systems.
9/30/19 | short.compositesworld.com/NASA_UAM

Continuous Composites, Arkema partner for continuous-fiber 3D printing
The companies will combine Continuous Composites' CF3D process with Arkema's photocurable resins to develop and certify composite 3D-printing solutions.
9/26/19 | short.compositesworld.com/CF3DArkema

Orbital Composites introduces Orb 1 industrial-grade robot 3D printer
Controlled by Orbital Composites' proprietary Orb OS software, Orb 1 allows users to easily print end-use thermoplastic composite parts from CAD files.
9/25/19 | short.compositesworld.com/Orb1_print

Solvay expands thermoplastic composites manufacturing capacity
Solvay is building a new thermoplastic tape production line at its Anaheim, Calif., facility, underscoring its focus on thermoplastic composites for aerospace.
9/23/19 | short.compositesworld.com/SolvayTPC

A&P Technology launches 864-carrier braiding machine
The company says the latest addition to its Megabraider line tops its own record for world's largest braiding machinery.
9/19/19 | short.compositesworld.com/864braider

LANXESS commissions two new production lines for Tepex TPCs
The 90,000-square-foot expansion to the Kansas facilities includes upgraded hot-melt film and tape lines, as well as a new R&D lab.
9/17/19 | short.compositesworld.com/LANXexpand

Siemens Gamesa to build world's largest wind turbine test stand
The company's site in Aalborg, Denmark, will be capable of performing full-scale tests on the next generation of rotor blades.
9/16/19 | short.compositesworld.com/SG_stand

Voith Composites, HRC to develop hydrogen pressure vessels for EVs
The next-generation filament-wound composite high pressure vessels will be designed for use with fuel cell electric vehicles.
9/12/19 | short.compositesworld.com/Voith_HRC


Source | Dieffenbacher and Arburg

Combined injection/transfer molding process developed for structural applications

Dieffenbacher (Eppingen, Germany) and Arburg (Lossburg, Germany) have partnered to develop new solutions for transfer molding of hybrid components. The companies recently collaborated on a research project to develop a "modular production plant for heavy-duty hybrid components," or MoPaHyb, which was funded by the German Federal Ministry of Education and Research (BMBF).

With the participation of Fraunhofer ICT (Pfinztal, Germany) and nine other partners, the companies developed a system that combines an Arburg 4,600-kilonewton injection unit for fiber direct compounding (FDC) with a Dieffenbacher 3,600-ton vertical press. This multi-machine cell is located at Fraunhofer ICT. Arburg's FDC injection process allows fibers to be added directly to the plastic melt. In this process, fiber length, fiber content and material combination can be customized to meet specific part properties. The modular system the partners developed is said to enable the production of parts with dimensions and complexities that could not be manufactured previously.

The technology combination offered by MoPaHyb allows continuous-fiber reinforcements to be preformed and consolidated in the Dieffenbacher press, followed by injection overmolding of a chopped fiber-reinforced thermoplastic material via the Arburg machine. The result is a hybrid part that offers the strength and stiffness benefits of continuous-fiber structures, combined with potentially ribbed and other geometric reinforcements provided by injection molding. The companies expect this material and process combination will open new areas of application in structural parts.

AUTOMOTIVE

All-composite wheel for electric vehicles takes a step forward

A project to develop the world's first commercially viable, low-cost, lightweight, all-composite wheel for electric and niche vehicles such as driverless cars, last-mile delivery vehicles, road sweepers and next-generation agricultural vehicles has won grant funding of £135,500. The ACRIM (All Composite Reduced Inertia Modular) wheel project, which is being developed by a consortium of U.K. composite experts comprising Carbon ThreeSixty (Wiltshire, U.K.), Far UK (Nottingham, U.K.) and Bitrez Ltd. (Wigan, U.K.), won the funding after entering a competition presented by the Niche Vehicle Network, an independent association aimed at promoting and stimulating R&D collaboration and partnership working to support the growth of U.K. niche vehicle manufacturers and their U.K. supply chains.

The consortium says its all-composite wheel will be 4 kilograms lighter than a generic 8-kilogram, 15-inch wheel, and is predicted to provide efficiency gains of 5-10% representing a 5% fuel saving or a 5% CO_2 reduction when retrofitted to a gas- or diesel-powered vehicle.

"Lightweighting of vehicles is a direct way of achieving efficiency gains, whether it's reduced CO_2 emissions from internal combustion engine vehicles or increased range on electric vehicles or saving weight so you can carry less for the same distance," says lead project partner, Edward Allnutt, managing director at Carbon ThreeSixty, which specializes in the design and manufacture of advanced composite structures.

The ACRIM (All Composite Reduced Inertia Modular) project, which is being developed by a consortium of U.K. composites experts comprising Carbon ThreeSixty, Far UK and Bitrez Ltd., has won funding from the Niche Vehicle Network.

Source | Carbon ThreeSixty

Cost, of course, is another important factor. Until now, carbon fiber wheels have been targeted toward luxury and high-performance vehicles. High material and production costs have kept carbon fiber wheel designs out of reach of niche vehicle manufacturers and everyday consumers.

"How do we go about making a lightweight, efficient wheel at the price bracket that niche vehicle manufacturers and normal human beings would find attractive?" says Allnutt.

According to Allnutt, the ACRIM project is approaching the project as a multi-piece co-manufactured wheel. He stresses the wheel will not be manufactured with autoclaved prepreg. The project is exploring a modified epoxy wet resin process incorporating different noncrimp fabric preform manufacturing technologies including tailored fiber placement (TFP) and potentially integrating sheet molding compound (SMC).

The resin formulation partner for the project is Bitrez Ltd., a manufacturer of specialist polymers and chemicals. "We're very proud to be the resin formulation partner for this project, developing high-performance, REACH-compliant matrix systems to meet the demands of process and performance, whilst also investigating how more sustainable materials can play their part," says Dominic Hopwood, the company's sales manager. "The all-composite wheel demonstrates how the industry is helping to reduce the world's carbon footprint. It's lightweight and low-cost and will help save fuel, reduce carbon emissions and increase the number of miles an electric vehicle can travel."

While still at the R&D level, the ACRIM project has an aim of medium volume production in the range of £200 ($246 USD) per wheel.

Over the next six months, the consortium will use the NVN funding to move the all-composite wheel from proof of concept through to demonstration and production readiness. According to Allnutt, the wheel's effectiveness is set to be tested by two OEMs and a global Tier 1 wheel supplier: GKN (Redditch, U.K.), MeV (Mansfield, U.K.) and Microcab (Coventry, U.K.).

"Without funding from the Niche Vehicle Network this project would not have got off the ground," Allnutt says. "The funding is enabling us to further invest in R&D and accelerate the time to market for innovative products such as the ACRIM wheel. Despite SMEs being the engine room for innovation within the U.K., we often struggle to access the finance required to exploit our ideas. Support from organizations such as the Niche Vehicle Network and Innovate UK enables us to do just that. The partnership for this project represents some of the foremost experts in the U.K. composites sector working together to launch a truly revolutionary product."

Lyndon Sanders, sales director at Far Composites, which specializes in the design and manufacture of lightweight structural composite components to reduce both weight and vehicle emissions, adds, "It feels like a great team, and a lightweight and cost-effective wheel, especially for new energy vehicles, feels like a great place to make a difference."

The funding from the Niche Vehicle Network will cover 50% of the project costs, with the remainder coming out of the consortium's resources.

California high school adds composites fabrication to curriculum

At the beginning of the school year, Knight High School Engineering and Digital Design Academy in Palmdale, Calif., U.S., held a ribbon-cutting ceremony for a new composites fabrication lab designed to provide learning opportunities geared toward giving students a head-start on local aerospace jobs.

The lab started out as a makerspace. According to James Stockdale, Academy coordinator, it was about seven years ago that the school administrators at Knight High, which is a nationally-recognized STEM school with 275 students, decided that they needed a way to provide students more hands-on instruction. They filled the makerspace with saws, drills and other traditional tools, Stockdale says, but also CNC lasers, routers and 3D printers.

"This space became a favorite amongst students for building ideas, but also one that local industry mentors came out to spend time with our kids in creating things," Stockdale adds. Those mentors included Northrop Grumman (Falls Church, Va., U.S.), Lockheed Martin (Bethesda, Md., U.S.) and NASA, as well as Scaled Composites (Mojave, Calif., U.S.) and The Spaceship Co. (Mojave). School administrators began to notice that a lot of the students who used the makerspace began pursuing careers at these companies after high school.

A new composites fabrication lab opened this school year at a STEM-focused high school in California.

Source | Knight High School Engineering and Digital Design Academy

The high school connected with Joel Morgan, who works at Goodwill Workforce and had previously developed an airframe fabrication certificate program, which included education in composites fabrication, to connect graduates from local Antelope Valley College with Northrop Grumman.

"[Morgan] started meeting with our kids regularly to enroll them in this program after graduation, and a couple of our teachers audited the composites class themselves," Stockdale says. "The fostering of these relationships led to the conversation that it would be in the best interest of our students, industry and the community as a whole if we could start the students earlier on composite training in the high school."

The former auto shop, which was located next to the existing makerspace, was selected to be remodeled into what is now the composites lab.

To educate themselves and to prepare the curriculum for the lab, Stockdale and Knight High science teacher Briana Gallegos attended training at Abaris Training (Reno, Nev., U.S.).

"During that training, we created a small airfoil using molds and multiple bonding techniques," Stockdale says. "We modified from this idea to create molds of our own and developed a curriculum for our new lab that has kids starting off simply with carbon fiber clip boards, fiberglass logos, and Kevlar panels with core material, and work our way up to using molds to create small airfoil pieces."

The curriculum also includes postprocessing and waterjet cutting, and students can enroll in a more advanced afterschool and weekend class to engage in more complex projects, like skateboards.

According to Stockdale, the program offers students a hands-on opportunity to gain a skill set that is directly transferable to the local workforce. "Our aerospace valley is booming with jobs related to the composite industry," Stockdale says, "and whether our students go on to become engineers or fabricators on the line of the F-35 fuselage, there are great opportunities for them."

CW's Top Shops puts operations in perspective

The inaugural CW Top Shops benchmarking survey is designed to help composites fabricators understand how efficient their manufacturing operations are.

By Jeff Sloan / Editor-in-Chief

» Composites manufacturing is notoriously varied. The mix of resin, fibers and processes creates a vast universe of manufacturing options that can be difficult to track and quantify. That said, such tracking and quantifying *is* worth doing, if only to help establish for the composites industry some baseline data regarding operations efficiency.

With that in mind, *CompositesWorld*, in cooperation with Gardner Intelligence, has launched the CW Top Shops benchmarking survey, designed to help composites manufacturing operations like yours measure and assess how well they compare to other composites manufacturers.

We asked composites fabricators — individual facilities — to provide a host of data surrounding several metrics including order lead time, machine uptime, capacity utilization, wages, customer retention, sales growth, labor turnover, scrap rate, materials used, processes used, inspection technologies used, inspection machinery employed, supply chain practices, marketing practices, certifications and much more. We received more than 110 survey responses.

This report aggregates all of those responses, which came from composites fabricators from around the world representing every major end market, including aerospace, automotive, marine, energy, consumer and industrial.

2019 CW Top Shops winners

These 31 top-ranked facilities earned the Top Shops label.

Company	City	State/Province	Country
Ability Composites LLC	Loveland	Colo.	United States
Advanced Aerospace	Auckland		New Zealand
Arisawa Mfg.Co. Ltd.	Taito-ku	Tokyo	Japan
ATC Manufacturing	Post Falls	Idaho	United States
CES Advanced Composites	Ankara		Turkey
Champion Fiberglass Inc.	Spring	Texas	United States
Cirgan Plast s.a.s. di Cirelli Bernardino & C.	Somma Vesuviana	Naples	Italy
Competition Composites Inc.	Arnprior	Ontario	Canada
Composiflex Inc.	Erie	Pa.	United States
Composite Resources	Rock Hill	S.C.	United States
Creative Composites Inc.	Rapid River	Mich.	United States
Fine Finish Organics Pvt. Ltd.	Navi Mumbai	Maharashtra	India
Freedom Innovations	Irvine	Calif.	United States
Global Composite Solutions	Umm Al Quwain		United Arab Emirates
GSE Dynamics	Hauppauge	N.Y.	United States
Kilwell Fibretube Ltd.	Rotorua	Bay of Plenty	New Zealand
Korean Air Lines	DongNae-Gu	Busan	South Korea
Leonardo	Pomigliano d'arco	Naples	Italy
MDA Corp.	Ste-Anne-De-Bellevue	Québec	Canada
Moldex Composites Pvt. Ltd.	Surat	Gujarat	India
Plasan Carbon Composites	Walker	Mich.	United States
Polygon Co.	Walkerton	Ind.	United States
R3 Composites	Grabill	Ind.	United States
Soucy Composites	Drummondville	Québec	Canada
Southern Spars	Auckland		New Zealand
Southwest Pattern Works	Albuquerque	N.M.	United States
Strongwell	Chatfield	Minn.	United States
Tila Kompozit Ltd. Sti	Istanbul		Turkey
Viking Technologies Corp.	Marblehead	Mass.	United States
Weihai Guangwei Composites Co. Ltd.	Weihai	Shandong	China
Wolfcomp Composites	Braunschweig	Lower Saxony	Germany

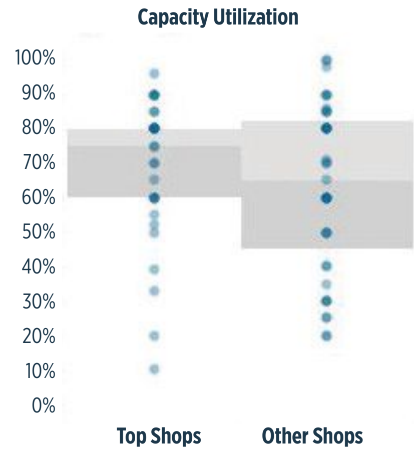
Composites manufacturing processes at surveyed facilities

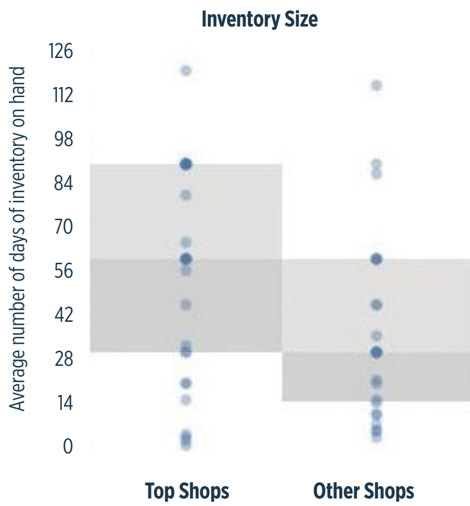
	Other Shops	Top Shops
Hand Layup	88%	81%
Infusion	51%	65%
Cutting/Kitting	55%	45%
Compression Molding	35%	52%
Resin Transfer Molding	49%	32%
Additive Manufacturing/3D Printing	35%	16%
Filament Winding	14%	26%
Pultrusion	8%	23%
Thermoforming	29%	10%
Sprayup	18%	10%
Injection Molding	14%	10%
Automated Tape Laying	8%	10%
Automated Fiber Placement	10%	6%

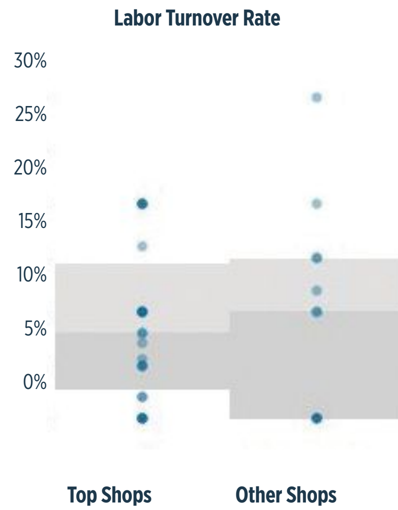
Shop type, industry for surveyed facilities

Shop Type	Top Shops	Other Shops
Contract Manufacturer	48%	31%
Design/ Engineering	7%	10%
Moldmaker	7%	4%
OEM	10%	22%
Sub-tier supplier	10%	6%
Tier supplier to OEMs	17%	27%

Industries Served	Top Shops	Other Shops
Aerospace, Commercial	42%	54%
Aerospace, General	29%	44%
Agriculture	13%	8%
Automotive	35%	27%
Construction/ Infrastructure	19%	17%
Consumer	23%	17%
Defense/Military	35%	46%
Industrial/Corro-sion resistance	35%	21%
Marine	39%	23%
Mass Transit	19%	17%
Medical	19%	15%
Oil and Gas	16%	15%
Sports and Recreation	26%	19%
Wind Energy	26%	10%







Interpreting the data

In each of the charts above, blue dots represent survey responses — the darker the blue, the more responses that were close to that value. The shaded area marks the 75th and 25th percentiles, where higher percentiles are better. The break in the shading represents the median value. The median is the value 'in the middle' when all values are ordered from lowest to highest. Median values can better represent 'middle of the pack' than averages, which can be skewed by even one extreme datapoint.

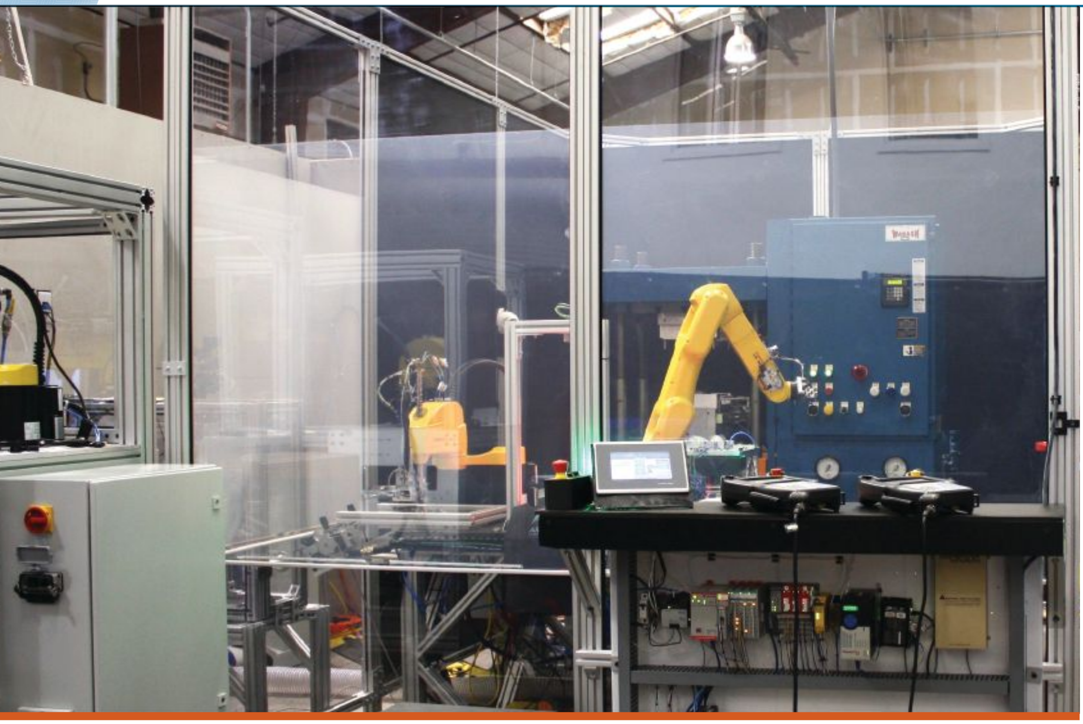
We then ranked each facility for each metric, which in turn gave us an overall ranking for each facility. The top 30 facilities (actually 31 as we had a tie) in our survey earned the Top Shops label, which we hope will become a highly coveted and respected badge of honor.

Included here is a sampling of CW Top Shops survey results, designed to give you a sense for the kind of data we collected, and where our respondents fell. Every facility that participates in the CW Top Shops survey gets a full, customized report that shows how the facility ranked against other respondents. If your facility did not participate, and if you would like to see the full results, you can purchase the CompositesWorld Benchmarking Standards Report at the Gardner Intelligence website (gardner-intelligence.com/report/top-shops). Cost is $395.

We encourage you to keep an eye out for the 2020 CW Top Shops survey, which will launch early next year. Look for an announcement in the *CW Today* newsletter, or send me a note at jeff@compositesworld.com and I will make sure you are on the distribution for the 2020 survey. Many thanks to everyone who participated in the inaugural CW Top Shops survey. CW

ABOUT THE AUTHOR

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



Robotic placement

In the Additive Molding process, prepregged tows and tapes are shaped, cut and placed in a mold cavity by proprietary robotic equipment.

Source, all images | Arris Composites

Additive Molding promises mass-produced high-performance composites

Arris Composites introduces a patent-pending technology that manufactures high-performance thermoplastic composite components with a combination of additive manufacturing technology and high-speed compression molding.

By Karen Mason / Contributing Writer

“Mass production” is a term not generally associated with complex composite components that feature continuous, aligned fiber reinforcement, yet composites technologists have long pursued this elusive combination. After all, the market potential is exceptionally large, especially in the automotive industry, for cost-efficient, high-volume, high-performance composite components.

With the exception of components pultruded into very simple profiles, this market potential has not been realized with today’s manufacturing technologies. Composites manufacturers either mass-produce complex composite components made with chopped fiber, or they use relatively low-volume fabrication technologies to make such components with continuous, oriented fiber reinforcement. Though maturing technologies like automated fiber placement (AFP) and continuous-fiber 3D printing are accelerating cycle times, they have not reached mass-production levels for complex high-performance composite components.

A recent effort to combine high performance and high volume, however, shows great promise to successfully bridge the gap. Newcomer Arris Composites (Berkeley, Calif., U.S.) caught the industrial world’s attention in May of this year when a *Forbes* article featured founder and CEO Ethan Escowitz. The article also covered the company’s announcement that it had closed $10 million in Series A funding — a strong endorsement of Arris’ trademarked and patent-pending Additive Molding process. Before this newsworthy event, Escowitz himself characterized the previous two years as “stealth work,” so it is only in the past few months that many composites stakeholders have started investigating and assessing the potential of Additive Molding.

High performance meets high volume

The vision for Additive Molding grew out of manufacturing innovation efforts in which two of Arris’ co-founders, Escowitz and Riley Reese, who is also chief technical officer, were involved. Escowitz and Reese worked on commercializing new 3D printing

■ Oriented fiber in complex shapes

Additive Molding is reportedly able to mass produce complex components in which the entire fiber volume is aligned along loading paths.

■ Fabricating complexity on a small scale

Arris Composites' trademarked Additive Molding process has the capacity to fabricate small, complex components.

applications across multiple employers. "The impact of 3D printing on high-volume manufacturing has a history of over-estimates," Escowitz argues, "and this is due to high process and finishing costs per unit produced, plus high material costs." (Though some 3D printers are finding ways to use commodity materials, many employ high-cost specialized materials.) The pair wanted to find a way to corral the performance benefits of 3D-printed continuous fiber-reinforced composites with the speed and cost benefits of molding technologies. Escowitz describes the idea as "aligned fiber-reinforced molding."

Believing that a hybrid technology could be developed for high-speed molding of aligned, continuous fiber-reinforced components, Escowitz set to work. He followed the classic inventor narrative — "tinkering with new technology in his Berkeley, California, garage," as *Forbes* described it. He anticipated that the technology could open the floodgates in the automotive and consumer goods »

■ **Truss optimization**

Arris Composites' demonstration truss is expected to outperform a conventional pultruded truss of the same cross-section because of its optimally aligned fiber reinforcement.

markets to wide adoption of complex, high-performance composites. Sure enough, before he had even incorporated Arris Composites, Escowitz received a purchase request from an undisclosed consumer products manufacturer. His work also caught the attention of former Autodesk CEO Carl Bass, who provided seed money, consulting and space in his personal manufacturing shop in Berkeley.

Bringing on Reese as well as mechanical engineer and startup veteran Erick Davidson (now Arris chief engineer and co-founder), Escowitz continued to advance the technology and capture the attention of a growing number of composites manufacturers and customers. In the process of securing the $10 million investment, the company and its technology were vetted by former GE CEO Jeff Immelt, who was duly impressed. "What we did in automotive to replace non-structural metal with low-cost, lightweight injection molded components in the 1980s, Arris has now enabled for the rest of the vehicle," he believes.

How it works

One key to Additive Molding is that it is vertically integrated from the point at which raw materials enter through the point at which the filled mold is ready for processing and on to demolding of the finished customer-ready parts. The process starts with dry carbon fiber tow, which is prepregged into both tape and tow form through an impregnation process. The prepreg tape may be flat, or it may be formed directly into the needed profile shape. Reese reports that Arris has in-house capability for prepreg tape production, and that a future development will make it possible to feed the tape (and tow) directly into the next manufacturing step. Currently, the company is using commercially available prepreg tape in widths of one to 24 inches, and feeding it to the next step from a spool.

Proprietary robotic equipment then shapes, cuts and places prepreg pieces into their final locations within the mold cavity. Once the prescribed prepreg is in place, the mold closes and applies heat and pressure to the composite materials for consolidation and cure. "The mechanism for placing material is different than the mechanism used in automated tape layup and 3D printing processes," Reese notes. "We are shaping the prepregs as opposed to consolidating and bonding them in-situ. As a result, our preforming process can run at incredible speeds."

One of the major advantages of 3D printing — the ability to place fiber at any orientation in three-dimensional space — is also true of Additive Molding. "We are bringing together the benefits of three disparate technologies for the first time," Reese explains, "the design latitude of 3D printing, the performance of aerospace composites, and the cost and speed of molding."

Escowitz describes the challenge that Additive Molding addresses as "scaling novel parts without the cost of traditional aligned fiber composites." The technology, he asserts, creates structures in which "the entire volume of fiber is running along the mechanical loading pathways you desire and reinforcing where the properties are needed. We can align fibers in a way that no one else can at high production volumes." This includes some of the rapid preforming methods recently developed, which he says require more capital equipment and cutting and consolidating time than Additive Molding does, and do not provide the level of fiber alignment that the Arris process does.

Reese continues, "By forming the shapes in our additive step, we are running the fiber paths around features, instead of cutting it out to fit around those features." By

+ LEARN MORE

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

Read more about continuous-fiber 3D printing | short.compositesworld.com/con-fib-3D eliminating this cutting step, Additive Molding generates less scrap than other processes, contributing significantly to economies of scale in high-volume production applications.

Escowitz and Reese hesitate to say just how much faster Additive Molding is compared to traditional fabrication techniques, but they expect the technology to deliver composite components at a cost that is an order of magnitude less than would be incurred with an existing manufacturing method. Reese notes that molding time is the rate-limiting step in their process — not layup. "We configure the additive portion to deliver the layup at the optimal moment for the mold cycle time," he adds.

Escowitz points out that, with high-volume applications of aligned, high-performance composites, "It's not the material cost; it's the process costs" that have kept such composite materials out of consideration. Capital cost per unit is anticipated to be extremely low for aligned composite structures made with Additive Molding — low enough to make the parts cost-competitive with parts they would replace, while offering much higher performance than those parts.

2020 production runs

An Arris demonstration truss highlights the added value of fully aligned reinforcement (see image on p. 24). "If you look at the cross-section of our truss compared to a similar pultruded shape of the same cross-sectional area, the entire volume of material in our truss is optimally aligned to support the beam's load, helping it substantially outperform the pultruded shape," Escowitz notes. "It is the same amount of material in both, but complexity unlocks performance in ours."

Arris expects to begin high-volume production runs in 2020 on some of the parts for which it has been producing test articles this year. Asked about potential sales of Additive Molding systems to other composites manufacturers, Reese reports that the company will manufacture parts itself and plans to keep the technology in-house for the next couple of years. Escowitz characterizes the timing of Arris' technology launch as "serendipitous. The last decade of 3D printing has seeded the design and engineering community with concepts for lightweight structures that require optimally aligned fibers. And if a company needs to produce a high volume of those lightweight structures — that's where we come in." 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

3D printing continuous fiber on the desktop

Additive manufacturing technology company expands offerings to include high-performance composites.

By **Scott Francis** / Senior Editor

Composite 3D printing on the desktop

Desktop Metal's Make continuous fiber 3D printing system brings high-performance composites onto the desktop.

Source, all images | Desktop Metal

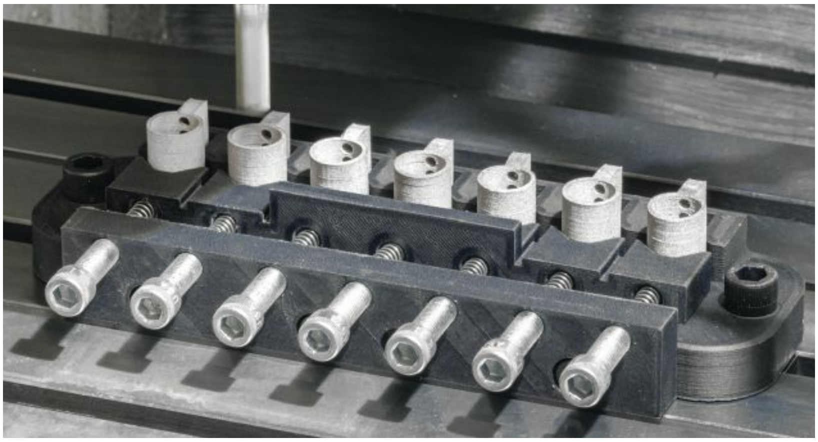
» Desktop Metal (Burlington, Mass., U.S.), a company that specializes in metal 3D printing for product development and mass production, has announced it will expand its technology to include the composites community. Desktop Metal was founded in 2015 with a mission "to make 3D printing accessible for all engineers, designers and manufacturers," and since then the company has brought two 3D printing technologies to market — its office-friendly metal 3D printing Studio System and its high-volume Production System metal 3D printer, which is capable of printing speeds up to 12,000 cm^3/hr. Now, the company is unveiling what it says is the world's first true continuous fiber desktop printer.

"We are now expanding our offering to bring continuous fiber 3D printing to the desktop of every engineer and designer," says Ric Fulop, CEO and founder of Desktop Metal.

Recent advances in additive manufacturing have seen its use become increasingly widespread for prototyping, as well as for jigs, fixtures and tooling. Desktop Metal predicts the technology will experience 10-50 times growth over the next decade as a means for manufacturing end-use parts. The company recognized an opportunity in the market to bring 3D printing to an underserved area — the automation of small composite parts manufacturing. Kicking off its entry into the composites sector, Desktop Metal recently acquired Make Composites Inc. (Boston, Mass., U.S.), a startup company founded by Konstantine Fetfatsidis. Fetfatsidis was recently named 2019 SAMPE Young Professional of the Year and served previously as the advanced manufacturing R&D lead at Aurora Flight Sciences (Manassas, Va., U.S.), a Boeing company.

Fetfatsidis, now vice president of composites products for Desktop Metal, explains his inspiration for starting Make. "Based on my experience in composites R&D and also in aerostructures business development dealing with customers, I got to see and work with what was accessible and the various manufacturing technologies available, and frankly got a little bit frustrated with hand layup still being state-of-the-art, particularly for the smaller parts," he says.

He argues that for small parts — less than 20 pounds — manufacturers still rely primarily on hand layup. Such labor-intensive processes require technicians, expensive tooling and a lot of time, all of which increase the overall cost of manufacturing a part.



Optimizing machining fixture manufacture

By 3D printing this CNC fixture as a continuous fiber composite on the Make system, the part can be made extremely stiff, allowing the lock barrels to be held firmly in place while the machining operations are performed. Carbon fiber tape can be selectively laid to add stiffness in sections of the fixture that experience the highest loading. Machining fixtures often need to endure extreme temperatures and using a carbon fiber-reinforced PEEK ensures stability at high temperatures. By 3D printing on the new Make system, machine shop engineers will be able to use an optimized fixture design that would have otherwise been too time-consuming and expensive to machine.

"Throughout my career there have been so many applications where we'd have loved to use carbon fiber — particularly at Aurora while working on eVTOL concepts — for its lightweight properties, stiffness and the strength, but the costs just didn't add up," says Fetfatsidis. "I thought to myself, there's got to be a better way to automate, consolidate the number of process steps involved in traditional manufacturing, reduce tooling and reduce lead times — all the costs associated with it."

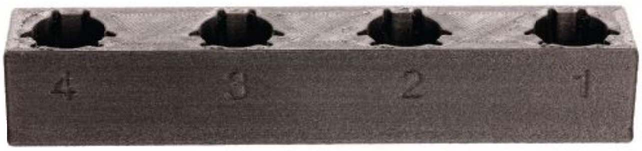
While attempts have been made to automate the manufacture of small composite parts, the properties rarely reach the quality that industrial users are accustomed to with hand layup, and certainly not in a desktop process. In most composites 3D printing today, the resins are often not the same as those used in traditional processes, and many printers use proprietary materials that do not offer the same high performance as qualified materials, leading to non-uniformity and variability in quality. Resulting parts typically have lower fiber volume content and higher porosity than parts manufactured by hand.

"Really there has been no end-to-end solution to do this on a desktop level with the materials that folks are used to using, until now," says Fulop. "We're combining the benefits of 3D printing with continuous fiber materials that are qualified for high-performance applications."

Based on tapes

Desktop Metal's new desktop printer adopts automated fiber placement (AFP) technology to produce high-quality fiber-reinforced thermoplastic composite parts. The technology leverages the same manufacturing lines that make commercial prepreg tapes, thus tapping into an existing supply chain and taking advantage of the growth already happening in the unidirectional (UD) tapes market. In essence, the technology takes AFP and scales it down for a desktop printer. In fact, the company derives its solution's name from Micro AFP Kinematic Extrusion system (Make).

The Make printer is designed as a modular tool changing system for use in an office or production floor environment and is capable of delivering industrial-grade »



Stiffer, stronger, lighter, faster

The Make system enables parts to be made stiffer, stronger and lighter than if printed with other materials. Quick print time and low material costs allow the designer to iterate quickly on the design to achieve an optimal part. Shown here are an electrostatic discharge (ESD)-safe end effector (bottom) used during the manufacturing process of printed circuit boards (PCB), a lightweight camera mount (middle) and a shroud load holder (top) used in the machining of metal injection molded (MIM) components.

manufacturing jigs, jaws, tools and fixtures, as well as end-use parts. The operator can use a Micro AFP head to lay out material, then park it and switch to a fused filament fabrication (FFF) head as needed.

The technology uses the same UD tapes qualified for high-performance applications. While the printer is capable of processing UD tapes with a wide variety of fiber and thermoplastic matrix systems, the materials available initially for Make will include polyamide 6 (PA6) with carbon fiber and glass fiber reinforcements, as well as polyetheretherketone (PEEK) and polyetherketonketone (PEKK) with carbon fiber reinforcement. The tapes, offered in a 3-millimeter-wide format, typically feature 6K-12K tow fibers and are spooled on proprietary reels. A single 3-millimeter-wide tow is fed through the head until it gets down to the nip region, where a non-contact heater elevates the temperature of the thermoplastic above its melt temperature, and a compaction roller applies pressure for consolidation of the incoming tape to the substrate beneath. A cutter in the head cuts the tape at the end of each pass. According to Fetfatsidis, the tapes offer a solution that is higher quality but more than 10 times less expensive on a per-liter basis than a spool of 1K tow filament used in some of the extrusion-based, continuous-fiber 3D printers. Plus, the higher quality of the tapes coupled with the ability to add pressure to the part through the AFP process translates to higher strength.

"We have high-quality tapes that are used in AFP/ATL processes with high fiber volume loading — 55% carbon fiber — and we put that together with PEEK or PEKK high-temp matrix," says Fetfatsidis.

Parts created with the Make system are said to be stronger than steel, lighter than aluminum and can be printed on the desktop. Make has a build volume of 320 by 240 by 280 millimeters (12.6 by 9.4 by 11 inches). Benefits include continuous fiber reinforcement throughout the entire part and very low porosity. Fetfatsidis says parts created with PA6 tapes have less than 4% porosity and PEEK/PEKK tapes yield parts with less than 1% porosity. The operator has the ability to steer tows to achieve complex shapes or particular load conditions. And because the resins are thermoplastics, the need for an autoclave cure is eliminated, as well as the need for storing the material in a freezer.

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"This is very much the first product in the 3D printing realm that combines continuous carbon fiber with really high-performance thermoplastics in a desktop," says Fulop.

Accessible for everyone

While Desktop Metal's solution boasts several benefits including the ability to create end-use parts and the use of thermoplastics, arguably one of the most exciting aspects of Make is its affordability. Most systems that use continuous fiber for the automated manufacture of composite parts are million-dollar systems. Desktop Metal's solution offers an automated process in an affordable solution that is easy to use with materials that are industry qualified. The company expects Make solutions to start at $3,000 per year.

"We want people to be able to buy the system, have it at their desktop at their home or office and make PEEK parts with continuous fiber," says Fetfatsidis.

"For a few thousand dollars you can start making composite parts with high performance made out of the same tape technology that's now used in really high-end AFP-manufactured parts," adds Fulop.

As 3D printing's role in manufacturing continues to grow, designers and engineers need solutions that enable a wide range of materials to be accessible. Make is a big step forward toward putting high-performance composite materials within reach of anyone who wants to take advantage of the light weight, strength and stiffness that composites offer. Desktop Metal will showcase the system at Formnext 2019 exhibition and conference, Nov. 19-22 in Frankfurt, Germany. CW

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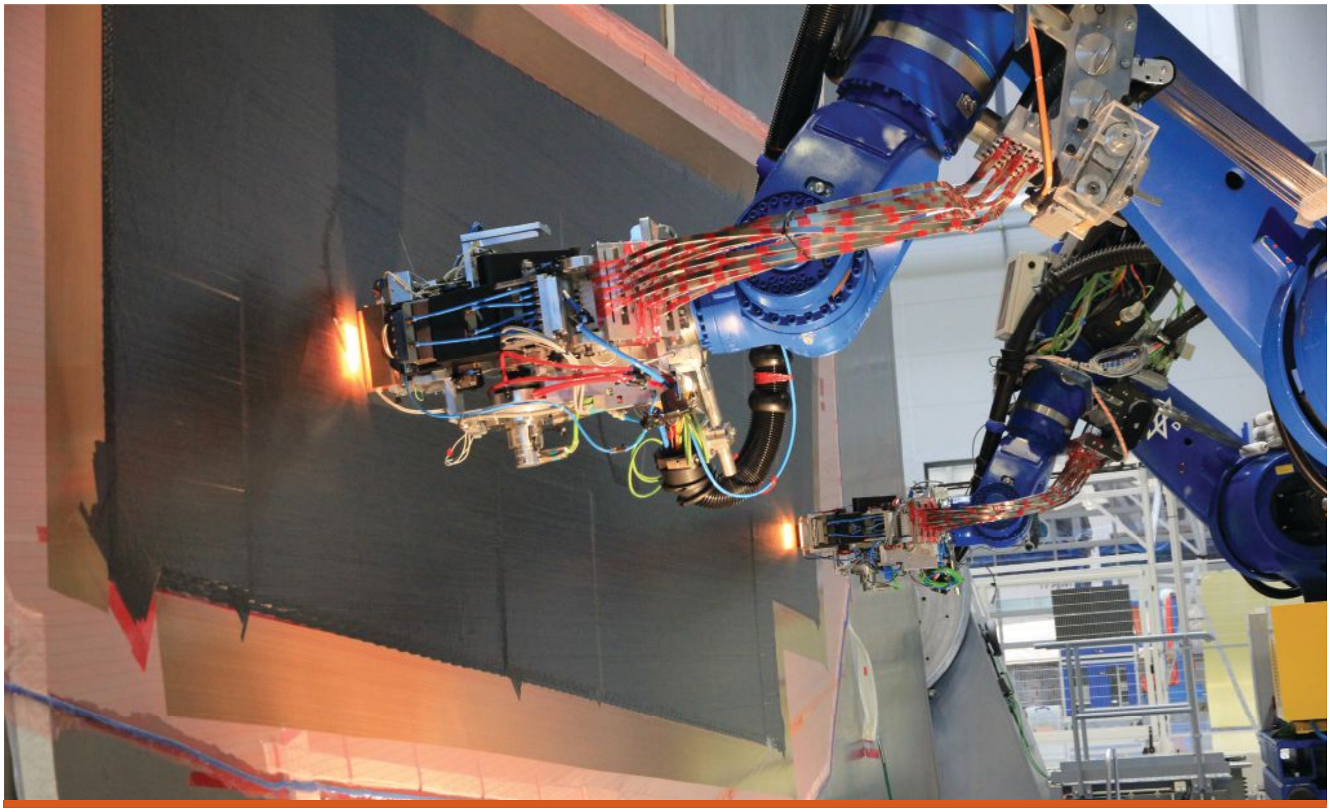
Scott Francis, senior editor for *CompositesWorld*, has worked in publishing and media since 2001. He's edited for numerous publications including *Writer's Digest*, *HOW* and *Popular Woodworking*.



Modular, mobile, multiple robotics poised to change the AFP/ATL paradigm

The German Aerospace Center (DLR) is working on two multi-robot automated fiber and tape placement technologies that could change the paradigm in large-part aerocomposites manufacturing.

By Jeff Sloan / Editor-in-Chief

Multi-robot AFP/ATL

The German Aerospace Center (DLR) has developed GroFi, a multi-robot AFP/ATL manufacturing cell that aims to increase fabrication speed and efficiency for large aerospace composite parts. Source, all images | DLR

» The current state of the art in automated fiber placement (AFP) and automated tape laying (ATL) of composite wings for commercial aircraft is based on a manufacturing model that assumes a mold oriented horizontally on a manufacturing floor, with a single AFP or ATL head acting on the mold from above, usually suspended by a gantry system.

Although this technology enabled the broader adoption of carbon fiber composites in aerostructures on the Boeing 787 and the Airbus A350, it likely is not sustainable for future aerocomposites manufacturing — particularly if, as expected, monthly deliveries for a next-generation single-aisle aircraft approach 100 shipsets. First, a horizontally oriented wing skin mold consumes much valuable footprint on the production floor. Second, AFP and ATL machines acting singly and serially are inherently inefficient.

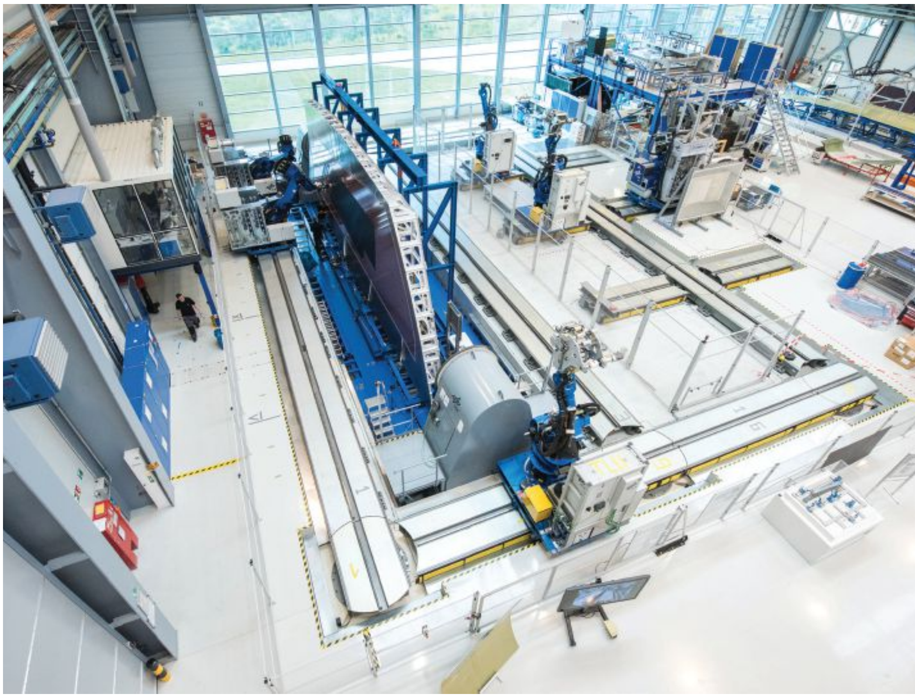
The solution to this problem is being explored by the German Aerospace Center (DLR, Stade, Germany) via its GroFi project, which launched in 2010 to develop technologies for high-rate, large-structure aerocomposites manufacturing. Christian Krombholz, research associate at DLR and coordinator of the GroFi project, says the technology has evolved to make two major changes in the AFP/ATL manufacturing strategy. In the first, the mold has been moved from its horizontal orientation and placed vertically on its edge. For the second change, AFP and ATL end effectors have been removed from the gantry, placed on multi-axis robots and multiplied. It is this multiplication of AFP/ATL machines that holds the most promise for making wing fabrication faster, more efficient and therefore more economic.

Krombholz says a wing skin fabrication cell, under the GroFi model constructed at DLR, comprises a vertically oriented wing skin mold surrounded by a linear axis and turntables on which the robot units operate to place tapes and tows. Each robot unit includes the AFP/ATL head, the multi-axis robot itself, and a creel carrier that houses the carbon fiber tapes or tows. The multi-robot approach means that tapes and tows of varying quantities and widths can be deployed simultaneously, thereby increasing manufacturing capability and flexibility. To date, the GroFi system has evaluated AFP/ATL heads from Fives Cincinnati (Hebron, Ky., U.S.), Coriolis (Queven, France) and Broetje Automation (Rastede, Germany).

In the GroFi cell DLR has constructed, five robots are available to work on any part of the mold simultaneously, moving around the molds on electrified tracks that obviate the need for cumbersome cabling. Depending on how many robots are working together on building up the laminate, the rest of the five robots are kept in ready-reserve to step in if a production robot needs replacement for lack of material, maintenance, malfunction, etc. Given the one-sided mold that DLR has deployed in GroFi, it is not difficult to imagine an even more complex and efficient cell, perhaps comprising multiple two-sided molds, with robots moving around and between each one to apply material.

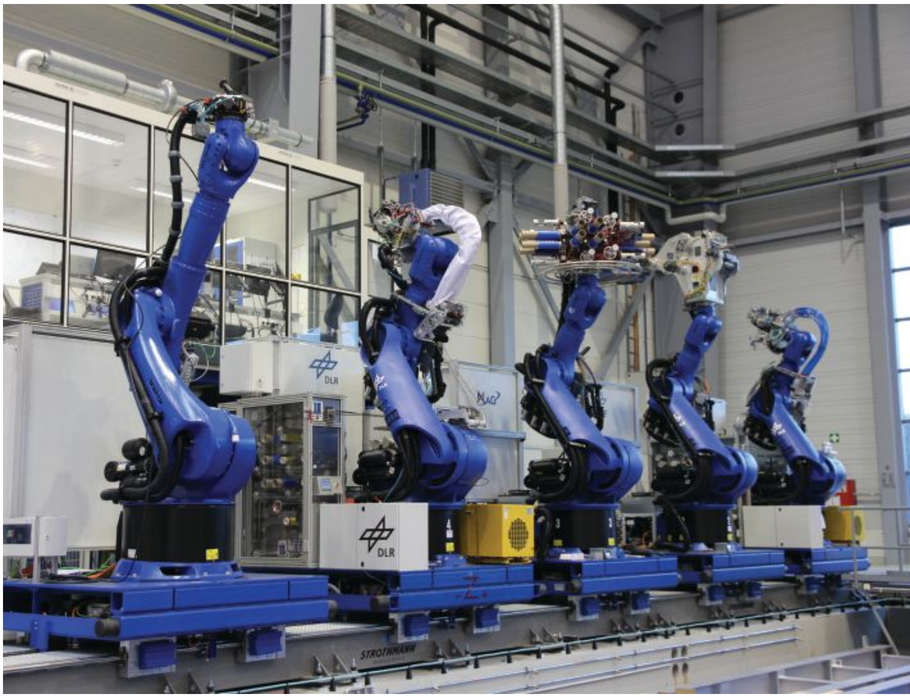
However, just the deployment of multiple robots creates hurdles heretofore not encountered in composites manufacturing. “The challenge with this,” says Krombholz, “is developing the algorithms and software to program the robots.” This is not just a matter of making sure that each robot knows where it is in space relative to the other robots (and the mold) so as to avoid collision. Each robot also must work cooperatively with the others to place the correct material — tapes or tows — in the right place at the right time.

Krombholz says DLR has developed an algorithm that splits the laying operation between »



Vertical orientation, multi-axis robots

The GroFi system orients molds vertically and allows multi-axis AFP/ATL robots to move around the mold on electrified tracks. The robots work cooperatively to place material on the mold surface.



Robots on ready-reserve

A GroFi cell includes a total of five multi-axis robots, which allows for placement of tapes or tows in a variety of quantities and widths. Up to four robots would be in production at one time, with the fifth in ready-reserve as needed.

several robots on the same guide rail and optimizes scheduling. "The algorithm determines which robot performs which course most efficiently, taking into consideration geometric dependencies, approach paths and collision avoidance on the fly," he says. "Path control, correction and quality control are implemented online for the production of aircraft-certified structures. This marks a huge step towards redundancy and robustness in production while speeding up the process using the given manufacturing infrastructure."

The level of programming, algorithm development and machine learning required for such a system is possibly without precedent in the composites industry and represents one of the biggest hurdles the GroFi program faces. Still, the potential benefits GroFi might convey to a commercial wing fabrication program are obvious, and not lost on the likes of a large commercial aircraft manufacturer, which is evaluating the technology to increase productivity of existing AFP / ATL plants. Meanwhile, GroFi has also stimulated more out-of-the-box thinking at DLR — a derivation of the multi-robot model.

From GroFi to Flappybot

Philipp Sämann, Dominik Delisle and Andreas Kolbe, research associates at DLR, looked at the GroFi cell and struck upon an idea that was first suggested somewhat jokingly: What if we put the mold back in its traditional horizontal position, kept the multiple AFP/ATL robots, but made them smaller and put them on wheels?

This technology, which is still in the early stages of development at DLR, is currently codenamed Flappybot (flexible autonomous production placement assembly robot); it takes all of the equipment and functionality of a fiber or tape placement system and encapsulates it in a modular, three-roller, self-driven, programmable, wireless robot that drives *on* the mold to place fiber and tape in the fabrication of a composite structure. It rides on three independently driven rollers and houses a sufficient number of spools of carbon fiber tape or tows for a laying width of 200 millimeters.

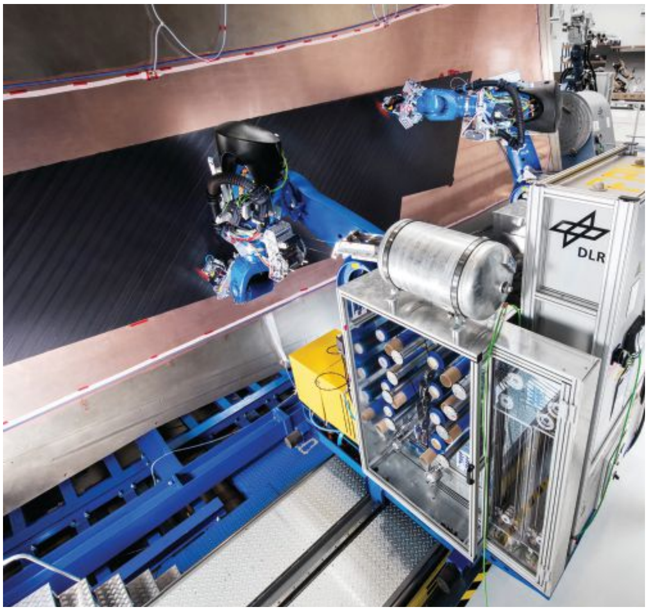
Sämann, coordinator of this technology, and his team pursued development of Flappybot and brought a mockup to JEC World 2019 in March. To reveal the concept at an early stage aims to assess market interest and to find out how the system might be evolved, modified and improved. "We had a lot of people at our stand looking at Flappybot," Sämann says, noting that it acquired the nickname "AFP Crawler" among show attendees. "Many people see the potential," he says.

Conceptually, the biggest hurdle to clear when thinking about Flappybot is just the very idea of a robot *driving* on a mold — driving on a laminate. It's not only counter-intuitive, but it introduces a host of process control and quality concerns. DLR built a testing rig to investigate quality issues. Laminates of different thicknesses were built by conventional AFP systems; those laminates were rolled over several times with driven rollers to assess critical pressure, driving torque and wheel spin. Those laminates were then autoclave cured and tested. "We did not find that any harm was done to mechanical properties from Flappybot driving on the mold," Sämann notes.

Because of this, he says concerns were raised about Flappybot possibly breaking fibers or causing fiber misalignment. Further, there was anxiety about the rollers sticking to and "grabbing" prepreg that has already been placed. The team attempted to mitigate these risks by employing rollers that broadly distribute the mass of Flappybot. And the material used to make the rollers — rubber-coated steel — also helped reduce the propensity for sticking.

It gets complicated

Even if driving a massive robot on a mold is viable, there are other factors to consider, and most of these, as with GroFi, revolve around software and programming, says Sämann. First, DLR's goal with Flappybot is to develop a solution that is cost-competitive with large ATL systems, particularly those used for commercial aircraft wing manufacture. Because of this, a »



Developing algorithms for use

The challenge of operating multiple robots is development of algorithms that coordinate robot behavior. Each robot must place the correct material in the correct place at the right time, and avoid collision with the other robots it's working with. This system is targeted toward production of next-generation, single-aisle commercial aircraft wings.

Introducing Flappybot

Growing out of the GroFi project at DLR is Flappybot, a three-roller, autonomous, modular AFP/ATL machine designed to drive on the mold. Like GroFi, DLR envisions deploying multiple Flappybots simultaneously on a mold for the manufacture of large commercial aerostructures.

large aerostructure would require multiple Flappybots working cooperatively. Sämann says DLR's calculation tools determine the most efficient density of Flappybots per machining area. Given the size of a wing skin for long-haul aircraft, it would — depending on the exact configuration — take up to five units working simultaneously.

"Generating the paths (NC) that determine where the tows are placed, when and where they have to be cut, etc., is just the same as any other gantry system or articulated robot uses," Sämann says. "It just depends on the design of the laminate. In the case of Flappybot, the software has to perform a precise path control because we have no guidance kinematics."

However, thinking about five Flappybots working together on a wing, there is the distinct possibility of collision. "Crashing two massive units is something to avoid at any cost," Sämann quips. As a result, his team is developing software and programming that allow for build priorities, build safety standards, tow/tape prioritization, dependencies and safety margins. This would include the use of onboard sensors to maintain safe distance from other Flappybots, along with governors to reduce speed within a given robot-to-robot distance.

"Our system is designed to decide over and over again which robot lays which tow, considering geometric dependencies in between tows and other boundary conditions such as collision prevention," Sämann says. "The target is efficiency. The benefit is speed. Multiple robots cooperate while working on the same ply."

Second, there is the matter of "referencing" — that is, making sure the Flappybot knows where it is on a mold. DLR is evaluating several solutions, says Sämann, including acoustic, optical, laser, induction and more. The technology chosen will likely come down to cost. In any case, there are two referencing strategy options. The first, and least complicated, is to develop a system that just tells Flappybot where it is on a particular mold. However, the most elegant solution, says Sämann, would be to reference Flappybot's location on the mold *and* in three-dimensional space (i.e., the manufacturing space).

Third, there is the matter of the rollers themselves, which, if not well controlled, could devolve to non-synchronous rotation, resulting in displaced or damaged fibers. "We want permanent all-roller drive," Sämann says. "It makes it more challenging because we have no mechanical differential adapting each roller's rotational speed when driving curves." The software of the drivetrain, therefore, must calculate the real time rotational speed and direction of each roller to prevent wheelspin and displacement of fibers. That makes coding the drivetrain more extensive than just operating one roller.

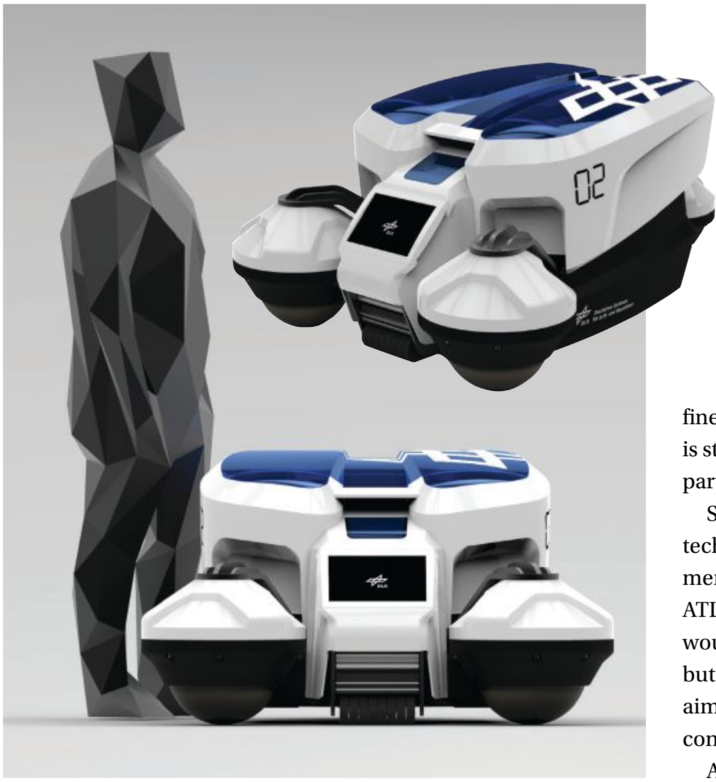
DLR envisions eventual use of a simulation-based programming environment for Flappybot, similar to that used for current AFP/ATL systems. "This is where the process parameters are defined and translated to NC codes the machines/robots understand," Sämann says.

There are other practical matters to consider as well. Chief among them is how Flappybot will be powered. Sämann notes that fiber placement requires heating of tows while laying them. A sufficiently large bank of batteries that enables extended use is heavy and bulky, thus DLR is evaluating in-situ contactless charging on the mold beside the laminate. Whatever solution will be selected, the energy capacity on board will not be the limiting factor when it comes to upscaling the part size.

And how would Flappybot behave when it runs out of fiber or tape? "The units need to track the current amount of material per spool on board," Sämann says. "In case of running out of material during the next tow, or if there is an irregularity, it needs to go to a service station near the mold and communicate its absence to the other units." At the service station, an operator would change the spool.

Where do we go from here?

Flappybot is not on the market, and probably needs a couple more years of developmental work before it can be commercialized. Sämann says that programming, in particular, must be evolved, »



Coordinating multiple robots

The programming and algorithm lessons being learned on GroFi have application for Flappybot as well. DLR says wing skin fabrication would require five Flappybots working simultaneously, so collision avoidance, material sequencing and other coordination will be critical. DLR says Flappybot weighs in at 350 kilograms, and the weight is needed to provide the compaction pressure AFP and ATL require. However, driving such a massive vehicle on a mold poses challenges. In early testing, however, DLR says the weight of the vehicle and the rollers it rides on do not degrade finished part quality.

fine-tuned and tested extensively. The cost and scope of this work is still being determined, and DLR is actively seeking industrial partners to help it progress the development work it has begun.

Sämann's group is also working on fiber/tape placement head technology, as well as fiber and tape width options. The placement head, he says, would ideally come from an existing AFP/ATL equipment manufacturer to keep costs down. Width options would depend on the application and the processed material, but could range from less than 1 inch to more than 1 inch. "The aim is a plug-and-play solution for the layup head and the spool containers," he says.

And, despite all the talk of AFP/ATL for aerostructures manufacture, Sämann says aerospace fabrication — because of qualification requirements — may not be a good starting point for Flappybot. He points to sailmaking (for racing yachts), architectural panels (for stadiums, bridges) and automotive battery covers as good initial targets. He envisions the possibility of Flappybot being deployed on-site to build highly customized composite structures that can be immediately installed. Flappybot could also be adapted for non-AFP/ATL work, including in-process or nondestructive inspection. In any case, Sämann notes, "It might be smarter to go for other applications first, which require lower payloads and energy consumption, to develop referencing, modeling, programming." CW

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Digital cutting system speeds business jet parts fabrication

Pilatus Aircraft AG cites its use of Zünd digital cutting systems as part of the success story for several iterations of commercial aircraft.

Thanks to carbon and glass fiber components, the *PC-24* business jet, manufactured by Pilatus Aircraft AG (Stans, Switzerland), boasts a base weight of only 5.3 tons (less than 12,000 pounds), which helps it take off and land on short, unpaved or gravel runways. In fact, the *PC-24* is capable of taking off on a runway as short as 890 meters (2,920 feet) and only requires 720 meters (2,362.2 feet) for landing.

Pilatus began using composite parts early on in its history of manufacturing airplanes, starting with its first carbon fiber-reinforced plastic (CFRP) and glass fiber-reinforced plastic (GFRP) components for the *PC-6* Porter metal universal aircraft. The few composite components on the *PC-6* were laid up by hand, necessitating an experienced workforce and high tolerances for parts. The company's latest aircraft type, the *PC-24*, uses composites for interior and exterior cladding, engine casings and wingtips, landing gear doors, air ducts, various pipes, covers and trailing edges on the wings. Not only does the *PC-24* include more composite components than the *PC-6* did, but assembly is much faster, made possible, Pilatus says, because of advances in production technologies, including digital prepreg cutting systems. For this, Pilatus has relied on Zünd (Altstätten, Switzerland) cutting systems for years, and in 2019 added a Zünd G3 L-2500 system, which cuts single-ply materials for the respective components in an automated process, and then labels cut pieces with an integrated inkjet module.

Source | Zünd

Pilatus processes about five rolls of prepreg per day (approximately 90 square meters), or about 90,000 square meters per year, with the rate of consumption steadily increasing as more and more CFRP and GFRP components are used on the company's planes. Pilatus composite structures can consist of up to 350 plies of prepreg.

Another factor in Pilatus' success has been a focus on increasing material utilization, thereby reducing waste. The company says it has reduced waste rates from 30% to 20%, and it cites the efficient nesting features in Zünd's Cut Center - ZCC software as an important factor in this success. In this process, the plies of a part are statically nested, which means one part's individual plies are nested in the requested quantity. Dynamic nesting, where individual plies of parts from multiple orders are nested and combined in a single cut file, is also available.

"When dealing with cost-intensive materials such as carbon or glass fiber, material efficiency and optimization are always a concern. We are constantly working to increase utilization and thereby reduce waste — particularly since we still have few options for recycling," says Patrick Rohrer, Pilatus' project manager of system procurement. CW

Composites Events

Nov. 5-7, 2019 — Farnborough, U.K.
Vertical Flight Expo and Conference
verticalflightexpo.com

Nov. 6, 2019 — Bristol, U.K.
NCC Discover: Composite Overmoulding 2019
nccuk.com

Nov. 7-8, 2019 — Krakow, Poland
Chemistry and Automotive 2019
chemiaimotoryzacja.pl

Nov. 12-13, 2019 — Washington, D.C., U.S.
ACMA Transportation and Defense Policy Fly-In
acmanet.org

Nov. 13-14, 2019 — Düsseldorf, Germany
European Thermoplastic Compounding Summit
wplgroup.com/aci/event/the-european-thermoplastic-compounding-summit/

Nov. 13-15, 2019 — Seoul, Korea
JEC Asia 2019
jec-asia.events

Nov. 14-15, 2019 — Cologne, Germany
Biocomposites Conference Cologne
biocompositescc.com

Nov. 19-21, 2019 — Carlsbad, Calif., U.S.
AWEA Clean Energy Executive Summit
awea.org/conferences

Nov. 19-21, 2019 — Amsterdam, Netherlands
METSTRADE Show
metstrade.com

Nov. 19-21, 2019 — Knoxville, Tenn., U.S.
CW Carbon Fiber 2019
carbonfiberevent.com

Nov. 20-21, 2019 — Vienna, Austria
Composites in Building & Infrastructure Summit
volanthengroup.com/en/events

Nov. 20-21, 2019 — Houston, Texas, U.S.
SpaceCom
spacecomexpo.com

Nov. 20-22, 2019 — Mumbai, India
World of Composites at Techtextil India
techtextil-india.in.messefrankfurt.com

Nov. 26-28, 2019 — Copenhagen, Denmark
WindEurope Offshore 2019
windeurope.com/offshore2019

Nov. 26-29, 2019 — Shanghai, China
Carbontech — 4th International Carbon Materials Conference
carbonconf.com

Nov. 28-29, 2019 — Istanbul, Turkey
Eurasian Composites Show
eurasiancomposites.com

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

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

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

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

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

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

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

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

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

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

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

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Richard G. Kline, Jr., President

New Products

» METERING MACHINES

PUR metering systems

RimStar. Source | KraussMaffei

KraussMaffei's (Munich, Germany) EcoStar Compact, RimStar Smart, RimStar and RimStar Plus polyurethane (PUR) mixing and metering machines are said to support digitization in foam production while offering customized options.

EcoStar Compact provides metering technology for pump sizes between 4 and 40 liters. Designed for laboratory or production use, the series features a Siemens KTP400 control panel, a metering pump with optional closed-loop technology for continuous optimum flow rate, and self-cleaning linear and deflection mixing heads for homogeneous mixing of reaction components.

In the RimStar series, customers can choose between standardized RimStar and RimStar Smart solutions, or assemble a customized RimStar Plus mixing and metering machine. The RimStar Smart offers equipment features for efficient series production of PUR components in Industry 4.0 production environments. Siemens TP 700 operating panels and volume flow meters (VC) are provided as standard and form the basis for the optional closed-loop control of the pour rate at shot time. The interface connects plant technology and automation, if required, and an additional RFID interface for mold recognition is said to increase efficiency. A pentane kit can be added as an optional feature.

Options for RimStar machines include multi-position metering, as well as a range of mixing heads for up to six components. Equipment options include sensor-controlled oil cooling for the mixing head hydraulics, gas and propellant loading, color aggregates and mixing heads with controlled nozzle technology. System interfaces enable integration into automated systems. RimStar is controlled by a TP-HMI from Siemens, with an optional PUC08 from KraussMaffei including production data acquisition. RimStar machines are set up for process data acquisition and evaluation using DataXplorer, which provides a basis for process documentation and optimization using Industry 4.0 automation.

kraussmaffei.com

» MOLDMAKING MATERIALS & EQUIPMENT

Benzoxazine tooling prepreg

SHD Composite Materials Inc.'s (Mooresville, N.C., U.S.) benzoxazine tooling prepreg (BX180-220) has been designed for large, high-temperature aerospace tooling applications that require temperature stability, long outlife and tool durability. The company says the material can be supplied in one of a variety of fabric options to meet cost and manufacturing requirements. BX180-220's low tack is said to provide optimal handleability in warm conditions, and it has a work life of one year at 70°F and a cure temperature of 360°F.

SHD Composite Materials Inc. manufactures advanced composite prepreg materials for a range of applications, offering the same tooling and component prepreg products available from SHD Composite Materials Ltd. in the U.S. **shdcomposites.com**

» THERMOPLASTIC SOLUTIONS

Carbon fiber/polypropylene unidirectional tapes

Mitsui Chemicals (Tokyo, Japan) has introduced TAFNEX PP-CF UD, a unidirectional carbon fiber/polypropylene tape available in widths of 12 to 600 mm in lengths up to 600 m per spool, with a fiber volume content of 40-50%. The company says the polypropylene matrix provides optimal processibility, low moisture absorption and fast processing, as well as relatively low cost and reyclability. TAFNEX PP-CF UD can be used with various manufacturing processes, including automated tape laying (ATL), winding and injection molding. Tapes can also be used to produce sheets or tailored blanks for further processing. The material has been used in automotive liftgate and front bumper beam applications, and to form reshapable thermoplastic tubes.

eu.mitsuichem.com

Source | Airtech

» FASTENING/WORKHOLDING

Pressure-sensitive tape

Airtech's (Huntington Beach, Calif., U.S.) Wrightlease4 is an extruded fluoropolymer film coated with silicone pressure-sensitive adhesive. The orange color is highly visible on most substrates and is said to offer high elongation and tensile strength.

Benefits to using the tape reportedly include optimal release from common resin systems for multiple releases; good adhesion to metal, composite, tooling block and rubber tooling; and easy covering of complex contour surfaces due to high elongation. airtechonline.com

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■ High-volume production possibilities

Because it is a thermoplastic, Maezio can be thermoformed at high yield rates, shorter cycle times and lower costs. Source | Covestro

Tuning the running shoe

Continuous fiber-reinforced thermoplastic composites enable high-performance athletic shoe components.

By **Scott Francis** / Senior Editor

» When approaching the design for an athletic shoe — or for sports equipment in general — performance is key. Numerous factors make up a performance shoe, and the requirements vary by shoe function; running shoes have different requirements than basketball shoes, for example. Running shoes are light and flexible and designed to cushion and stabilize for a long run, while basketball shoes are designed to provide ankle stability and absorb shock during sudden changes in direction. How a running shoe allows a runner to land and push off for each step is a subject of constant evaluation for engineers as new technologies emerge. High-performance materials such as carbon fiber can help provide stiffness without adding a lot of weight in such parts of a shoe as the midsole, toe kick and shank (a supportive structure in the shoe that runs beneath the arch of the foot).

Chinese sportswear startup Bmai (Beijing, China) had the goal of making a high-performance marathon shoe at a price that everyday consumers can afford, but it wanted to take advantage of carbon fiber's light weight and stiffness.

"One of the key drivers for footwear innovation is new materials," says Axis Liu, lead designer for Bmai. "Material technologies have advanced by leaps and bounds in the past one or two decades. There are now a plethora of materials to choose from, but lighter weight materials that provide better support, stability and performance are increasingly sought after as brands rely on them to increase their competitive advantages."

Carbon fiber has been used in high-performance footwear since the 1990s, with footwear brands such as Nike and Adidas adopting it for elite athletic shoes.

DESIGN RESULTS **Continuous fiber-reinforced thermoplastic composite shank for running shoe**

- 1-1.2-millimeter-thick shank achieves desired weight while being strong enough to meet torsion requirements
- Fiber orientation optimized to enable high stability of the shank for torsion
- Compatible for adhesion with other shoe components

Susan Kraus / Illustration

Running shoes featuring carbon fiber can range from $160 to $250. For example, the Nike ZoomX Vaporfly, which features a full-length carbon fiber plate in the midsole, retails for around $250. When you consider that running shoes need to be replaced every 300-500 miles, which ends up being every 4-6 months for a runner who averages 20 miles per week, the cost can add up quickly. Bmai wanted to produce a sneaker that offers good performance, yet is accessible, aesthetically appealing and affordable for the mass market.

"One of the best things about running is you pretty much just need a pair of good quality shoes to start," says Liu. "We don't want to let expensive footwear become a barrier."

The company set out to test a prototype carbon fiber shoe shank in a limited edition version of its flagship running shoe, Mile 42K — a design aimed at recreational marathon runners. The ultimate goal was to find a solution that would allow Bmai to produce a commercial shoe that could retail for around 399 yuan ($56 USD). The company also aimed to reduce weight while providing torsion resistance and organic aesthetic properties, which carbon fiber does well.

A tunable material

Enter the new Maezio brand of continuous fiber-reinforced thermoplastic (CFRTP) composites introduced by Covestro (Leverkusen, Germany; Shanghai, China) in October 2018. The product line includes unidirectional (UD) reinforced tapes and »

Torsion resistance

Covestro's carbon fiber shank runs beneath the arch of the foot in Bmai's marathon sneaker.

Source | Covestro

sheets made from carbon fibers impregnated within a polycarbonate (PC) matrix. According to Covestro, the CFRTP can be tuned for performance, aesthetics and economies of scale, and can be used in products in a wide range of industries. A thermoplastic polyurethane-based product line was also recently added, extending the portfolio for the footwear industry.

Maezio can be thermoformed at high yield rates, short cycle times and relatively low cost for millions of parts per year. Other production technologies such as overmolding, automated tape laying (ATL) and automated fiber placement (AFP) can also be integrated. The company sees Maezio as a material enabler for high-volume production in a diverse range of applications.

New athletic footwear designs require a high degree of material and design adaptability.

"We believe the Maezio brand can bring value to a new generation of products across industries by delivering a combination of lightweight construction, specific strengths and finishes at a scale yet to be reached by advanced materials," says Lisa Ketelsen, head of thermoplastic composites for Covestro.

The main advantage of Maezio is its tuneability. The UD tapes, which are just 120 microns thick, can be laminated at different angles to form sheets tuned to meet a variety of performance and mechanical criteria. Resulting sheets are strong, stiff, lightweight and have a natural, unidirectional surface finish. In addition, CFRTP composites are recyclable.

A good fit

New athletic footwear designs require a high degree of material and design adaptability. Modification is part of the design process and a great deal of testing and iteration is often required.

"[Shoe performance] is very targeted to the specific objective," says Arne Boettcher, market development manager for Maezio. "You need a material that you can tailor to the exact needs of the application and the athlete — and that's exactly what Maezio is."

Bmai says Maezio is well suited for Bmai's shoe because in addition to offering stiffness with low density, the material offers the freedom to tune.

"Depending on how you lay the tapes, the material is able to generate different stiffnesses or torsion performance dependent on very specific needs of that shoe," explains Ketelsen.

In order to meet weight targets for the Bmai shoe, the shank has to be thin, but also strong enough to meet torsion requirements. With that in mind, the team focused on determining ply count for the shank. While Covestro would not comment on exact number of plies or fiber orientations, the company did state that typical shank thicknesses are 1-1.2 millimeters and hypothesized that a fiber orientation of 45 degrees would achieve the required torsion resistance at the required thickness. From that starting point, Covestro tested and iterated different layups.

According to Ketelsen, the key to designing the optimal solution for Bmai was a cycle of fast iterations that included design brainstorming sessions, tuning the product, simulating different compositions, creating a sample based on the simulations, cutting and slitting each sample to shape, and delivering test samples to Bmai for feedback.

Thin, but strong

Shank thicknesses are typically in the 1-1.2-millimeter range. Source | Covestro

Iteration and communication

Bmai lead designer Axis Liu works with Covestro team members at Covestro's APAC Innovation Experience Center in Shanghai. Source | Covestro

Covestro uses ABAQUS (ABAQUS Inc., Pawtucket, R.I., U.S.) for structural simulation and MOLDFLOW (Autodesk, San Rafael, Calif., U.S.) for rheologic simulation as standard software. "There are certain requirements that we can simulate internally," says Ketelsen. "We do the simulation [and] have facilities in Germany, the U.S. and China to assemble certain parts, do physical tests and analyze the data and take it back to production and adapt."

During the course of the project, Covestro iterated the design several times, sharing details and results, and then adapting the design. Close communication was important between Bmai and Covestro's APAC Innovation Experience Center in Shanghai, where a range of tests were conducted including bending and fatigue tests, and quality tests for suitability and performance. The company relayed results to Bmai frequently, communicating the ways in which the product needed to be tuned.

"You can't just sit down and design it — you have to test and iterate," adds Boettcher. "Companies like Bmai are more used to just *doing* and *finding it out* ... testing, failing and then testing again."

Throughout the many design iterations, Covestro also found itself balancing several additional considerations, including the component's adhesion compatibility with other materials in the shoe. Nevertheless, speed to product launch was also important given the highly competitive athletic shoe market, where new styles debut quickly. According to Boettcher, speed and agility in producing testing samples was essential.

LEARN MORE

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

Learn more about Covestro's thermoplastics | short.compositesworld.com/CovestroTP

Lessons learned

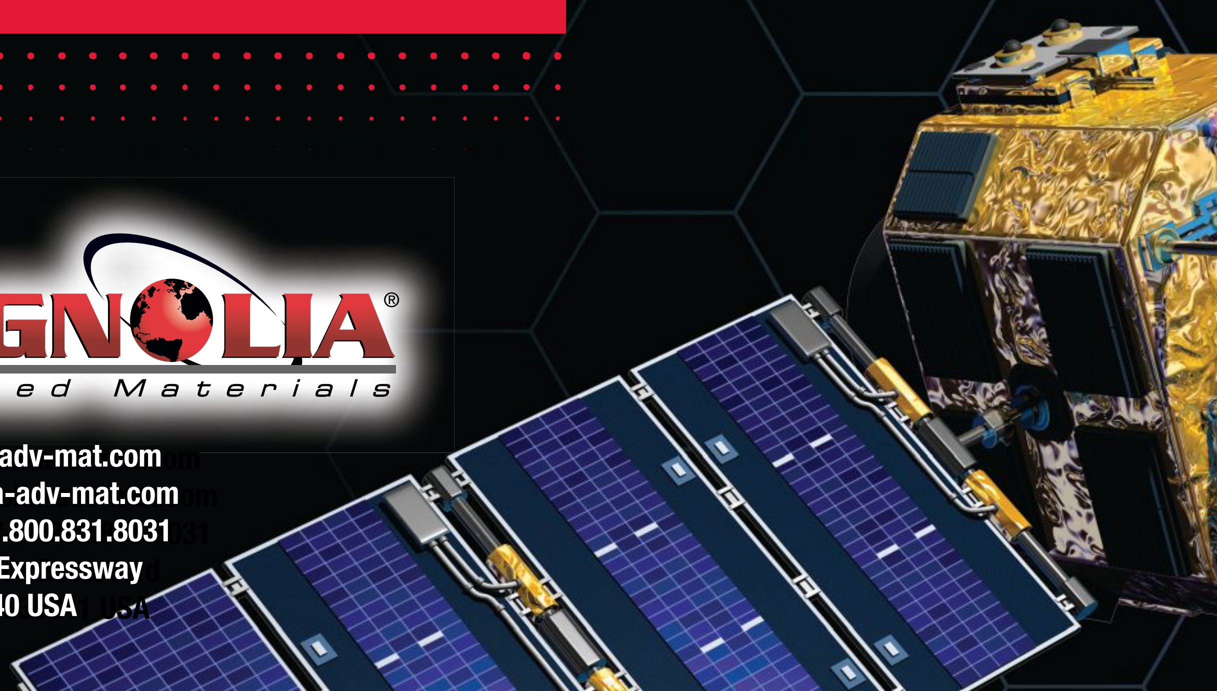
Bmai's 42K Lite was unveiled last year and met the company's requirements for torsion, aesthetics and overall performance. Covestro says the design process with the shoe offered insights into how the company might work with Maezio in other markets.

"[The] key is the interaction with the designers, and the interaction with those that make decisions," says Ketelsen. "What we did very well in this example with the shoes — and something we want to take into other industries as well — was to set up a hypothesis based on what we think is valuable, and then test and iterate that with the customer."

According to Covestro, Maezio is also attracting interest in the electrical and electronics industry, automotive, medical technology, consumer goods — like household appliances, furniture and luggage — in addition to sporting goods and athletic shoes. To further its research, Covestro launched a new R&D tape line in Germany in July 2019 (see Learn More). CW

ABOUT THE AUTHOR

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

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