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COMPOSITES TECHNOLOGY

JUNE 2014 | VOL. 20 | NO. 3

THE LEIPZIG FACILITY

BMW i3 PLANT TOUR

Cutting, Kitting & Nesting Update

UMaine Floats New Turbine Concept

2014 JEC Europe Show Review

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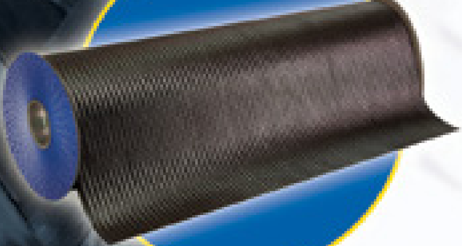

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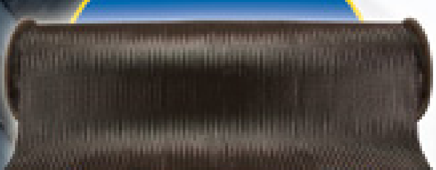

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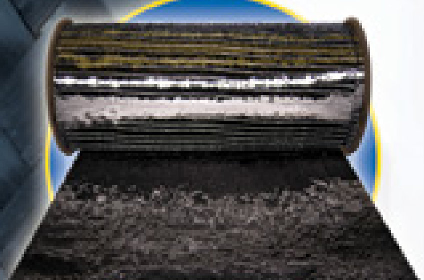

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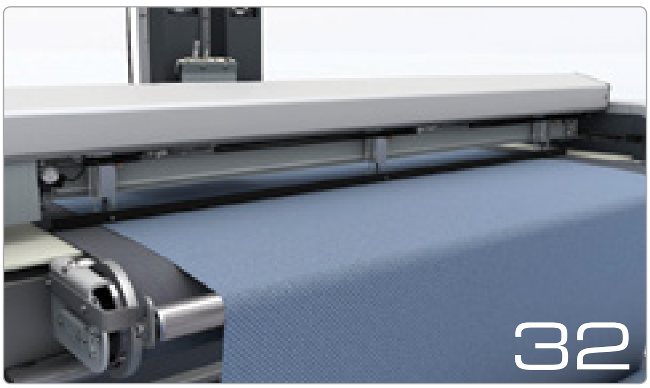

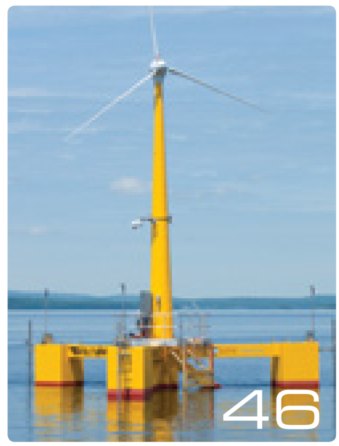

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COVER PHOTO

The Munich, Germany-based BMW Group's Leipzig manufacturing plant is rolling out 100 of its stylish new *i3* all-electric commuter cars per day. The car's carbon fiber composite passenger protection cell, what BMW calls its Life Module, is molded and assembled in a highly automated production scheme. *CT* got inside for a close look. Read about it on p. 24.
Source | BMW AG

EDITORIAL OFFICES

Publisher Richard G. Kline, Jr. / rkline2@gardnerweb.com
Editor-in-Chief Jeff Sloan / jeff@compositesworld.com
Managing Editor Mike Musselman / mike@compositesworld.com
Technical Editor Sara Black / sara@compositesworld.com
Senior Editor Lilli Sherman / lsherman@compositesworld.com
Senior Editor Ginger Gardiner / ggardiner@compositesworld.com
Graphic Designer Susan Kraus / skraus@gardnerweb.com
Marketing Manager Kimberly A. Hoodin / kim@compositesworld.com

Midwestern U.S. & International Sales Office
Associate Publisher Ryan Delahanty / rdelahanty@compositesworld.com
Eastern U.S. Sales Office
District Manager Barbara Businger / barb@compositesworld.com
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District Manager Rick Brandt / rbrandt@gardnerweb.com
European Sales Office
European Manager Eddie Kania / ekania@btopenworld.com

Contributing Writers
Dale Brosius / dale@compositesworld.com
Donna Dawson / donna@compositesworld.com
Michael LeGault / mlegault@compositesworld.com
Peggy Malnati / peggy@compositesworld.com
Karen Wood / karen@compositesworld.com

GARDNER Business Media, Inc.

6915 Valley Avenue
Cincinnati OH 45244-3029
P 513-527-8800
Fax 513-527-8801
gardnerweb.com

PO Box 992,
Morrison, CO 80465
P 719-242-3330
Fax 513-527-8801
compositesworld.com

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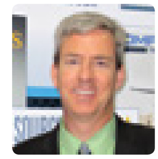
MEMBERSHIPS:

Where are they now?



We first heard about the vehicle now known as the BMW *i3* in 2010 at the JEC show in Paris. There, we met for the first time Andreas Wüllner and Jörg Pohlman, managing directors of the then new joint venture between SGL Group and BMW Group, called SGL Automotive Carbon Fibers (SGL ACF). Wüllner and Pohlman told us about a new all-electric passenger car BMW was developing, called the *Megacity Vehicle*. It would feature a passenger cell made entirely of carbon fiber, which would be captively sourced from SGL ACF at a new plant to be built in Moses Lake, Wash. The car, they said, would be a production vehicle and thus would represent the first use of substantial amounts of carbon fiber in a car ostensibly targeted toward the everyday driver.

That vehicle, which became the BMW *i3*, is on this month's cover, and on p. 24 you'll find the *i3* plant tour we have long looked forward to. Now, the *i3* is on the market in Europe and in the U.S., BMW is making 100 *i3s* a day and the sporty hybrid *i8* — also featuring a carbon fiber passenger cell — is due out later this year.

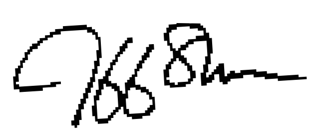
So, it appears that the long-awaited electric vehicle (EV) culture is here. There is, however, a certain amount of *déjà vu*. The same year we met Wüllner and Pohlman, we published in *CT* a story about other up-and-coming electric vehicles that promised to use composites for lightweighting. We wrote about Myers Motors' two-seat *Duo* and one-seat *NmG*. We reported on Tesla's *Model S* EV and the two-seat Aptera *2 Series* being developed by Aptera Motors. We told you about Fisker Automotive's hybrid-electric *Karma*. Where are they now?

> It appears the electric vehicle culture is here, but there is a certain amount of *déjà vu* at work.

The Tesla *Model S* lives on, but all of the others saw either limited or no life in production. Fisker, running out of money, entered bankruptcy in 2013 and was acquired by Wanxiang America Corp., which might or might not resume production of the *Karma*. Myers Motors is alive, but production of its EV depends on a crowd-funding campaign. Cash-strapped Aptera was forced to close its doors in late 2011, was subsequently bought by Chinese automaker Jonway and reactivated as Zaptera USA, which in turn created Aptera USA. Aptera USA has promised to produce the Aptera *2 Series*, but as of mid-May, it was nowhere to be seen.

The bottom line here is, well ... the bottom line. Developing and manufacturing cars is expensive, and not for the shallow of pockets. The consumer market might be ready for smaller, nimbler, lighter, urban-friendly EVs, but meeting that demand takes investment on a scale that only companies like BMW and Tesla and Toyota can muster.

Even the *i3* is not a guaranteed success, yet, but it has the corporate muscle behind it to give it more than a fighting chance, and for that reason, we in the composites industry should be glad.



Jeff Sloan

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Why are suppliers morphing into fabricators? Part II

Bio | Mike Musselman

A journalist with 20 years of technical trade magazine experience, Mike Musselman is in his 13th year as the managing editor of *CT* and sister publication *High-Performance Composites* for CompositesWorld. Based in Denver, Colo., he coordinates the efforts of a team of inhouse and freelance editors and writers and steers each issue's editorial content through the production process.

Last issue, in this space, we observed that materials suppliers and distributors — purveyors of not just resin, core and fabric, but tooling, molding compounds and other items necessary to the production of finished composite components in many end-markets — are venturing, in greater numbers, into parts manufacturing. Either directly or through subsidiaries, they are electing, at least to a degree, to *compete with their customers*. (You can read the commentary in *CT* April 2014 (p. 4) or visit short.compositesworld.com/whymorph1.) At its end, *CT* asked: *Where does that leave the suppliers' customers — composite parts manufacturers?*

To find out, *CT* asked a select group of readers — suppliers/distributors *and* parts fabricators — to participate in an online survey. A total of 8,621 survey invitations were sent out on Wednesday, April 9. As of April 21, 2014, 104 surveys were returned for a 1.2 percent rate of response. Respondees each represented one or more of the major markets served by the composites industry and the group included businesses of every size, from 1- to 10-employee shops through plants that employ 100 or more.

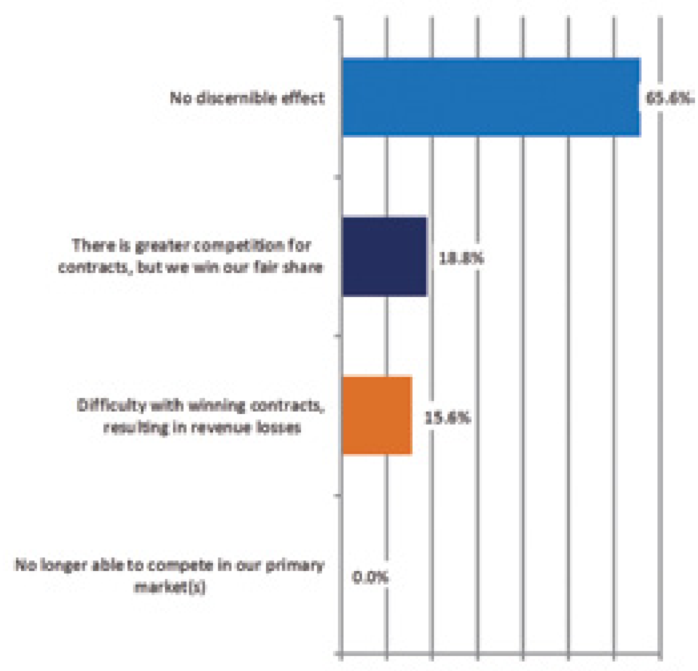
Survey results indicate the trend is growing and likely will continue to do so. But, as the graph at right shows, those who manufacture composite parts, for the most part, say their businesses are currently unaffected by the trend. However, 18.8 percent say that the entry of suppliers/distributors into part manufacturing has increased competition for contracts, and 15.6 percent say that they've experienced greater difficulty in winning contracts, with the result that business revenue is down.

Exactly half the suppliers/distributors who responded told *CT* that they currently have no intention of adding part manufacture to their range of business activities (see graph on p. 7). But nearly 20 percent said they were considering the manufacture of finished parts, either directly or through a subsidiary. Today, more than 17 percent already manufacture finished parts directly and another 2.2 percent say they do so through a subsidiary. An additional 10 percent provide premaunfactured substructures to part fabricators. Put that all together and we also see that fully 50 percent of suppliers and distributors are, today, either engaged in or considering the manufacture of substructures and/or finished parts.

When we asked the same group to give us a peek at their short-term futures (see graph on p. 9), almost 60 percent said they anticipate no change in their current approach, but almost 25 percent intend to manufacture parts (directly or through a subsidiary) and 2.2 percent said that they will move from prefabricated-substructures manufacturing to making finished parts.

These data harmonize with the anecdotal evidence from survey respondees who also contacted *CT* with comments about the trend. "Your editorial … gave a great account of the state of things," commented Brett McAteer, the director of marketing and communications at Aonix Advanced Materials Corp. (Ottawa, Ontario, Canada). He noted that materials advances in thermoplastics, for example, "have outpaced the developments on the molding side of the business." Aonix responded by developing proprietary molding systems to guarantee material/machine compatibility, rather than to mold the actual parts. "Aonix works with OEMs and end-users and with suppliers, in fact, to get our UltraMaterials specified. Then we offer the molders (wherever they may sit in the supply chain) an integrated solution — blanks, machines and support …. We see this approach as one that can actually *protect* the molders' place in the supply chain while allowing suppliers to focus on what they do best," he adds.

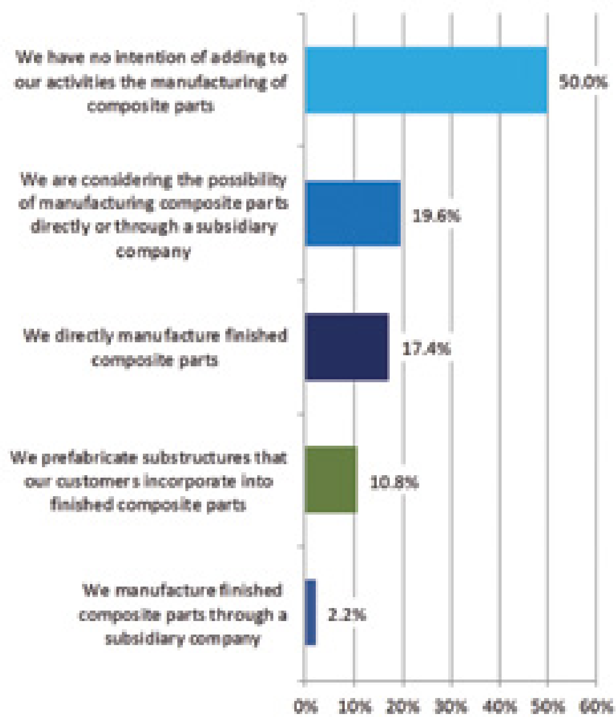
Retired from Röhm Tech, the U.S. marketing arm of ROHACELL foam manufacturer Röhm GmbH (Sontheim/Brenz, Germany; ROHACELL is now produced in the U.S. by Magnolia, Ark.-based Evonik Foams), Donald J. Loundy observes that in the diverse and still quickly evolving composites industry, "smaller compa- ►



When *CT* asked composites fabricators how the supplier transitioning to manufacturing trend affected their business revenue, 34 percent saw some negative impact.

nies, frequently operated by their founders, often have narrow visions of their role in the overall market. They are reluctant, uncomfortable to expand those visions, thus limiting their ability to adapt and grow with changing technologies and market demands." Given that reality, he suggests, "maybe developers of new materials or methods are forced to bypass those further along the chain in order to move those developments into the market."

Michael J. Cichon, director of product marketing at TenCate Advanced Composites USA Inc. (Morgan Hill, Calif.), agrees that suppliers offer added value to customers if they can also be an enabler of a materials technology, especially "if the subcontractor lev-



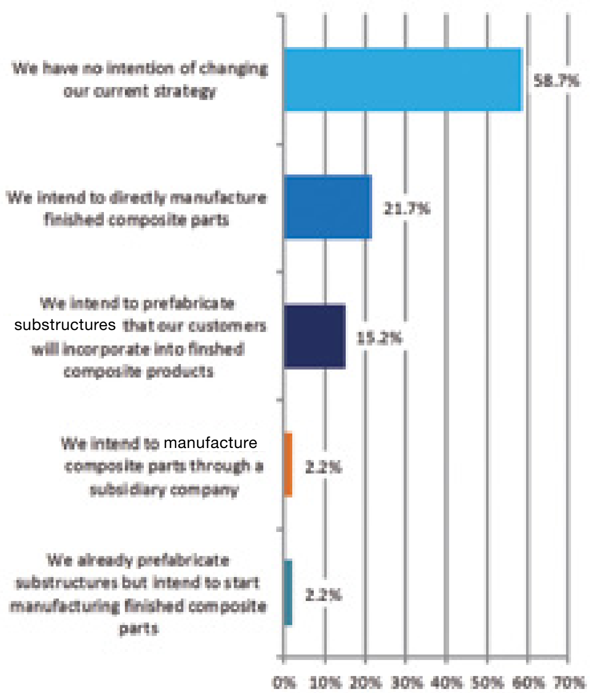
Asked about their current status with respect to the trend, *half* of the suppliers/distributors said they did, or were considering, part fabrication.

el does not have the skills or knowledge of emerging technologies, and the technology is *shifting*, then perhaps the faster and more direct way to market could be offering fabricated parts." But Cichon warns that the obvious conflict of interest might, sooner or later, hinder progress. "I wonder if there is a limit to how far a material supplier can go with fabrication given both the obvious competitive issues with customers and the reality of the investments needed for capital and personnel to run a successful fabrication business?" he asks.

CT's survey data, however, point to a third option, that of supplier/distributor/fabricator *collaborations*. Almost 29 percent of those surveyed said they are exploring such possibilities: 13.1 percent see a partnership or joint venture in their future, and 2.4 percent see a merger with, or acquisition by, a supplier in their sights. Both groups saw these moves as "essential if we are to remain in business." Further, more than 10 percent of parts fabricators "welcome the opportunity to outsource previously inhouse func-

tions to our suppliers." Notably, only 28 percent of them said this trend has no significance or impact on their businesses. The rest said it had import to varying degrees, with 46 percent indicating moderate to significant impact.

Out of the game for more than a decade, Jeff McClelland, who retired from Dexter Corp. (Bay Point, Calif.) when its resin and adhesive divisions were absorbed by Henkel Corp. in 2000, contends that the supplier-cum-manufacturer phenomenon is "nothing new." Although vertical integration is more prevalent today, "it was alive and well several decades ago," he affirms. "The 'issue' has been around for a long time and appears to be alive, well and growing!" In fact, he says, the need for growth is an underlying



Looking ahead three to five years, suppliers/distributors indicated there would be a modest upswing in the trend toward supplying substructures and/or finished parts.

morph motivator. "Senior management, especially in public companies, always wants *growth*," he points out. "Of course what they mean is EPS [earnings-per-share] growth for the shareholders. For the minions running the various businesses, it means finding ways to increase volume, margins and income. Preferably all three, but especially income. Oft' times — and probably now more than ever — it means to seriously consider forward and/or backward integration of your capabilities." | CT |

Editor's Note: More survey results, broken down by market, and an extended version of this commentary, can be found at short.compositesworld.com/whymorph2. And CT will continue to track the trend. Meanwhile, the discussion is still open. Comments continue to be welcome. Address them to mike@compositesworld.com.

Is it possible to change the infrastructure paradigm?

Bio | Dale Brosius

Dale Brosius is the head of his own consulting company and the president of Dayton, Ohio-based Quickstep Composites, the U.S. subsidiary of Australia-based Quickstep Technologies (Bankstown Airport, New South Wales), which develops out-of-autoclave curing processes for advanced composites. His career includes a number of positions at Dow Chemical, Fiberite and Cytec, and for three years he served as the general chair of SPE's annual Automotive Composites Conference and Exhibition (ACCE). Brosius has a BS in chemical engineering from Texas A&M University and an MBA. Since 2000, he has been a contributing writer for *Composites Technology* and sister magazine *High-Performance Composites.*

For those of us who live in the eastern half of the United States, it was a pretty tough winter. Many cities, including Detroit and Indianapolis, set records for snowfall and saw exceptionally cold temperatures. Inevitably, the snow melts, the temperatures warm up, and spring arrives, bringing with it longer days, sunshine and flowers. Spring also brings some things not as pleasant, such as roads with a lot of new potholes and bridges deteriorated by road salt and freeze/thaw cycles — and the inevitable "construction" season.

While I navigated rough roads around the U.S. Midwest over the Easter weekend, I came across an article in the April 16 *Txchnologist Blog* about a new "superhydrophobic concrete," doped with copious amounts of siloxane-based additives to repel water, and augmented with polyvinyl alcohol (PVA) *fibers* to impart flexibility. (See http://txchnologist.com/tagged/concrete.) Developed by a team of researchers at the University of Wisconsin (Madison, Wis.), laboratory testing of the formulation suggests this advanced concrete could last more than a century, compared to 30 years for conventional concrete roads.

I was reminded of an experiment conducted by the Utah Department of Transportation in 1989 when I lived in Salt Lake City. A 4-mile/6.4-km stretch of the busiest portion of Interstate 15 through Salt Lake City was coated with a 0.75-inch/19-mm layer of a material called Syn-crete, a polymer-modified concrete. The idea was to prolong the life of the highway for at least 10 years, delaying reconstruction and its associated costs. Within days, large chunks of the topping cracked and disbonded from the underlying roadway, breaking windshields and causing other damage to vehicles. The topping was completely removed soon after, at considerable expense. A decade later, I-15 through Salt Lake City was completely rebuilt in preparation for the 2002 winter Olympics. To my knowledge, this was done with conventional techniques.

The new superhydrophobic concrete from Wisconsin is being tested in a university parking structure to see if the results seen in the lab can be replicated in everyday use. The inventors say the product costs more than conventional concrete, but, in time, would "pay for itself with diminished maintenance." Hold on! Are we talking *lifecycle costs?* I think I've seen this movie before, as it relates to composites in infrastructure. And the evidence is in — *lifecycle costs just don't matter unless the price premium is fairly small.*

There are more than 600,000 bridges in the U.S. and it is estimated that almost 26 percent are either structurally deficient or functionally obsolete. This represents a huge potential market for repair and/or replacement. Faced with limited annual budgets, state and local transportation executives have the choice to replace a certain number of bridges with concrete that will last 30 to 40 years, or half as many using composites that could last up to 100 years. In both cases, their careers will be *long* finished before anyone will hold them to account, so the *easy* answer is twice as many low-cost bridges.

I contacted Scott Reeve, president of Composite Advantage (Dayton, Ohio), to see if any progress has been made in winning the lifecycle-cost argument. Reeve, whose company is among the most successful fabricators of composite bridge decks, confirmed the problem still exists. "A composite vehicle deck is about twice the price of a concrete deck. Even accounting for lower installation costs, we are probably 1.8 times the traditional solution," he noted. "Until we can get that differential down to around 15 percent, market penetration will remain slow. The existing government procurement structure does not value life cycle costs in infrastructure."

On a bridge, a composite vehicle deck is about twice the price of a concrete deck. Until we can get that differential down to around 15 percent, market penetration will remain slow.

Numerous contractors are using composites for remediation of concrete bridge decks and columns. While this is good for material suppliers and the reputation of composites as a whole, it doesn't help fabricators of composite structures, says Reeve. Composite Advantage has established a strong reputation in pedestrian bridges and has been able to capture vehicular bridge deck replacements where composites bring immediate value over concrete — for example, being able to use the existing structural elements, which would not otherwise be able to support the weight of a concrete deck, or the addition of a sidewalk where one did not previously exist. Integrated properly, composites can enable replacement of a bridge over a single weekend — clearly a benefit in congested cities.

Despite the resistance posed by economics, Reeve is a long-term optimist regarding the potential for composite bridge decks. "It took 30 years for steel to replace wood in bridge structures, so the opportunity to change the mindset is still there." I hope he's right, and I hope that the new super concrete — which is, after all, a *fiber-reinforced composite* — succeeds as well. I certainly wouldn't mind seeing a few less potholes every spring. | CT |

Composites Business Index 51.8: Growth rate cools

Bio | Steve Kline

Steve Kline is the director of market intelligence for Gardner Business Media Inc. (GBM, Cincinnati, Ohio), the parent and publisher of *CT* and *High-Performance Composites* magazines. He started as a writing editor for another of GBM's publications before moving into his current role. Kline holds a BS in civil engineering from Vanderbilt University and an MBA from the University of Cincinnati.

In March, the U.S. Composites Business Index reached a recent high of 56.3, and grew at its fastest rate since March 2012. The Index was 8.7 percent higher than in March 2013, and it was the seventh month in a row that it was higher than in the same month the year before.

New orders grew for the fourth straight month. Production expanded for the third consecutive month, reaching its fastest rate in nearly two years. Backlogs grew at an accelerating rate in the first three months of 2014, indicating that capacity utilization and capital spending should increase all this year. Employment had increased for 13 months, and the hiring rate picked up sharply. Exports grew for the first time, and supplier deliveries lengthened at their fastest rate, since April 2012. Material prices increased again, but at a noticeably slower rate than in February. Prices received, however, contracted for the second time in five months. Future business expectations fell slightly, but was still strong and near its highest levels since the CBI began (December 2011).

The CBI was up sharply for facilities with 20+ employees, and at a rate as high as at any time in CBI history. But fabricators with 19 or fewer employees contracted after two "up" months.

For the first time, all U.S. regions grew in the same month. The East North Central and Pacific regions grew fastest in March and the Pacific grew for the sixth consecutive month.

THE COMPOSITES BUSINESS INDEX

Subindices	April	March	Change	Direction	Rate	Trend
New Orders	54.0	57.5	-3.5	Growing	Slower	5
Production	57.1	62.5	-5.4	Growing	Slower	4
Backlog	47.2	53.1	-5.9	Contracting	From Growing	1
Employment	53.7	56.8	-3.1	Growing	Slower	14
Exports	45.1	51.1	-6.0	Contracting	From Growing	1
Supplier Deliveries	53.8	56.7	-2.9	Lengthening	Less	29
Material Prices	64.2	64.3	-0.1	Increasing	Less	29
Prices Received	51.2	49.3	1.9	Increasing	From Decreasing	1
Future Business Expectations	73.8	76.0	-2.2	Improving	Less	29
Composites Business Index	51.8	56.3	-4.5	Growing	Slower	5

After contracting significantly in February, future capital spending plans increased 16.3 percent compared to March 2013.

April's CBI of 51.8, lengthened the growth string to the fifth straight month and the sixth time in the previous seven months. Compared to one year ago, the index was up 2.2 percent. This was the eighth consecutive month the index was higher than it was one year earlier. The annual rate of change had accelerated for three months, but it was also the CBI's lowest showing in 2014.

Every subindex contributed to the slower rate: New orders grew for the fifth straight month, but the rate had slowed significantly since its January peak. Production had expanded for four straight months but at its slowest rate in 2014. Backlogs contracted for the first time this year but were still 6.5 percent higher than they were one year earlier. The annual rate of change in backlogs continued to accelerate, indicating higher capacity utilization and capital spending for the remainder of 2014. Employment, for two months, increased at a faster rate than at any time since August 2012. After growing in March, exports contracted significantly in April. Supplier deliveries lengthened at a noticeably slower rate but continued a trend begun in October 2013.

Material prices increased at the March rate, and material prices continued to increase at a significantly faster rate than in 2013. Prices received increased slightly in April after decreasing in March. Future business expectations remained high, despite falling in the previous two months.

A prime cause of April's noticeably slower growth was the change in business conditions at mid-size fabricators (50 to 249 employees). After growing at significant rates for some time, they saw sharp contraction in April. For those with 100 to 249 employees, the overall index fell nearly 20 points. The largest fabricators saw their growth rate dip, but this slower rate was counterbalanced by faster growth at plants with 20 to 49 employees. Those with fewer than 20 employees contracted at a rate similar to that in March.

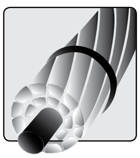
Four U.S. regions grew in April. The North Central – East grew at its fastest rate for the second month in a row, having grown for seven straight months. The Northeast, Southeast and West followed, the latter growing for the ninth month in the past 10. Only the North Central – West contracted, ending three months of growth.

Future capital spending plans had been above $1,000,000 in five of the previous six months. Compared to one year ago, April's spending plans subindex was up 9.1 percent. Although the annual rate of change was noticeably lower than it was from November to January, it had grown at an accelerating rate since January. | CT |

Composites | WATCH

A new composite solution cuts overall utility investment in power transmission while in the realm of power generation, forecasts go up for wind energy.

ENERGY



Carbon fiber featured in new electrical transmission cable

Celanese Corp. (Dallas, Texas) and Southwire Co. LLC (Carrollton, Ga.), North America's largest wire and cable producer, have introduced a new option for utility transmission lines: the C^7 Overhead Conductor, featuring a lightweight and high strength-to-weight, multi-element composite core of Celstran continuous fiber-reinforced thermoplastic rods (CFR-TPR), made by Celanese. Mark Lancaster, Southwire's director of overhead transmission engineering, says the technology behind C^7 was seven years in the making and represents a step-change in overhead wire and cable design and engineering. The goal, he says, was to develop a product for utilities that want to increase right-of-way capacity without the expense of erecting new infrastructure. Line sag, he says, is the largest limiting factor in how much current can be passed through a utility line. "We wanted to increase capacity of the right of way over the same equipment." The result is a product that, reportedly, not only increases capacity, but provides cost-avoidance benefits by obviating the need for new towers and poles, a need that would have to be met if increases were attempted with traditional steel-cored conductor cables.

Source (both photos) | Celanese/Southwire

Codeveloped by Celanese and Southwire, the conductor cable reportedly nearly doubles the transmission capacity, yet exhibits less sag than an aluminum conductor steel-reinforced (ACSR) cable of the same diameter. How does C^7 compare to other composite-cored conductors already on the market? Michael Ruby, global composites business manager at Celanese, says, "This combination of materials provides distinct advantages compared to alternative High Temperature Low Sag (HTLS) technology and conventional conductors." For one, the C^7 core comprises seven (or more, depending on cable diameter) 3.2-mm/0.13-inch diameter strands of aerospace-grade carbon fiber pultruded with Fortron PPS (polyphenylene sulfide) from Celanese. The core is isolated from direct contact with the cable's aluminum conductor strands by an overwrap of polyetheretherketone (PEEK), which protects the aluminum from galvanic corrosion and prevents abrasion of the core. Unlike previously introduced solid, composite-cored cabling, the Celstran CFR-TPR core's construction is said to eliminate the potential for single-point failure of the C^7 cable: The bundled core strands and the overwrapped aluminum conductor strands, together, provide structural support redundancy in high-load conditions, which means that the failure of one or two or even three strands will not result in cable failure. In addition, Lancaster notes that the carbon fiber composite core operates at a generally lower temperature, which maximizes energy throughput and minimizes capacity loss. Nonetheless, the carbon fiber/thermoplastic core reportedly can operate under hotter conditions (180°C to 225°C/356°F to 437°F) without damage to the line.

That said, Lancaster points out that the success of C^7 as a replacement cable product rides on whether or not cable installers can use the same tools and equipment they employ with metal-cored cables. On that subject, C^7 delivers. "Install and repair strategies *had* to be the same," he says, "so that our customers can seamlessly integrate it into their work environment."

ENERGY

More wind farm installations in the energy industry forecast


Source | NREL

The Global Wind Energy Council (GWEC, Brussels, Belgium) has issued its *Global Wind Report – Annual Market Update*, detailing the current status of the global industry, with market projections for 2014-2018. GWEC expects installations of at least 47 GW of new capacity in 2014, a significant increase over 2013 levels. The market will be led by China, but will show strong recovery in the U.S. market and record installations in Canada and Brazil, with hundreds of megawatts expected in South Africa.

"The global market is back on track for 2014," says Steve Sawyer, GWEC secretary general. "A strong Chinese market, recovery in the U.S. and an increasing role for emerging economies in the global market means that after 2014, the market will resume its steady if unspectacular growth, and end up just about doubling total global installations during the-five year period to 2018."

GWEC cautioned, however, that without a strong global climate policy, market growth is unlikely to return to the 20 to 25 percent or more average growth which has characterized most of the last two decades.

In many markets, today, wind's most compelling selling point is cost-competitiveness. GWEC says wind already competes successfully against heavily subsidized incumbents in a growing number of markets around the world as the technology and its implementation steadily improve.

AMPLIFICATION

CT's recent Special Report "Styrene and cobalt: Headed for the exit?" (*CT* April 2014 issue (p. 34) | short.compositesworld.com/SCExit) prompted the following letter from the American Composites Manufacturers Assn.'s (ACMA, Arlington, Va.) VP of government affairs John Schweitzer, reprinted here in its entirety:

"The *CT* article, "Styrene and cobalt: Headed for the exit?" is inaccurate in its summary of styrene toxicity data. For styrene, it is not true that 'a cursory inspection of the studies and data … raises more questions than answers.' Several recent weight-of-evidence reviews of the ample styrene toxicity database concluded the preponderance of the evidence fails to support a cancer concern for this substance. And the most recent review of the potential for styrene to cause developmental or reproductive toxicity was similarly negative. Useful summaries of these data are available at www.styrene.org. The cancer data is specifically addressed in a report published online in January 2013 by the journal *Human and Ecological Risk Assessment*, and the reproductive toxicity data were thoroughly analyzed in a February 2006 report by the U.S.'s National Toxicology Program.

Styrene is a uniquely useful chemical. Manufacturers of all sizes have safely used styrene-based thermoset resin systems to make important and useful products since the Second World War. The market acceptance of many products we depend on to save energy and prevent pollution, such as durable and light weight auto and truck components, and the corrosion- and leak-resistant underground storage tanks used for several decades at petroleum filling stations, is based at least partially on the long history of the successful performance of these styrene-based composites products.

And it's important to know that no matter what their actual toxicity, cobalt salts are not volatile and no route of human exposure related to the manufacture or use of composites products has been identified. Avoiding actual harm to people and the environment is not a defensible reason for suppliers and composites manufacturers to move away from styrene or cobalt."

Composite Essential Materials revives Nida-Core/3M's U.S. core business

Marista Dan, president of startup Composite Essential Materials (CEM, Port Saint Lucie, Fla.), reports that CEM has taken over the core materials business previously known as Nida-Core/3M. 3M (St. Paul, Minn.) had acquired Nida-Core in January 2011, but subsequently decided to exit the core-manufacturing business.

Dan says that Dan Family Holdings, the owner of CEM, has agreements with all of the previous Nida-Core suppliers, including NidaPlast (Thiant, France), the source of Nida-Core materials for plastic honeycombs, PGI Matline for laminating bulkers and Flexokore for balsa products. CEM also will offer polyvinyl chloride (PVC), polyurethane (PU) and polyethylene terephthalate (PET) foam core as well as glass-reinforced fiberboard. In addition, CEM will be a North American distributor of resin supplier Nord Composites (Condé Folie, France).

Future plans include expansion of product offerings to honeycomb in low-, medium- and high-densities as well as fire-retardant versions, plus honeycomb designed for use in infusion and resin transfer molding (RTM) processes. Resin products to come include tooling resins, skinning material, transom putty and sprayable print-blocking core. A second distribution site will be established in Elkhart, Ind., where CEM will produce large pultruded panels with several options for core and fiber-reinforced plastic surfaces.

Dan says previous and new customers are welcome to call the previous Nida-Core phone number (772) 343-7300 or e-mail mdan@composite-essentials-llc.com.

2014 JEC Europe | REVIEW

The composites world met again in Paris, vibrant, stronger, and more forward-looking than ever before.

The 2014 edition of JEC Europe (March 11-13, Paris, France) was the biggest and busiest iteration of the show yet, with more than 1,200 exhibitors and, according to show organizer JEC Group (Paris, France), 32,000 attendees passing through the doors. Spread for the first time across two floors at the Paris Expo's Porte de Versailles exhibition center, the event proved, again, the dynamism, creativity and ingenuity of the composites industry. (JEC is considering adding a third floor in 2015.) The *CT* staff was there in force and returned with the following highlights — for a more detailed report see "Learn More," p. 23. (*CT* reviews new products that made their debuts in Paris, beginning on p. 40.)

THE SHAPE OF THINGS TO COME

Clear from the first day were several trends that show all the earmarks of transforming the way composites industry suppliers and parts fabricators approach their common goals in the future. Many of them show great promise for composites in automotive applications — in particular, those reinforced with carbon fiber. Significant among the trends and trendsetters were the following:

SNAP-CURE RESINS

A molding system is only as fast as its resin, and it was clear at JEC that materials suppliers are getting that message. The biggest news came from Dow Automotive (Schwalbach, Germany and Auburn Hills, Mich.), which leapt into the fast-cure epoxy market with the introduction of its trademarked VORAFORCE 5300. Designed specifically for use in RTM and aimed at the automotive market, the material offers a sub-90-second cycle time — from *preform insert to press open*. Dow believes a cycle time of about 60 seconds is possible (see "Learn More").

The resin's extremely low viscosity (15 mPa/s) reportedly gives it good "persistent flow" throughout the preform and helps reduce press tonnage requirements. Dow also reported that the resin offers mechanical performance on par with competitive epoxies, and thermal performance of about 120°C/248°F. It features an internal mold release, thus eliminating external mold release costs. (Read about other Dow new products on p. 40.)

Also aimed at automotive production, Momentive Specialty Chemicals' (Columbus, N.Y.) EPIKOTE 05475, introduced in 2013, was on exhibit. The fast-cure, low-viscosity epoxy, for use in compression molding, infusion, pultrusion and RTM processes, offers a cure time of about 90 seconds, and Momentive officials said the company has been working with the France-based Technical Center for the Mechanical Industry (CETIM) to develop applications, including exterior body panels, suspension arms and a crash box targeted to automotive OEMs — the latter was on display in the Momentive stand (see photo, bottom left, this page). Momentive says volumes up to 1,000 units per day are possible.

Henkel (Toulouse, France and Bay Point, Calif.), Cytec Industries (Woodland Park, N.J.), Huntsman Advanced Materials (The Woodlands, Texas) and Bayer MaterialScience (Leverkusen, Germany) also were on hand with thermoset materials in the same cycle-time range, for RTM, pultrusion, infusion and compression molding processes — all with the auto industry's part-per-minute production standard in mind.

THERMOPLASTIC-FRIENDLY CARBON FIBER

The SGL Group (Wiesbaden, Germany) and Toho Tenax (Wuppertal, Germany and Rockwood, Tenn.) each introduced at JEC Europe a new carbon fiber sizing optimized for thermoplastic resins. Toho Tenax VP of sales Greg Olson said his company's sizing is formulated for use with polyetheretherketone (PEEK) in aerocomposites, but he added that Toho Tenax also is looking at oil and gas, and medical applications. The new sizing, he notes, does not burn off during processing and is compatible with weaving or braiding processes. The company is working on additional sizings for use with other thermoplastics.

The snap-cure and carbon fiber/thermoplastics trends made it all the more noteworthy that Paul Mackenzie, VP research and technology at U.S.-based aerospace carbon fiber and prepreg supplier

Source | *CT* / Photo: Jeff Sloan

Hexcel (Stamford, Conn.), introduced a new high-modulus carbon fiber (HexTow HM63), a new epoxy (HexPly M92) and, notably, a new snap-cure prepreg epoxy, targeted toward automotive applications. Characterized as a response to thermoplastics' incursions into automotive molding, the also new HexPly M77 offers a two-minute cure. (Detailed data for Hexcel's new materials are available on p. 40).

With interest in carbon fiber/thermoplastic applications so high, pre-show rumors of yet another new PAN-based carbon fiber manufacturer piqued *CT's* interest. The rumors proved untrue, but *CT* found that the subject of the rumors, UHT Unitech Co. Ltd. (Zhongli, Taiwan), established in 2011, offers not a new fiber but a *graphitization service* for composites fabricators who purchase T700-grade PAN-carbon fiber from existing manufacturers. Unitech's president, Ben Wang says the company unspools PAN carbon fiber (3K to 48K) provided by his customers, burns off the factory-applied sizing, then graphitizes it in Unitech's patented 2000°C/3632°F *microwave* ovens, reapplies fiber sizing (Wang says he specializes in sizings compatible with *thermoplastic* resins for sporting goods and industrial applications) and re-spools the product. The result? Wang quips that "no one believes it" but he says he can deliver the equivalent of T800 or T1000 fiber at 15 to 30 percent lower cost, because the microwave technology reportedly consumes 30 percent less energy and processes fiber 50 percent faster than conventional graphitization ovens. He says test results indicate that his UT800 and UT1000 products are roughly equivalent to others on the market. Currently capable of producing 300 metric tonnes of converted fiber per year, Wang emphasized that he's not planning to engage in spinning or carbonization of raw PAN fiber and is willing to partner with other carbon fiber manufacturers interested in adapting his microwave process.

TURNKEY SYSTEM INTEGRATION

This third trend defined the proverbial handwriting on the wall: Touch labor is out, automation is in, and suppliers are uniting to offer OEMs complete manufacturing systems. Several consortiums introduced or emphasized *turnkey* composite part manufacturing cells. Each emphasized that merely selling equipment is a strategy long out of date.

A preshow announcement by molding machinery supplier Pinette Emidecau (Chalon-sur-Saône, France) requested *CT's* presence at its press conference Tuesday, March 11, to hear about a new consortium made up of four companies combining technologies to provide global solutions for automated and high-speed RTM production technology. What wasn't revealed until that morning was that after *10 years* of close collaboration, the four had incorporated a new multinational company, Global RTM, to focus on marketing a complete high-pressure resin transfer molding (HP-RTM) production line. Headquartered in Bellignat, France, Global RTM will build and market turnkey production systems that integrate ply preparation, preforming, tool preparation, injection and forming, postcuring and finishing, for shop floor product flow inside the customer plant. Although the focus, for now, is aerospace, Pinette's president Jérôme Hubert, who also will head Global RTM, says the system will impact the automotive market within three years.

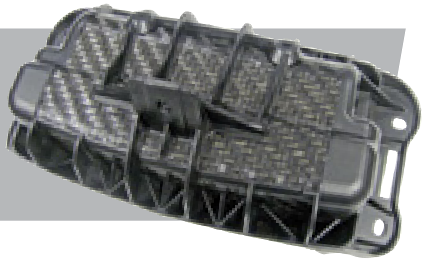
Fives Cincinnati (Hebron, Ky.) also announced an entire manufacturing system, developed since Five's much publicized acquisition of Hebron, Ky.-based MAG Americas and designed expressly for autocomposites. It comprises two manufacturing cells: A Cincinnati Small Flat Tape Layer HV, which features a tape layer with integrated ply cutters, provides net- or near net-shaped and kitted stacks of carbon or glass fiber fabrics, and a Cincinnati Form & Cure HV cell, which features a conveyor that receives the kitted stacks, then places them in a compression press supplied by Continental Structural Plastics (Auburn Hills, Mich.). At showtime, the system had already produced a car hood inner liner with a fiber volume fraction of 65 percent. Fives officials said two-minute cycle times are within reach and that the company also wants to trial a glass/vinyl ester prepreg supplied by Mitsubishi Plastics Composites America Inc. (Chesapeake, Va.).


Source| ENGEL Austria

ENGEL Austria GmbH (Schwertberg, Austria) spotlighted a nearly mass-production-ready, "geometrically optimized and stress-resistant" composite automotive brake pedal (see photo, above) produced in collaboration with automotive manufacturer ZF-Friedrichshafen AG (Friedrichshafen, Germany). The carbon fiber is from Zoltek (St. Louis, Mo.) and woven by Chomarat (Le Cheylard, France and Anderson, S.C.).

The pedal features a layered thermoplastic fabric structure adapted by ZF to the component geometry. This reportedly enabled a weight reduction of about 30 percent compared to steel brake pedals, without reducing the load-bearing capacity. ENGEL's organomelt method, which enabled a one-shot process, involves heating of fabrics woven from thermoplastic fibers in an infrared (IR) oven, preforming them in an injection mold, and then overmolding them with polyamide resin immediately afterwards. The manufacturing cell integrates a vertical ENGEL insert 200 injection molding machine, an IR oven, a shuttle system, and an ENGEL multiaxis robot. The oven enables rapid heating of thick-walled semifinished products. It and the robot are fully integrated into the injection molding machine's control unit.

Similarly, turnkey systems were touted by Dieffenbacher (Eppigen, Germany), Krauss-Maffei AG (Munich, Germany) and RocTool, each working in collaboration with other suppliers to meet automotive industry demands. ►



PASSENGER PROTECTION CELLS

This fourth trend could be the tip of the proverbial auto industry iceberg — but without the *Titanic* overtones. Taking a page from Formula 1 race car designers, whose carbon fiber composite safety cells for drivers are well established on the world's racing circuits, automotive composites fabricators determined collectively to alert automakers to their molding proficiencies by displaying carbon fiber composite passenger protection cells ("tubs" for short), either for real (typically high-end sports) cars or as capability demonstrators. *CT* staffers counted no fewer than *10* tubs on display.


Source | *CT* / Photo: Jeff Sloan

Among them was an impressive display by Mubea Carbo Tech (Salzburg, Austria) of a carbon fiber monocoque cell. The company manufactures tubs for the McLaren *MP4-12C* supercar, the Porsche *918 Spyder* and the Volkswagen *XL1*. It has recently opened a second, highly automated production facility in Žebrák, Czech Republic, which, it says, can deliver 50,000 parts per year via epoxy HP-RTM. (Mubea Carbo Tech also mints carbon composite auto wheels. See "Extended out-time polyurethanes, below.")

E700 series carbon fiber prepreg from TenCate Advanced Composites BV (Nijverdal, The Netherlands) was used by Adler Group (Naples, Italy) to manufacture another tub monocoque, this one for Alfa Romeo's *4C* (photo above). The car is manufactured in Modena, Italy, and 3,500 cars will be produced annually. Carbon fiber composites represent 25 percent of the car's overall volume and the monocoque weighs a mere 65 kg/143 lb.

Taking a different approach, Axon Automotive Ltd. (Wollaston, U.K.), a subsidiary of Far Composites (Nottingham, U.K.), showed a carbon fiber monocoque that won the 2012 JEC Innovation Award as a composite automotive Body in Black (BiB) system.

STYRENE-FREE THERMOSETS

In the wake of recent government scrutiny of styrene in the U.S. (see "Learn More"), Reichhold Inc. (Research Triangle Park, N.C.) said it has cracked the styrene-replacement code for vinyl ester, introducing at JEC a new product called ADVALITE. The liquid resins can be used in resin transfer molding (RTM), infusion, filament winding, liquid molding and pultrusion processes (see more on p. 40).

3B – The Fibreglass Co. (Battice, Belgium), won a JEC Innovation Award for, and exhibited a wind blade section to demonstrate the capabilities of, a new sizing for its new SE3030 glass roving. It's optimized for use with DSM Composite Resins' (Schaffhausen, Switzerland) Beyone 201-A-01 styrene- and cobalt-free vinyl ester resin, with 40 percent bio-content. The two companies are working with Siemens Wind Power (Hamburg, Germany) and DTU Wind Energy (Roskilde, Denmark) to evaluate the fiber/sizing/resin combination for use in wind blades. Initial tests show that the SE3030/Beyone 201-A-01 combination offers desired tensile and shear strength with reduced postcure time and lower temperature thresholds. The result could be faster blademaking cycles.


Source | *CT* / Photo: Jeff Sloan

Cytec Industrial Materials (Woodland Park, N.J.) claimed what it called "the industry's first application of a volatile-organic compound (VOC)-free thermoset vinyl ester resin/woven glass-reinforced prepreg" in the composite battery pack for the General Motors (GM, Detroit, Mich.) Chevy *Spark*. Working with GM, molder Continental Structural Plastics (CSP, Troy, Mich.) sought a materials solution from Cytec for the battery pack that would meet formidable processing and performance requirements: 30° offset-barrier, side-impact, and rear-barrier crash; 50G impulse shock (x, y and z); post-crash package integrity; fire-resistance testing; 3m/10-ft drop testing (bottom/end); 1m/3.3-ft water-submersion test; and vibration/shock testing. Cytec's solution, MTM 23, a tailored, self-releasing, rapid-cure prepreg, made with Reichhold's new ADVALITE vinyl ester, enables CSP to compression mold parts 40 percent lighter than metal alternatives in less than 10 minutes at 150°C/302°F. Cytec says MTM 23 can rapid-cure in less than three minutes.

EXTENDED OUT-TIME POLYURETHANES

Another recent trend, that of delaying the reaction time of polyurethane (PUR) resins to permit injection of larger and more complex parts (see "Learn More"), was revisited in Paris. A noteworthy example was the roof on the *R1 Roadster*, a two-seater sports car on display by Roding Automobile GmbH (Roding, Germany). Comprising two rectangular sections, each measuring 772 by 585 by 2 mm (30.4 by 23 by 0.08 inches) and weighing 2.57 kg/5.7 lb, the roof panels are made via a high-pressure RTM (HP-RTM) process developed by Henkel, Krauss-Maffei (Munich, Germany) and Dieffenbacher. The matrix is Henkel's Loctite MAX 3 PUR, a three-part formula (resin, hardener and release agent). The surface PUR is provided by Rühl Puromer GmbH (Friedrichsdorf, Germany). ►

Mubea Carbo Tech mints its high-end carbon fiber composite automobile wheels using PUR and a "very complex" set of RTM tools for the all-carbon-fiber version. Starting with an 11-kg/24-lb high-end aluminum wheel, a weight savings of almost 20 percent is achieved by switching to the aluminum/carbon fiber hybrid at 9 kg/20 lb per wheel and almost 30 percent is saved with an 8-kg/17-lb all-carbon fiber wheel, the latter measuring 20 inches/508 mm in diameter with a 9-inch/229-mm rim. The global market for carbon composite wheels is estimated at roughly 1 million units per year, with a rising trend. Mubea Carbo Tech's Salzburg production is currently targeting a fraction of that: 20,000 units per year.

PUR also advanced in the infrastructure market. Dow (Horgen, Switzerland and Coreggio, Italy) showcased its VORAFORCE TW 1100 series PUR for filament-wound composite utility poles, formulated to enable fast winding speed and optimal viscosity to avoid dripping during processing. "With polyurethane we want a controlled, slow increase in viscosity so that the resin stays liquid until the winding stops, at which point we want a reasonably paced cure," explained Dow research scientist Paolo Diena. "We have now managed the catalysts to do this very effectively."

On display were wound sections of a 110-kV electrical power transmission pole. "We have supplied polyurethane for smaller filament wound 10-kV poles," Diena notes, "but the higher voltage versions are much longer and must combine multiple sections. We took on the challenge to achieve the longer open time to allow these longer sections." The PUR composite poles reportedly outperform both concrete and polyester-composite poles in durability, electrical insulation and crack resistance, and are lighter and easier to install.

Source | CT / Photo: Ginger Gardiner

THE *OTHER* TUB

Winners and also-rans in the JEC Innovation Awards display are often crowd pleasers, but what caught *CT's* attention in particular this year was a glass fiber-reinforced polypropylene (PP) washing machine tub. Molded by Polyplastic Group (Moscow, Russia), using PP resin reinforced with PERFORMAX 249 chopped glass fiber supplied by Owens Corning's (Ried im Innkreis, Austria and Toledo, Ohio) business unit in Gous-Khroustalny, Russia, it cleaned up in the 2014 JEC Europe Innovation Awards' Consumer Goods category. Developed for a leading European appliance OEM that sought these benefits for its machines sold into the Russian market, the new tub retained the 30 percent glass content of a previous but unsatisfying tub design, but the PERFORMAX 249 fiber is credited with enabling improved flow during the injection molding process and promoting better fiber/resin adhesion, the latter resulting in 15 percent higher strength and stiffness. This, in turn, enabled thinner but still hydrolysis-resistant walls, 30 percent more tub capacity (5 kg to 7 kg or 11 lb to 15.4 lb), without increasing the tub size and with spin cycle speeds of up to 1,500 rpm compared to a norm of 1,000 rpm.

GROUNDBREAKING APPLICATIONS

Cannon SpA (Borromeo, Italy) revealed that its Hanau, Germany-based Cannon Deutschland unit is the machinery supplier behind the Benteler Automobiltechnik GmbH (Schwandorf, Germany)/SGL Group joint venture Benteler/SGL Automotive Composites' joint production of carbon composite parts for BMW AG's (Munich, Germany) *i3* commuter car and *i8* sports car. Cannon contribution to Benteler/SGL's (Ried im Innkreis, Austria) fully automated production plant includes one ESTRIM high-pressure dosing unit for the epoxy resin, two 1,000-ton presses, five handling robots for the manipulation of carbon reinforcements and finished parts, and all electronic controls, safety devices and chemical storage facilities. The ESTRIM unit features high-pressure impingement mixing heads that allow the use of fast-reacting resins. Its LLD distribution method deposits a uniform liquid "ribbon" of formulated resin over the reinforcement. As a result, low-tonnage clamping presses can be used (limiting capital investment and energy use), yet the process enables part cure within three minutes.

Source | CT / Photo: Ginger Gardiner

At a press conference, RocTool (Paris, France) updated *CT* on its efforts to commercialize its 3iTech technology, in which inductor coils are directly integrated into steel tools for compression molding processes. RocTool's CEO Alex Guichard displayed a smartphone back cover for Motorola Mobility (USA), produced in a four-cavity mold at a rate of 15,000 parts *per day* by Taichung, Taiwan-based partners Complam and Ju Teng, a global manufacturer and RocTool licensee. The MotoX rear housing, a molded polycarbonate (PC) composite reinforced with thermoplastic polyester (PET) fiber, features a high-quality surface finish, which helped it earn a JEC Innovation Award in the Mobile Devices category.

Guichard noted that electronic applications currently account for 60 percent of RocTool's business and reiterated the company's aspiration to place 3iTech systems with *30* major brands of the same stature as Motorola. Toward that end, RocTool recently opened a subsidiary in Taiwan, and, at the show, announced two new subsidiaries, one in Japan and the other in Germany. RocTool also called attention to a "100 percent ecological" luggage shell that features flax fiber reinforcement. RocTool credited a 10-bar/145-psi vacuum bagging system for much of the success, and called it "ideal" for natural fiber-reinforced composites, and the system's heating and cooling quickly prevents degassing. Guichard also revealed that 3iTech technology recently broke a world record time by heating a mold from 60°C to 160°C (140°F to 320°F) in 5.3 seconds.

Used in transport interiors since the 1970s, honeycomb-cored sandwich panels form luggage bins, lavatories, galleys, tables, trays, partitions, doors and trolley carts as well as shaped sidewall and overhead panels. SMTC (Bouffere, France) announced its launch of DYNATECH thermoplastic sandwich panels, based on its acquisition of Foamed In-situ Thermoformable Sandwich technology from FITS Technology (Driebergen, The Netherlands), headed by inventor and CEO Martin de Groot.

SMTC's automated, inline panel-making process enables polyetherimide (PEI) to be foamed *in situ* as a core (with a vertical cell structure) and then receive fiber-reinforced PEI skins that are "welded" to the core. The resulting panels are reportedly easily thermoformed and then edge-sealed. Notably, DYNATECH panels require no potting, a key to weight savings (see "Learn More").

Arkema (King of Prussia, Pa.) made waves at the show with the introduction of Elium liquid acrylic thermoplastic. It is transformed using the same processes as composite thermosets, but results in parts with thermoplastic polymer chains. Elium resins are said to polymerize quickly and can be used to design structural parts as well as aesthetic elements in automotive, transportation, wind power, sports, and building and construction applications. Arkema told *CT* that Elium is engineered for reactive closed-mold processes, including RTM, infusion and Magnum Venus Product's (Kent, Wash.) Flex-Molding Process. Further, they require activation with peroxide. Officials at the show said Elium offers impact properties equal to or better than epoxy. **| CT |**

LEARN MORE

www.compositesworld.com

Read a much expanded version of this article online | short.compositesworld.com/JECParis14.

See Dow Automotive's VORAFORCE 5300 epoxy's 60-second cycle time video online | www.youtube.com/watch?v=lgtjkpySvhY.

Read more about delayed-onset cure in polyurethanes in "Processing within the PUR cure window" | short.compositesworld.com/PURinauto.

For background on FITS technology see "Thermoformable Composite Panels, Part II" | short.gardnerweb.com/WTBKM1Jl.

Read more about SMTC's DYNATECH sandwich panel concept online | short.compositesworld.com/DYNATECH.

Read more about the status of styrene *and* cobalt in "Composites Watch" (p. 15, this issue) and online | short.compositesworld.com/SCExit.

BMW Leipzig

The epicenter of *i3* production

A glimpse into the inner workings of an automaker at the forefront of serial-production autocomposites.

The composites industry is full of innovators and creative thinkers, people who move the industry forward incrementally toward greater efficiencies, lower costs and higher quality. But the *big* material and process leaps the composites community has seen throughout its history have required *more* than individual expertise. In the aerospace market, for example, The Boeing Co.'s 787 *Dreamliner* and the Airbus A350 are products of a massive, collective corporate commitment, backed by a capital investment as big, bold and precedent-setting as the envisioned product — a commitment that, to some composites pessimists, appears reckless, hasty, ill-timed and doomed.

Corporate trailblazers are rare, and rarely attempt such leaps without a good command of the materials, processes and technologies required to achieve success. Even so, the risk of failure is real, and redoubles with the size of the enterprise. Missed deadlines and technical setbacks are all the more embarrassing to risk takers for being so public — and inevitably exploited by naysayers. But at the end of what is, at best, a colossal controlled experiment is the honor and recognition as the first to reach a bold and audacious goal.

Onto this less-traveled corporate road, Munich, Germany-based BMW Group steered when, in 2009, it elected to manufacture an all-electric, four-door passenger car using carbon fiber composites. Originally denoted the MegaCity Vehicle, the commuter car now known as the *i3* is designed primarily for urban driving and can travel about 100 miles/160 km on a single charge. The *i3* features two primary structures, the aluminum Drive Module — which incorporates the powertrain, chassis, battery, and structural and crash functions — and the Life Module (passenger cell), made from carbon fiber composites. The latter is capped by a composite roof made with recycled carbon fiber, and features a spare but comfortable

Source (both photos) | BMW AG

BMW's *i3,* the first series-production car with a CFRP passenger cell, what BMW calls the Life Module, entered the European market in late 2013, and came to North America in spring 2014. Designed for city driving, the plug-in electric can travel up to 100 miles/160 km on a charge. It also features a composite roof, reinforced with *recycled* carbon fiber, as well as convenient — and very stylish — rear-hinged "coach doors" (above).

BMW Leipzig comprises 10 buildings, a test track, and four wind turbines that supply part of its electric power. In four of the 10 buildings, 100 *i3s* roll out per day. Visitors and employees at the Leipzig site's three-story reception/administration center (lower right) get a striking reminder of the plant's core purpose in an overhead stream of semifinished BMW bodies-in-white.

Source (both photos) | BMW AG

interior that also incorporates recycled materials and other composites made with natural fiber reinforcements. Exterior body panels, hood and fenders are made with what BMW terms an "unreinforced" thermoplastic.

The rear-hinged passenger doors on the *i3* (called "coach doors" by BMW) eliminate the need for a center pillar in the Life Module and give the car a more open feel, despite its relatively small size.

A SUSTAINABLE SUPPLY CHAIN

To realize the Life Module, BMW launched what has since become the largest and most complex composites material and fabrication supply chain ever established for a production automobile. It vertically integrates every aspect of the Life Module's journey, from the spinning of the polyacrylonitrile (PAN) fiber precursor and fiber carbonization to the conversion of fibers to fabric and fabrication of the carbon fiber structures themselves.

In just five years, the *i3* has become the first series-production consumer vehicle in the world to make extensive use of carbon composites in primary structural components. And long before the first *i3* rolled into an auto dealer showroom in late 2013, the project had driven a growing group of other auto OEMs to embark on similar paths — a sign that BMW might be the first to successfully complete the journey but won't be the last to attempt it (see "Learn More").

CT was offered a chance in March 2014 to visit BMW Group's *i3* manufacturing and assembly facility in Leipzig, Germany. That visit was the genesis of the following firsthand account of the materials and processes BMW engineers used to make this car and the challenges they met and overcame.

MOLDING LIFE INTO THE LIFE MODULE

The manufacture of every carbon fiber part produced for the *i3* actually begins far away, in Otake, Japan, where a joint venture of Mitsubishi Rayon Co. Ltd. (Otake) and carbon fiber maker SGL Group (Wiesbaden, Germany), called MRC SGL Precursor Co. Ltd. (MSP), produces the PAN precursor required for the manufacture of the carbon fiber used in the car.

The precursor is delivered to another joint venture, this one between BMW and SGL, called SGL Automotive Carbon Fibers (SGL ACF). Based in Moses Lake, Wash., to take advantage of relatively inexpensive hydroelectric power there, the SGL ACF facility is dedicated exclusively to supplying BMW, and it produces 50K tow on two production lines with a total nameplate capacity of 3,000-metric tonnes/6.613 million lb (see "Learn More," p. 47). The facility was designed with expansion in mind and, indeed, demand for the *i3*, coupled with BMW's plans for carbon fiber use in other vehicles, has prompted BMW and SGL to *triple* the plant's production.

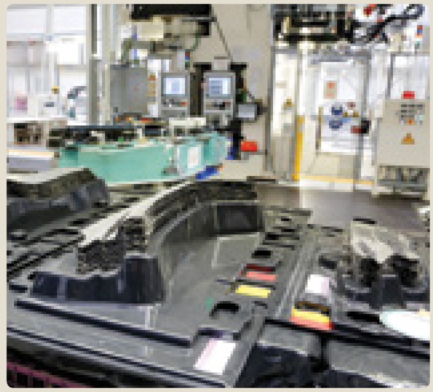
From Moses Lake, carbon fiber roving is sent to a second SGL ACF manufacturing facility in Wackersdorf, Germany. Here, the fiber is converted into a variety of fabric forms, including unidirectional tapes and multiaxial weaves (±45°/90°). These are cut, kitted and stacked in preparation for resin transfer molding (RTM).

RTM'd parts for the *i3* Life Module are actually produced at *two* BMW facilities in Germany: Leipzig and Landshut (northwest of Munich). BMW Leipzig, which opened in 2005, is the principal *i3* manufacturing hub. It RTMs *all* part numbers for the *i3* and also houses assembly operations for the Life Modules and subsequent integration of Life Modules and Drive Modules. The Landshut plant provides supplementary production of certain components, using identical processes and equipment.

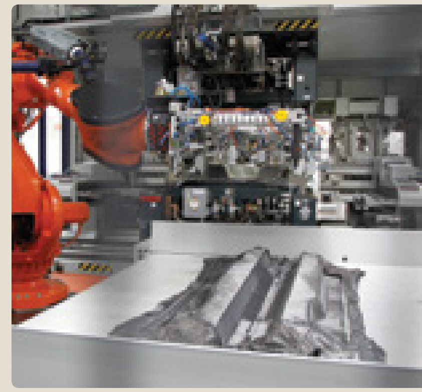
Located just northwest of the city in an open, sprawling industrial park, the Liepzig campus hosts 10 buildings and is ►

Source (all step photos) | BMW AG

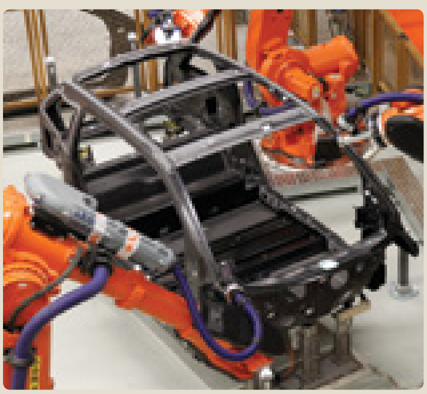
1 In the CFRP Building, carbon fiber fabrics for the life module (cut and kitted by BMW in Wackersdorf, Germany, then delivered to Leipzig) are sprayed with a thermoplastic binder.



2 Each *i3* Life Module comprises 39 different stacked kits, which are used to make 49 preforms, which are then combined to produce 16 resin transfer molded parts.

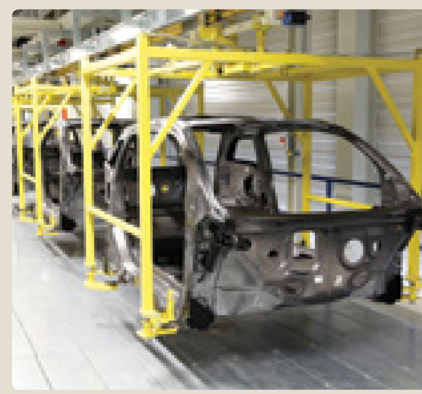


3 Kitted fabrics are preformed in a Fill Gesellschaft (Gurten, Austria) Preformliner press (see press photo on p. 28). Shown here is a part preform, fresh out of the press and ready for trimming and stapling.



6 Life Module assemblies are adhesively bonded in an entirely automated process. Here, three of the 173 ABB robots in the Body Shop put the finishing touches on a bonded module.

7 The *i3* roof features carbon fiber recycled from scrap generated during Life Module processing. The stitched, nonwoven fabric allows BMW to give the car the highly prized "carbon fiber look" and enhances the vehicle's sustainability.



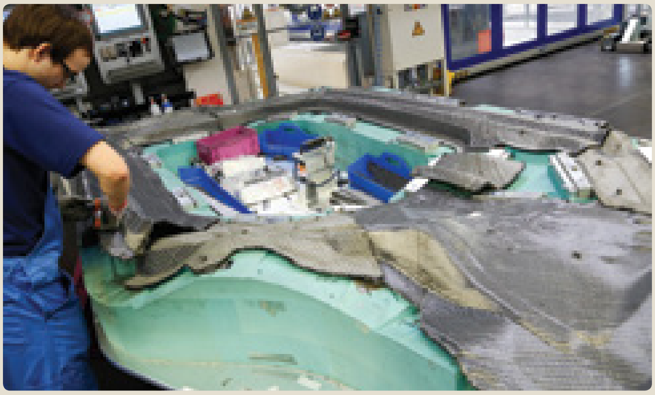
8 Finished Life Modules are transferred from the Body Shop to final assembly.

bordered on one side by four 2.5-MW wind turbines, which provide some, but not all, of the power consumed by the facility. The complex of buildings is dominated at its core by the structure that serves as the main entrance and architectural focal point — an imposing glass-and-concrete structure that conveys the modernity of the plant and the company. Inside is a three-story vaulted hall that is home to several functions presented in layers. Its reception area is backed by an elevated bank of desks, arrayed in cubicles and glassed-in offices. Overhead is a conveyor system on which BMW's production bodies-in-white move through the hall from the adjacent assembly plant on their way to paint booths elsewhere. This striking feature, visitors are told, is intended as a continual reminder to the plant's employees of the importance and immediacy of the job at hand — making cars.

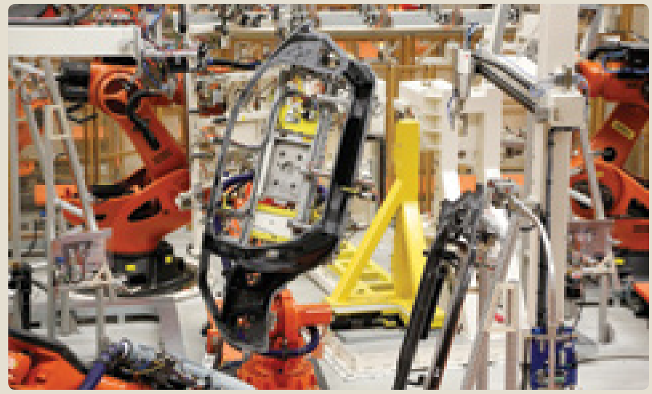
Six of the 10 buildings at BMW Leipzig are devoted to manufacture and assembly of standard (gas-powered) BMW models, including the *X1*, the *1* series (5-door) and the *2* series (coupe). Buildings 7 through 10, however, are devoted to BMW's *i*-series vehicles. BMW reportedly invested €400 million ($597 million) in these manufacturing facilities, which turn out the *i3* and the hybrid-electric *i8* sports car, due out late this year.

MOLDING THE MODULE

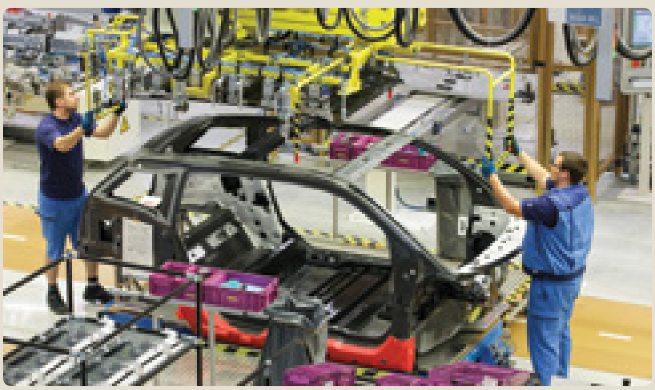
The *i3* Life Module, in its finished form, looks like a basic body-in-white car frame, but comprises several carbon fiber composite components that are adhesively bonded. Its components take shape in what BMW calls the CFRP Building. The kitted carbon fiber fabrics, produced in Wackersdorf, are delivered here for



4 Pressed preforms are cut to near-net shape, stapled together to maintain proper orientation during injection, and then layed up in a mold for resin transfer molding (RTM). Here, a technician loads a Life Module side-frame preform into its mold (this task is now automated) prior to resin impregnation, via Krauss-Maffei injection unit, and cure in a Schuler press.



5 In the Leipzig Body Shop, RTM'd parts for the Life Module are brought together. Before assembly begins, each side frame has hinge and crash reinforcements attached robotically.



9 As final assembly of the *i3* begins, the carbon fiber roof is lowered into position for attachment to the Life Module.

10 An *i3* Life Module, with doors and glass installed, is lowered onto a Drive Module, the aluminum-framed lower section of the car that incorporates the batteries, motor and wheels.

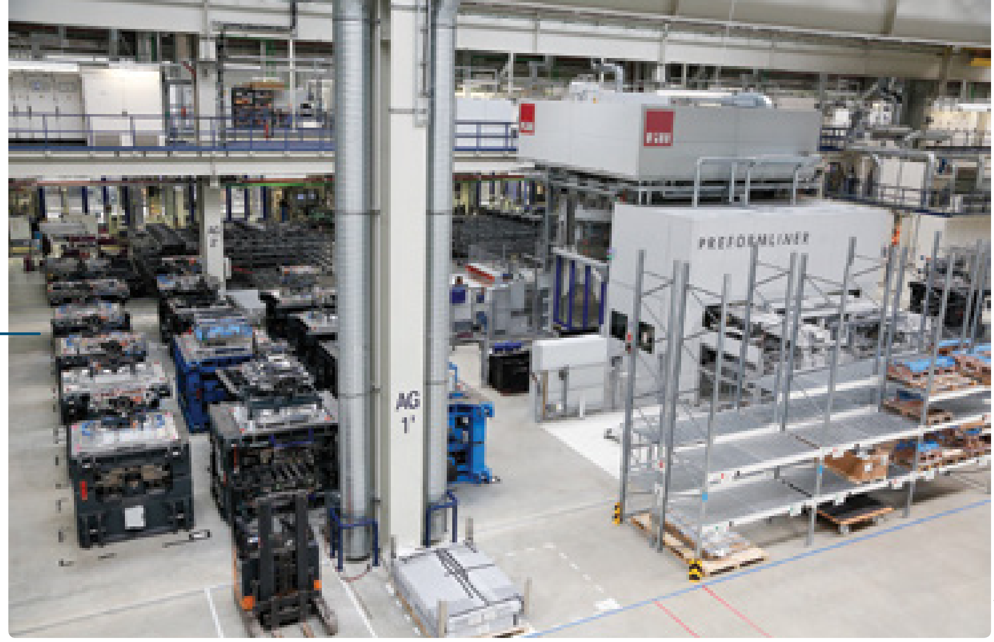
preforming, resin transfer molding (RTM) and preparation for assembly as part of the Life Module.

The most important person in the CFRP Building is a youthful, energetic and busy engineer named Rene Koschkar, head of production planning, carbon fiber parts at BMW. Standing on a mezzanine that overlooks the composites manufacturing floor, Koschkar explained the materials, tools and equipment used to fabricate the Life Module.

When kitted stacks arrive from Wackersdorf, he explained, the plies in the stacks are first stapled together to prevent slippage and then delivered to one of three Fill Gesellschaft mbH (Gurten, Austria) Preformliners in use in Leipzig. There, the stack is placed in a heated preforming mold where a thermoplastic binder is applied to the carbon fiber. The Fill Preformliner press then preforms the stack to conform it to the shape of the mold. Next, the preformed stack is transferred to a cutting station, where an ultrasonic knife is used to trim the preform to near-net shape.

Koschkar noted, here, that BMW has worked hard to minimize touch labor in composites manufacturing, relying on robotics wherever possible to staple, move, place, remove and cut stacks and preforms. This is particularly important, he pointed out, as the *i3* approaches rate production, to ensure efficiency and repeatability in its manufacturing processes.

Following ultrasonic cutting is the most important step in the fabrication process: high-pressure resin transfer molding (HP-RTM). The Leipzig plant is equipped with seven 3,000-ton hydraulic presses supplied by Schuler Pressen GmbH (Waghäusel, Germany). Each is serviced by two Krauss-Maffei (Munich,



This view of the *i3* CFRP Building from its mezzanine shows one of Leipzig's three Fill Preformliner presses (foreground). Behind it are the seven Schuler presses, each equipped with two Krauss-Maffei resin transfer molding injection units.

Source | BMW AG

Germany) HP-RTM injection units. Preforms are robotically placed in steel molds in the Schuler presses, followed by mold closure and resin injection. (The Landshut facility has three Shuler presses and six Krauss-Maffei HP-RTM injection units).

The resin matrix is Huntsman Advanced Materials' (The Woodlands, Texas and Basel, Switzerland) Araldite LY 3585 epoxy with Hardener XB 3458. It's injected, says Koschkar, at more than 40 bar/580 psi. Huntsman says the epoxy can be cured in as few as five minutes at 100°C/212°F. Koschkar would not reveal the actual cure time BMW has achieved except to say that it is "less than 10 minutes" and enables BMW to meet its rate production requirements.

Koschkar also told *CT* that BMW is comfortable with the preforming and RTM process it has in place, noting, "we have 10 years of experience with the *M*-series roof." This is a reference to BMW's *M*-series car, which offers a carbon fiber roof made via RTM. And, he adds, "We have fewer problems with dimensions with our carbon fiber parts than we do with sheet metal."

That said, Koschkar admits that BMW is constantly looking for opportunities to improve materials and process. "Our biggest challenge with RTM is curing of the part — filling the part without dry spots," he notes. Outside of RTM, he says, "our big challenge is how to reduce our scrap. We are always looking at ways to save material." This has led BMW to assess increased use of glass fiber instead of carbon fiber in some parts of preforms where material is sacrificed. The company is also looking at ways to reduce resin use via more

The Life Module Body Shop features 173 ABB 6-axis robots, each working in cordoned-off cells. Employees only touch parts to move them from cell to cell, delivering them on specialized racks through cell doors that segregate man and machine.

Source | BMW AG

efficient injection, and Koschkar notes that BMW is keeping a close eye on thermoplastic material options as well.

Wackersdorf produces 39 different stacked kits for the *i3* Life Module, and from these, BMW in Leipzig and Landshut produces 49 preforms (some stacks produce more than one preform). These preforms are then combined to mold, ultimately, 16 carbon fiber parts for the *i3*. The largest and most complex carbon fiber structures made for the Life Module are the left hand and right hand side frames. Each comprises nine preforms that are placed in one mold. The dimensional stability and strength of this structure are both critical parameters, because, as will be shown, much of the *i3's* subsequent form and assembly process is oriented around these parts.

After cure, parts are robotically demolded and transferred to one of two sandblasting stations for removal of mold release and other contaminants. Clean components are then moved to one of four KMT Waterjet Systems Inc. (Baxter Springs, Kan.) waterjet cutting machines for trimming and hole drilling. Koschkar pointed out that process control at the plant is such that discovery of fatal flaws in finished parts is rare. Quality assurance, therefore, is performed on a randomized basis only, using a nuclear magnetic resonance technology that reveals dry spots and delamination problems.

After trimming, drilling and (if necessary) quality assurance is complete, the carbon fiber composite parts are deemed ready for assembly, loaded into specialized racking systems, and then transferred to the Body Shop.

LIFE MODULE ASSEMBLY

Housed in a separate building on the Leipzig campus, the Body Shop supports some of the most technically complex aspects of *i3* manufacture — assembly of the Life Module's 16 RTM'd parts. The job is complex for two reasons: First, no mechanical fasteners are used to attach one part to another — the Life Module is completely adhesively bonded. Second, no touch labor is involved in Life Module assembly — adhesive application and part manipulation are automated.

Body Shop head Ralf Brüggemann, like Koschkar, manages most of the operations in the facility from a mezzanine that overlooks the plant floor. At first glance, the Body Shop visitor confronts a sea of orange robots (173 in all, supplied by ABB Robotics, Zurich, Switzerland), constantly turning, rotating, lifting and placing black carbon fiber parts and structures in an array of discrete, enclosed assembly cells. Only occasionally does one see shop personnel move components from one cell to another.

With Brüggemann's guidance, it becomes clear how the facility functions. Life Module assembly starts with the addition to each side frame of other parts, including door-hinge reinforcements and a door latch (both metal), an injection molded thermoplastic honeycomb crash-protection system (mounted along the frame bottom) and a 2-inch/51-mm diameter braided carbon fiber roll with a foam core, which provides support in case the car rolls during an accident. ►

After all side frame hardware is mounted, robots begin the task of integrating the side frames with the floor assembly and other structures. This is done exclusively with BETAFORCE, a polyurethane-based adhesive supplied by Dow Automotive (Auburn Hills, Mich. and Schwalbach, Germany) that is applied in the robot-equipped cells.

Brüggemann said each Life Module consumes 160 linear m/525 linear ft of adhesive, and added that BMW spent considerable R&D time determining how much adhesive to apply and where to apply it, to achieve the necessary bond strength. This involved careful measurement of adhesive bead height and width and how this correlates to the height and width of a compressed adhesive bead. In the end, says Brüggemann, BMW sought a compressed adhesive bead width of 20 mm/0.8 inch at a height of 1.5 mm/0.06 inch and learned that an applied bead width of 8 to 9 mm (0.3 to 0.35 inch) met that requirement. The goal, then, is to have each adhesive-application robot meet that bead width specification.

It takes three to four hours for BMW to assemble each Life Module. To speed adhesive curing on some parts, attending robots feature a series of small heat lamps on their end-effectors, which generate localized heat at the bond line. Dow says BETAFORCE cure time is about one minute, but that heating of the type BMW applies can shorten that time significantly. To verify bond integrity, says Brüggemann, BMW relies on ultrasonic scanning and, occasionally, dismantles a finished Life Module to assess bond strength and fidelity. "We are at 99.7 percent quality," Brüggemann claims, but adds, "we are always chasing higher quality."

Brüggemann, who has experience in other BMW assembly plants, also says that the *i3* Life Module Body Shop is "less complex than a steel body shop. Lighter weight makes product handling much simpler."

PUTTING IT ALL TOGETHER

Finished Life Modules leave the Body Shop ready for integration with the rest of the *i3* vehicle. This is done in a third facility on the Leipzig campus where Life Modules and Drive Modules finally meet on one of two *i3* assembly lines. There, automated carriages transport *i3s* from station to station along the assembly line.

Assembly starts with the Drive Module, which arrives with batteries, motor and wheels intact on an aluminum frame. Before the Life Module joins the Drive Module, BMW adds the carbon fiber roof, doors, windshield and other glass. The roof is fabricated from a stitched, nonwoven carbon fiber fabric supplied by SGL ACF. Notably, the fabric is made from carbon fiber scrap material leftover from the *i3's* weaving and HP-RTM manufacturing processes.

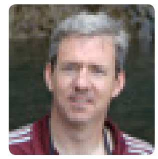
The doors, fenders and hood of the *i3* are injection molded from an unreinforced polypropylene/ethylene-propylene-diene monomer (PP/EPDM), a "thermoplastic vulcanizate." Virgin and recyclate grades of the material are used, respectively, for the exterior and interior sections. (For more on *i3* body panels, see "Learn More.")

The partially assembled Life Module is then placed atop the Drive Module frame and attached with adhesive and 10 screws. Following this, the vehicle's interior is pieced together, including seats, dashboard and dashboard components. Lighting systems for the headlamps and taillamps are added, as are fenders, motor and hood.

Despite speculation in the automotive press that BMW has been unable to meet *i3* production rates, BMW officials in Leipzig told *CT* as the June issue went to press that the rate was up to 100 vehicles per day (approaching 36,500 per annum) — on par with expectations. Further, said one official, "that number is always growing."

Adjacent to the *i3* vehicle assembly line, BMW will soon begin assembly of the *i8*, the second in what auto bloggers believe will be a *number* of BMWs that will eventually bear the *i* prefix. Like the *i3*, the *i8* also features a Life Module. And it, too, is a carbon fiber composite assembly, but one that is, according to one BMW engineer, "more complex."

Complexity seems to be a key descriptor when it comes to molding carbon fiber parts for a series electric vehicle (EV). Yet BMW appears to have managed the *i3* Life Module's progress from carbon fiber precursor to its place as the carbon fiber passenger protection cell on this premier EV with relative ease. Drawing on a wealth of experience, a secure supply pipeline and strong support from material and machinery suppliers throughout the composites industry, the company promised a comfortable, well-designed, lightweight, efficient car. Now, it's delivered. *That* has silenced doubters and positioned BMW in the lead as the automotive industry begins its conversion to composites. **| CT |**



Editor-in-Chief

Jeff Sloan, CT's editor-in-chief, has been engaged in plastics- and composites-industry journalism for 20 years.
jeff@compositesworld.com

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

Read more about BMW's process for "Molding *i3* body panels" online | short.compositesworld.com/BMWi3body.

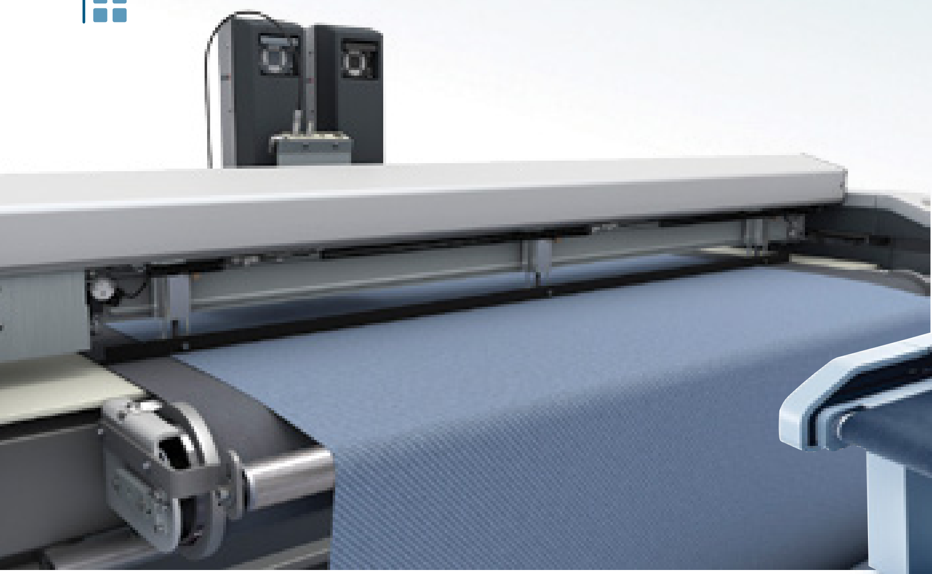
Read about the SGL/BMW Moses Lake, Wash., carbon fiber production facility in "SGL Automotive Carbon Fibers plant's two fiber lines in production" | short.compositesworld.com/6u9fjkUc.

Read more about recent carbon fiber autocomposites ventures and automotive market implications in the following:

"Auto composites quest: One-minute cycle time?" | *CT* August 2012 (p. 24) | short.compositesworld.com/G651LhR0.

"The markets: Automotive (2014)" | short.compositesworld.com/SBAuto2014.

"Automotive CFRP: The shape of things to come" | *CT* December 2013 p. 30) | short.compositesworld.com/8MhEyKb3.



Source (both photos) | Zünd

Automated CUTTING ACCELERATES

Software/hardware advances and peripheral equipment make flatbed cutters essential to automated production scenarios.

As composites molders prepare to take their place in the "part per minute" automotive industry and other fast-paced industrial sectors, *automation* is the key weapon, and production *bottlenecks* are the enemy. Among the latter, one of the most troublesome is the time-, labor- and waste-intensive process of cutting and kitting reinforcement materials.

"Compared to 10 years ago, today, there are more composites production facilities, more industrial parts being produced *and* tighter part tolerances and specifications," says Elizabeth McGruder, marketing manager at Eastman Machine Co. (Buffalo, N.Y.), one of more than a dozen machinery suppliers that have offered automated flatbed cutting systems to composite manufacturers for decades. "Manual cutting," she contends, "is no longer viable."

The good news, says Jonathan Palmer, the chief technology officer at Autometrix Inc. (Grass Valley, Calif.), is that automated cutting — in a part-per-minute or a part-per-*day* scenario — need not be prohibitively expensive. One recent aerospace customer, he contends, "recouped their investment in less than 12 months, based on time and labor savings, and employee satisfaction has improved, since hand-cutting has been eliminated — what used to take hours now takes minutes," he notes.

NESTING AND CUTTING SOFTWARE IMPROVE SPEED AND UTILIZATION

Although production speed is critical, an overriding concern is the high cost of composite materials, particularly carbon fabrics and prepregs. Part cost in manufacturing is directly related to material waste and cut-ply identification and organization. Two of the greatest tools that cutting systems suppliers bring to the task, therefore, are nesting and kitting programs resident in the software that drives the cutters. "We look at the need *behind* the customer's need, and solve business and process problems," says Paul Epperson, VP of manufacturing sales at Lectra (Smyrna, Ga.).

Nesting software automatically arranges part shapes over the material expanse in a way that minimizes waste, a complex task that, manually done, could consume days. "Automated nesting software enables manufacturers to combine several jobs and nest parts using multiple algorithms to find the highest material utilization, while still controlling ply placement within the nest to ensure accurate fiber orientation and integrity," explains Gerber Technology's (Tolland, Conn.) director of industrial product management Tom Gordon. Gerber's ComposiNest software enables a customer to nest multiple jobs from the same material, providing a greater choice

Automated, conveyorized cutting tables come in all sizes, from very long to (as shown here) short, such as these built by Zünd (Alstatten, Switzerland). A longer bed can keep materials flat for pickup (see photo, below right), while a short bed can be equipped with a "cradle" or basket to catch cut materials.

of parts to nest and, thus, a greater opportunity to compact pieces more tightly together. "Field tests have shown up to 4 percent savings in composite material use with automated nesting compared to manual nesting," he reports. The software enables nest generation and cutting 24/7, to meet peak production needs.

Kitting functions automatically label, assign layup order and assign other identifiers to cut pieces. To identify cut parts and accelerate the kitting process, Gerber's InfoMark cut-part identification system, for example, prints and applies paper labels, or customers can specify InfoJet, which automatically prints alphanumeric text on cut materials, using a variety of inks (including Boeing-spec ink).

Lectra's Diamino nesting software, developed in-house (Version 6 is the current iteration), is a key part of Lectra's composites offering, and Epperson says it is constantly revised and upgraded to achieve greater efficiency. "Even small upgrades in the nesting program can significantly reduce costly material consumption, and positively impact the bottom line," Epperson claims.

Epperson notes that with today's conveyorized cutting beds, nesting programs have become more efficient, because the available nest length is as long as the material roll, a huge benefit because end loss and process setup time are greatly reduced. He cites the case of GKN Aerospace (Cowes, Isle of Wight, U.K.), where to keep pace with lean manufacturing goals, manual and ultrasonic cutting operations were replaced with multiple Lectra tables for single-ply nesting, cutting and marking. The move significantly reduced material waste, according to Peter Steen, GKN's value stream manager, composite logistics.

David Cook, operations manager of Pathfinder USA Inc. (Hickory, N.C.), the U.S. arm of Melbourne, Australia-based Pathfinder Pty. Ltd., says nesting and kitting improvements permit customers that make very long, thin parts to cut pieces longer than the conveyorized bed from the roll in a continuous process. "The cut pieces are simply caught and folded into a 'cradle' device as the bed advances," he notes. The company's Pathworks CAD system and PathCut cutting software, developed in-house, enables manual drag-and-drop of cutting file pieces, or it can automatically select for best nest efficiency. Cook is a proponent of cutting straight from the roll, for the most efficient nests. Pathfinder's "color bundling" feature color-codes each kit's cut pieces on an optional offload display screen, a useful feature especially when multiple part kits are cut from multiple rolls of material.

Some customers don't want or need a conveyorized system, but need instead a system that can cut quickly in a prototyping or production setting, often where space is limited. Autometrix, therefore, improves throughput via optimized motion control, a feature that Palmer says is especially beneficial when cutting prepregs, for which material out time is a concern. PatternSmith software, developed in-house, guides the cutting, and has a built-in interface with software from Laser Projection Technologies Inc. (LPT, Londonderry, N.H.). Customers, then, can easily integrate LPT's projection system with the cutting process, to guide operators in cut piece pickup order, for kitting applications.

Autometrix also integrates its software with nesting software from Scapos (Scapos AG, Sankt Augustin, Germany) and Nestfab (New Basford, Nottingham, U.K.). "Our software allows importing of piece patterns from engineering CAD programs, and then offers easy-to-use tools to optimize these patterns for very smooth and fast machine cutting," Palmer contends. At Composite Solutions (Auburn, Wash.), whose Autometrix machine cuts prepregs eight hours a day, tooling manager Dave Garrett says, "The software was easy to learn and we decided to add automatic nesting with our new machine. It was a great decision and big time saver."

McGruder cites increased interest in Eastman's trademarked EasiSelect software. "If you are molding multiple parts that require several different materials, it's more efficient to cut everything you need from the first material roll, one time, then move to the second roll, and so on." The software analyzes the parts' data, identifies the materials they require, nests for minimum waste, then cuts all pieces that can be cut from each material roll at one time, then clearly marks the pieces to indicate which part kit they belong to, before moving to the next roll. Marking can be done via pen, ink jet, air brush or stick-on labels — functions integrated within the cutting head. "The EasiSelect software is very helpful for organizing a company's bill of goods, especially for complex, multicomponent parts," she adds.

AXYZ Automation's (Albrighton, Wolverhampton, U.K.) PanelBuilder software system contains advanced nesting and op-

Source | AGFM

American GFM (AGFM, Chesapeake, Va.) and parent company GFM GmbH (Steyr, Austria), offer several types of composites-related machine tools, including this model US-15 flatbed ultrasonic ply cutter, with a 32-ft/9.75m cutting length.

Source | Eastman Machine

Automated feeding of material onto the cutting table can improve production efficiency. Devices such as this double power cradle from Eastman Machine Co. (Buffalo, N.Y.) can eliminate manual feeding and offloading, improving cutting speed and worker ergonomics.

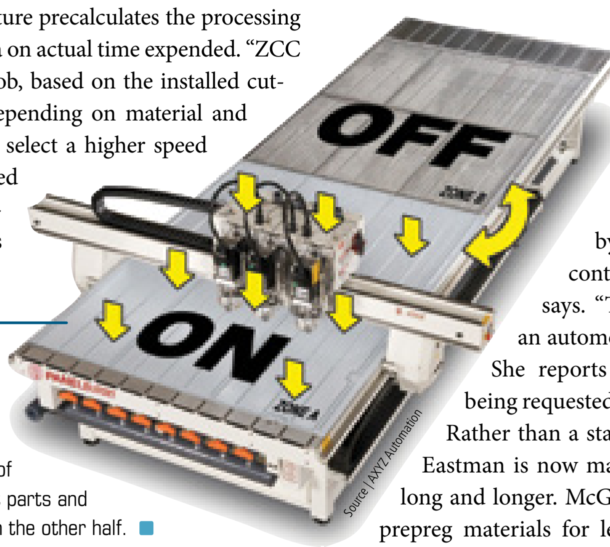
timization features that can operate in fully automated or semi-automated mode to reduce waste when cutting pre-formed sheets of material, says Robert Marshall, VP of market development. The software's material library can be used for stock control, ensuring that there is sufficient material available for scheduled jobs. PanelBuilder includes barcode labeling for identifying parts in large kits, and, says Marshall, the barcode feature also can be used to start the correct cutting program, automatically.

Axel Hofmann, the executive VP responsible for U.S. sales of Gunnar International (Rebstein, Switzerland) cutting systems, says that his customers can choose an entry-level, manual nesting application or an automated nesting software suite with a wide range of additional CAM features. "The core nesting program is developed externally by a well-known German research institute, but the front-end user interface is provided by our Gunnar workbench software partner," adds Hofmann.

Zünd (Franklin, Wis., and Alstatten, Switzerland) offers an interactive and multifunctional user interface, the Zünd Cut Center (ZCC), says Beatrice Drury, Zünd America's director of marketing and communications. ZCC's material database can track the fabricator's stock, and its "cut queue" feature precalculates the processing time for each material *and* saves data on actual time expended. "ZCC recommends the best tool for the job, based on the installed cutter configuration," adds Drury. "Depending on material and job specifications, the operator can select a higher speed for greater throughput or slower speed for better edge quality or tighter tolerances. Either way, the system helps take the guesswork out of cutting and dramatically reduces the potential for errors."

For nesting, Zünd offers several solutions, including AutoNest software (developed by Zünd UK in St. Albans, U.K.), which imports drawings from any CAD package and, says Drury, quickly designs a tightly nested layout. A virtual machine simulator allows operators to preview how the nest will appear on the cutting bed. "The software is also compatible with other nesting programs, and is designed with 'open' architecture so a customer can integrate with other systems, such as a laser projector for kitting."

American GFM (AGFM, Chesapeake, Va., part of GFM GmbH, Steyr, Austria), which manufactures several types of composites-related machine tools including ultrasonic ply cutters, has developed its NS2 Nesting system, which optimizes the cutting process in several ways, says Frank Elliott, the company's advanced initiatives coordinator. "NS2 optimizes cutting feed rate, based on our ply cutter's very high-speed feed system. It also is based on the optimum 'part shape smoothing routines' that are unique to us." He adds that AGFM provides CNC-controlled, integrated inkjet marking or labeling, which he asserts is much faster than pen marking.



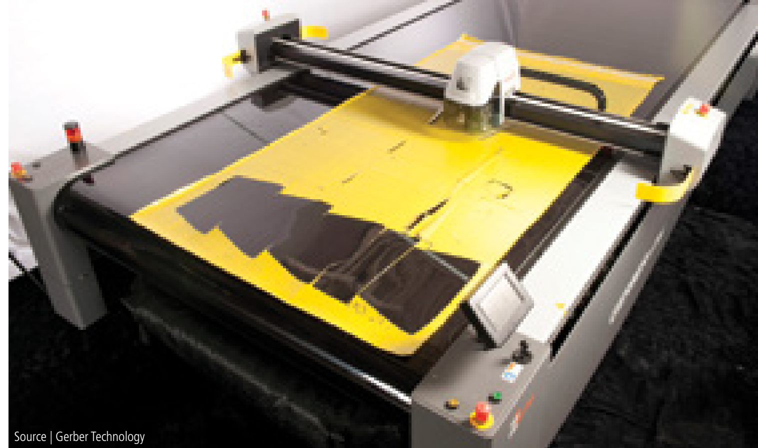
Source | AXYZ Automation

"Pendulum processing," developed by AXYZ Automation (Albrighton, Wolverhampton, U.K.), enables continuous processing on a static table, by automated switching of vacuum zones. While cutting occurs on one half of the table under vacuum, unloading of cut parts and loading of fresh material can be dome on the other half.

HARDWARE CHANGES HASTENING PRODUCTION EFFICIENCY

Eastman, says McGruder, also sees increased demand for conveyorized table systems. "We believe it's driven by the need to synchronize multiple continuous production machines," she says. "The cutting table has to keep up with an automotive manufacturing cell, for example."

She reports that *longer* conveyorized tables are being requested more frequently by customers, as well. Rather than a standard 16- to 20-ft (5 to 6.2m) length, Eastman is now manufacturing tables that are 36 ft/11m long and longer. McGruder explains that longer tables keep prepreg materials for lengthy parts from folding or rolling,



All flatbed cutter vendors offer ways to identify cut parts and accelerate kitting. Gerber Technology's (Tolland, Conn.) InfoMark cut-part identification system (top photo) prints and applies paper labels, or customers can specify InfoJet, which prints alphanumeric text on cut materials using a variety of inks. Melbourne, Australia-based Pathfinder Pty. Ltd.'s M5-180 cutter (bottom photo) can be ordered with an offload display computer screen to facilitate use of the company's Color Bundling feature for faster kitting.

which could compromise their integrity. Greater length also enables multifunctionality: While cutting occurs on one end, manual or robotic piece pickup and kitting can occur on the other.

Marshall explains that AXYZ's static tables can be configured with twin virtual processing areas, which operate simultaneously in "pendulum processing" modes that, in effect, "lengthen" the table. The control software automates the switching of vacuum zones, allowing the cutting of one set of part pieces on one half of the table, while the other half is unloaded, then reloaded with new material to start again. "Pendulum processing allows true continuous production," he asserts.

Lectra offers customers a modular, add-on bed extender for conveyorized systems, says Epperson, to increase the available flat space for cut-piece pickup and kitting. Ink printers integrated into the cutting heads print part identifiers directly on prepreg materials that can't be marked with a pen or adhesive label.

Drury says Zünd's table extensions can double the machine length to free up space for cut piece offloading. For longer machines, half extensions are also available. On prepregs, Zünd multi-tool cutting heads can be equipped with an inkjet marking system from Videojet (Wood Dale, Ill.)

Gunnar's Hofmann says, "The GUNNAR TTC119 cutting machines are manufactured to lightweight standards, and as a result have one of the smallest installation footprints." Despite its smaller size, output is reportedly equal to larger tables thanks to system speed, and he adds, "Less space and equipment are needed for the same output, which lowers overall production costs. For example, one machine operator can manage both the cutting and the offloading, with the automatic material advance."

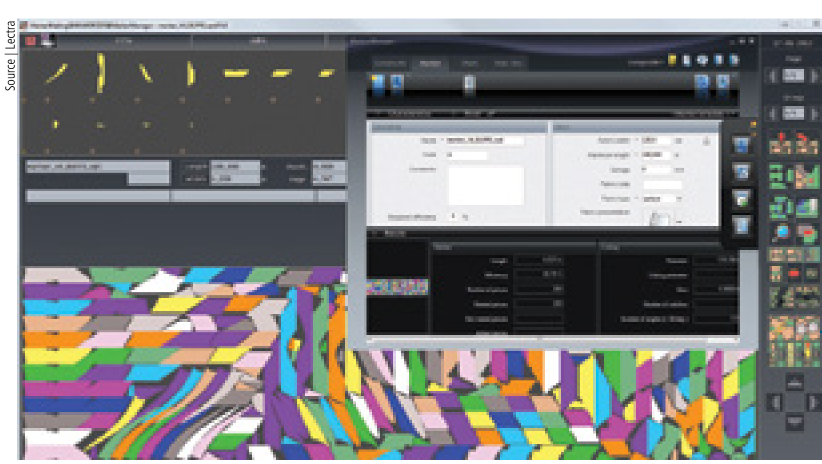
AUTOMATED FEEDING VS. MANUAL LOADING

To increase machine efficiency, cutters can be equipped with a custom-designed system that facilitates continuous cutting by automatically feeding and spreading the rolled broadgoods.

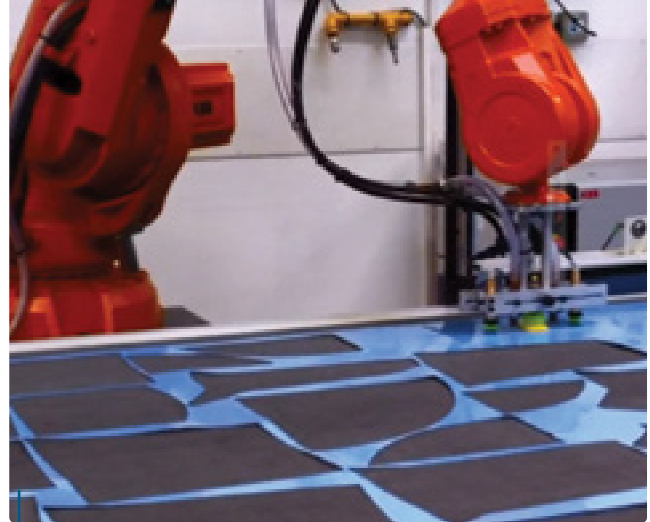
Pathfinder can pair its Easy Loading Feeding Table with its conveyorized tables. As the device feeds material into the machine, material alignment with the table edge is maintained via the system's optical sensors.

Eastman sells several automated feeding and spreading systems, engineered and built in-house, for typical roll widths and weights. These include motor-driven roll stands, and power feed systems that can handle multiple rolls. Infrared edge control maintains precise material, and tension controls preserve fiber alignment. "We're helping customers to address time-consuming problem areas," McGruder notes, adding, "Automation relieves workers from having to manually load the material onto the table, for better ergonomics and higher speed." Also available are rewinding modules on the downstream end of the table, which gather long cut strips or pieces for later laydown in the mold, typically for wind blades or other large parts.

"We studied one customer's operation and found that actual cutting was occurring only 38 percent of the work day, says Lectra's Epperson. Lectra's patented Eclipse feeding option now allows the head to continue cutting even as material is advanced onto the conveyorized cutting surface. This prevents wasted "dry haul time," he says, and the gradual and continuous flow of cut parts also eases the off-loading task. He asserts that Eclipse alone enables a 5 percent or greater productivity increase in a production setting. Using a software feature employed



This screen shot of Lectra's (Smyrna, Ga.) Diamino nesting software (Version 6) shows how composite material is "nested" or grouped tightly together to avoid unnecessary waste. Color-coding identifies each kit's pieces.



Robots can be integrated into a cutting table system, like this one from Assyst Bullmer (Wakefield, U.K.) to assist in, or take over entirely, the cut piece offloading step.

Source | Assyst Bullmer

in the garment industry, Lectra's CAD system can tell the head to identify and cut the parts from parallel strips, explains Epperson, dispensed simultaneously from narrow material rolls, such as four parallel 18-inch/450-mm wide strips of prepreg.

Gerber's single-ply material feeding device, used in conjunction with its conveyorized tables, features a synchronized cradle that accurately feeds dry composite material onto the cutting surface with little or no tension, says Gordon. A built-in infrared edge sensor ensures precise table alignment.

Assyst Bullmer Ltd.'s (Wakefield, U.K.) director David Bell also points out, "If prepreg pieces are cut with the release film in place, the robot must remove it before placing the piece in the mold, which really slows down the process." The solution? The company recently added a new device to its roll feeding systems that removes the interleaved paper or polymer film — top film, bottom film or both — from prepreg material as the material is fed onto the cutter, to improve robotic pick and place.

"Large cutting machines often have a problem when it comes to holding material securely in place while being cut," observes AXYZ's Marshall. AXYZ's remedy is its "auto-zone manager," which automatically adjusts the vacuum deck configuration during cutting so that the vacuum is focused only at the area being cut. The enhancement reduces waste caused by sheet movement and requires no human intervention.

AGFM has a totally automated material dispensing system that is controlled by the machine's CNC program, says Elliott. It can automate the change from one roll of material to a different material roll, saving considerable time.

ROBOTIC CUTTING-TO-MOLDING INTEGRATION

"Using robots to pick up cut pieces from a composite ply cutter and place them either into a tool or a direct press former is logical and essential where composites are required in high-volume production — the challenges are in the details," says Assyst Bullmer's Bell.

Although Assyst Bullmer supplies static and conveyorized cutters, for robotically assisted applications, only a conveyorized table can move the pieces forward to the robot. If a robot is to choose and place a ply accurately in a tool, it must know the exact orientation and location of the piece on the table. "If the robot's needs control the nesting, so that the pieces come out in the order it would place them in the tool," he points out, "nesting efficiency … is unacceptably low." The company has developed nesting software that harmonizes the often conflicting need to simplify pick-and-place for the robot and the desire to minimize waste by nesting pieces most efficiently. Bell points out that the robot can pick up pieces individually or, better, pick up a full "window" of parts, leaving the scrap to be pushed into a container by the moving table surface.

"We can recommend an effective cutting solution that's compatible with many different CAD, cut file formats and ERP systems, *and* offer standard interfaces for robotic communication on the offload side," says Gunnar's Hofmann. "For us, it is important to work together with our customers to analyze their specific needs. He adds that the company's robotic interface provides a fast automatic way to offload cut parts. "But, depending on the application, our laser projection identification system is an efficient way to optimize manual offloading, as well."

Zünd's "open" control systems make that company's cutting tables compatible with many other types of peripheral equipment, including robotic control systems, which facilitate their incorporation into high-rate production molding cells: "We're not selling a canned solution," says Drury. "We offer customized, and adaptable, solutions for many processing situations."

AGFM actively incorporates commercial robots, as well as internally produced automated pick-and-place systems, into its machine systems, notes Elliott. "These types of application requests from customers are reviewed in detail by our technical staff to determine the best solution," he adds.

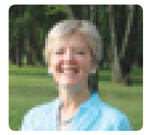
Lectra's Epperson, whose background includes robotic manufacturing, sees more automation on the horizon, including robotic pick and place, but points out that his customers typically add such systems *after* purchase of a cutting table. As regards robotic integration, Cook sees the utility, but still believes that a human operator is best: "There might be a benefit with a robot, but a human operator can inspect the cut pieces and identify potential quality issues."

CW LEARN MORE
compositesworld.com

Read this article and two Web-only sidebars online *and* view some of the flatbed cutting systems described here *in action*, via video | short.compositesworld.com/AutoCut.

KEEPING UP WITH THE PRESS

In the end, it comes down to making molding processes more efficient to compete with lightweight metals, particularly in the automotive sector. But a production line is only as fast as its slowest link. Automated cutting plays a critical role in removing the bottlenecks that remain in the industry's pursuit of production speed. | CT |



Technical Editor
Sara Black is *CT's* technical editor and has served on the *CT* staff for 15 years.
sara@compositesworld.com

Applications

PUBLIC TRANSIT | Modular composites update Sao Paulo ferries

The Brazilian state of São Paulo recently undertook a project, through its state-controlled company DERSA, to improve public transportation infrastructure. Formed in 1969, DERSA manages state highways and operates ferry boat services along 622 km/383 miles of coastline. Scheduled for completion this year and intended to reduce commute times by 30 percent, the project involved refitting 12 car ferries and replacing their steel superstructures with composite constructions. DERSA engaged distributor **Barracuda Advanced Composites** (Rio de Janeiro, Brazil) not only to specify and supply the composite materials, but also to engineer the superstructure design.

Source (both photos): Barracuda

Barracuda's CEO Jorge Nasseh says the project called for a composite deck, side-rail assemblies and a topside operator cabin as prefabricated, 3m by 2.4m (9.75-ft by 7.8-ft) flanged panels, which could be assembled and bolted onto the existing steel hulls. The modular design allows the addition of panels to fit the various ferry lengths, which range from 35m to 48m (114 ft to 156 ft).

Panels are sandwich constructions, but flanges are solid (uncored) to optimize assembly by adhesive bonding and mechanical fastening. Larger, 75-mm/3-inch thick flanges are used where panels are bolted to the hull's steel flanges (see computer rendering). Multiaxial fabric from **Owens Corning** (Toledo, Ohio) forms the faceskins, over a polyvinyl chloride (PVC) Divinycell H80, 32-mm/1.3-inch thick core supplied by **DIAB International** (Laholm, Sweden). The core is grooved by Barracuda in a proprietary manner that Nasseh says improves infusion flow. The resin is an orthopolyester formulated by **Ashland Performance Materials** (Columbus, Ohio). He adds that the infusion process was modeled prior to finalization of the design using Polyworx software from **Polyworx** (Nijverdal, The Netherlands). To meet transportation requirements, each panel is overcoated with an Ashland fire-retardant polyester.

"The new composite design will allow overall weight reduction, fuel economy, less maintenance cost," says Nasseh, "and offers a better cosmetic design."

TOWERLESS TURBINE | Airborne system powers rural locales

Far from the power grid, remote settlements pay dearly for electricity. In Alaska, for example, the cost of energy from diesel generators reportedly can reach $1/kW-hr (compared to $0.10/kW-hr or less for coal-, natural gas- or wind-sourced energy in the lower 48 states of the U.S.). Altaeros Energies (Boston, Mass.) aims to change that. A spin-off from the Massachusetts Institute of Technology (Cambridge, Mass.), the startup's lighter-than-air Buoyant Airborne Turbine (BAT), can harvest the more consistent winds at higher altitudes because its elevation is not limited by the need for a tower. A $1.3 million (USD), 18-month demonstration project, partially funded by the Alaska Energy Authority's Emerging Energy Technology Fund, is set, at a site south of Fairbanks, to break a world record as the highest wind turbine ever deployed — 1,000 ft/308m.

Adapted from aerostats (blimps) that have long lifted heavy communications and weather equipment skyward, the BAT consists of a helium-filled inflatable shell surrounding a turbine. High-strength tethers do double-duty, holding the BAT steady and transporting electricity to a power microgrid on the ground (Altaeros estimates the remote power and microgrid market at $17 billion per annum). Altaeros cofounder/CEO Ben Glass says the BAT prototype uses a small *Skystream* turbine, from XZERES Wind Corp. (Wilsonville, Ore.), with carbon fiber composite blades made by the University of Maine's **Advanced Structures and Composites Center** (Orono, Maine). Altaeros, however, replaced the turbine's aluminum nacelle with one made in-house to reduce turbine weight, says Glass, using a sandwich construction of three-ply carbon fiber skins over an aramid honeycomb core. "BAT is a low-cost power solution … that can power more than a dozen homes," explains Glass, and can be transported easily and set up without the need for a crane.

Source: Altaeros

In 2013, Altaeros successfully tested a proof-of-concept BAT in 45-mph/72-kmh winds and at a height of 500 ft/152.4m in Maine, and is currently working on rotor and nacelle designs for commercial-scale BAT deployments. The first product will have about 30 kW of capacity, slightly larger than the prototype, followed by scaled up products in the 100- to 200-kW range.

Calendar

JUNE

June 2-5, 2014 — **SAMPE Tech 2014**
Seattle, Wash. | www.sampe.org/events

June 2-6, 2014 — **MCM-2014, the XVIII International Conference on Mechanics of Composite Materials**
Riga, Latvia | www.pmi.lv/New/EnConferenceAbout.html

June 8-11, 2014 — **1st International Conference on Mechanics of Composites (MECHCOMP2014)**
Atlanta, Ga. | https://sites.google.com/site/mechcomp2014

June 9-12, 2014 — **RAPID 2014**
Detroit, Mich. | www.sme.org/rapid

June 10-11, 2014 — **SAE 2014 Design, Manufacturing and Economics of Composites Symposium**
Madrid, Spain | www.sae.org/events/dtmc

June 11-12, 2014 — **CW CompositesWorld's Thermoplastic Composites for Automotive Conference/amerimold 2014**
Novi, Mich. | http://www.amerimoldexpo.com/zones/track-info?alias=thermoplastic-composites-for-automotive

June 26-28, 2014 — **Composites Pavilion – American Institute of Architects Convention 2014**
Chicago, Ill.| Convention.aia.org/event/convention-home.aspx

JULY

July 13-19, 2014 — **ICCE-22, 22nd Annual International Conference on Composites and Nano Engineering**
Island of Malta | www.icce-nano.org

SEPT

Sept. 9-11, 2014 — **SPE's Automotive Composites Conference and Exhibition (ACCE)**
Novi, Mich. | speautomotive.com/comp.htm

Sept. 10-11, 2014 — **CW TRAM – Trends in Advanced Machining, Materials and Manufacturing at IMTS 2014**
Chicago, Ill. | www.tram-conference.com

Sept. 11-12, 2014 — **FRP Bridges 2014**
London, U.K. | www.netcomposites.com/calendar/frp-bridges-2014/1335

Sept. 23-25, 2014 — **SAE 2014 Aerospace Manufacturing and Automated Fastening (AMAF) Conference and Exhibition**
Salt Lake City, Utah | www.sae.org/events/amaf

Sept. 23-26, 2014 — **HUSUM WindEnergy 2014**
Husum, Germany | www.husumwindenergy.com/content/en/start/start.php

Sept. 30-Oct. 2, 2014 — **IBEX 2014**
Tampa, Fla. | www.ibexshow.com/tampa2014.php

OCT

Oct. 7-9, 2014 — **Composites Europe**
Düsseldorf, Germany | www.composites-europe.com

Oct. 13-16, 2014 — **CAMX – The Composites and Advanced Materials Expo**
Orlando, Fla. | www.thecamx.org

Oct. 27-29, 2014 — **SAMPE China 2014**
Beijing, China | www.sampe.org.cn

NEW Products

Introduced at JEC Europe 2014

Carbon fiber/epoxy prepreg for autocomposites

Aerospace prepreg and fiber supplier **Hexcel** (Stamford, Conn.) introduced prepregs designed specifically for automotive applications. Topping the list was HexPly M77, a rapid-curing carbon fiber/epoxy prepreg from which automotive components and sporting goods reportedly can be press-cured in a two-minute cycle at 150°C/302°F (80 bar/1,060 psi pressure). The prepreg's low tack allows the prepreg to be cut easily by laser cutter. Once in the mold, HexPly M77's "optimized" gel time allows the resin to flow into contours to produce the geometries required. A T_g of 125°C/257°F enables cured parts to be demolded while hot, to speed cycles. HexPly M77 also is supplied as HexMC compound developed specifically for compression molding processes.

Also new is HexPly M79 low-temperature-cure prepreg for wind blades and marine applications. Cure cycle options include an 8 to 10 hour cycle at 70°C/158°F, or a more rapid cycle (4 to 6 hours) at 80°C/176°F. HexPly M79 has an outlife at room temperature of six weeks. **www.hexcel.com**

Styrene-free vinyl-less-the-ester

Reichhold Inc. (Research Triangle Park, N.C.) unveiled ADVALITE. Technically a vinyl "hybrid," it offers no-VOC performance without the use of reactive diluents, which effectively eliminates the "ester" label. ADVALITE vinyl hybrid liquid and ADVALITE vinyl hybrid hot-melt prepreg resins reportedly exhibit good mechanical properties and temperature resistance up to 200ºC/392°F. The resin is cured using standard free-radical inhibitors and initiators. This is said to allow significant processing advantages when compared to epoxy resins. The resins' low exotherm allows for rapid curing of thick laminates without cracking. ADVALITE liquid resins can be used in resin transfer molding (RTM), infusion, filament winding, liquid molding and pultrusion processes. The ADVALITE hot-melt prepreg resins can be directly coated or adhesive filmed for fiber impregnation. Reichhold says the materials have 3.5 to 4 percent elongation on some parts. **www.reichhold.com**

Noncontact optical encoders

Renishaw (Hoffman Estates, Ill.) debuted ATOM, a noncontact optical linear and rotary incremental encoder system. With a readhead as small as 6.7 by 12.7 by 20.5 mm (0.26 by 0.5 by 0.8 inch), ATOM is said by Renishaw to be the world's first miniature encoder to use filtering optics with auto gain control (AGC) and auto offset control (AOC) for enhanced signal stability and dirt immunity. Applications include laser scanning, precision microstages and space-critical motion control (cutting tables, machining fixtures), inspection and metrology. ATOM features a low Sub-Divisional Error (SDE), low jitter, analog speeds to 20 m/sec and digital resolutions to 1 nm when used with Renishaw interpolation electronics. **www.renishaw.com**

Rapid-cure epoxies and polyurethanes

Although the big news at **Dow** (Schwalbach, Germany and Midland, Mich.) was Dow Automotive's new, trademarked VORAFORCE 5300 epoxy family (see "2014 JEC Europe Review," p. 18), the company also premiered its VORAFORCE 5200 series, which offers low viscosity, high flow and fiber wetting and rapid cure (4 and 18+ minutes coupled with a long possible injection time at very low viscosities) for large glass, carbon or aramid fiber-reinforced composite parts that require rapid injection times. Also new, the VORAFORCE 5100 series delivers even faster production (cure in less than three minutes), with similar processing, capability, strength and quality. It's suitable for resin transfer molding (RTM) of automotive and commercial transportation components.

Also new was the VORAFORCE TW 1100 polyurethane series, which reportedly enables full 110-kV composites pole winding capabilities and, thus, complements Dow's available range of polyurethane systems for smaller poles (e.g., 10 kV). In this application (see photo), it helps improve elongation, toughness, and crack resistance as compared to conventional materials and other types of resins. Advantages are said to include a fast reaction profile and workability in secondary cutting and drilling. **www.dow.com**

Composites cost-estimating software

Galorath (El Segundo, Calif.) announced that its SEER for Manufacturing cost-estimating software is now available as an integrated module of **Dassault Systèmes'** (Waltham, Mass.) CATIA V5 design software. This will allow manufacturers to use SEER's Ply Cost Estimator in CATIA and let fabricators model and test composites manufacturing processes and evaluate tradeoffs during the earliest stages of product design. SEER features composite part cost estimates for labor (setup, direct, inspection, rework), material and tooling. Estimates are updated and refreshed as the design evolves, and the user can save multiple scenarios for each part to compare and trade options — a feature that helps designer's understand the cost of design decisions. Part cost estimates include ply placement, debulking, core prep and machining, panel layup, hot press forming, curing (autoclave, RTM or VARTM), postcure trim, nondestructive inspection, tool prep, cleaning and tool design and fabrication. **www.galorath.com; www.3ds.com**

Surfacing veils

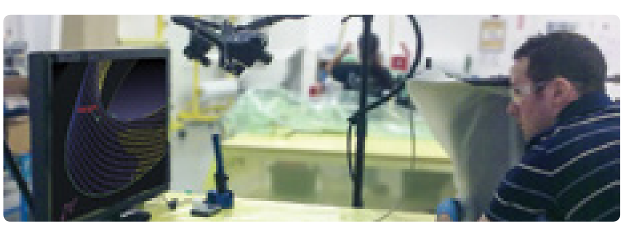
Technical Fibre Products Ltd. (TFP, Burneside Mills, U.K.) and **Technical Fibre Products Inc.** (Schenectady, N.Y.) showcased their newest Optiveil carbon fiber veil, which they claim is one of the lightest nonwovens available, at only 2 g/m^2 or 0.1 oz/yd^2. The Optiveil product line ranges up to 400 g/m^2 and is used for electrical conductivity, EMI shielding and stabilization for fragile reinforcements and as an adhesive substrate. Other developments include recycled carbon nonwovens and an extended range of lightweight PEEK, nylon, PEI and PPS thermoplastic veils, which can be incorporated as interlaminar layers in a composite structure to reduce microcracking and, thus, improve fracture toughness. **www.tfpglobal.com**

New-generation, recyclable PET foam core

3A Composites (Sins, Switzerland) unveiled what it characterized as a "completely new technology platform" for polyethylene terephthalate (PET) foam core materials, under the tradename AIREX GEN2. The foam reportedly features a very homogeneous cell structure, yet has enhanced mechanical properties compared to its predecessor, AIREX T92. While it remains a recycled and recyclable material, its formability and processability have been improved. Thanks to a lean and highly automated production process, GEN2 reportedly will offer customers a considerable total cost savings in the end application. **www.3acomposites.com**

Versatile ply placement guide

Anaglyph Ltd.'s (London, U.K.) visitors saw the latest versions of its software products Laminate Tools, LAP and CoDA and the new software/hardware capabilities of its trademarked PlyMatch ply-placement technology in action. Unlike conventional fixed, overhead-mounted laser ply placement



systems, the PlyMatch system is designed to be uniquely flexible: Notably, its laser projection head and support arm and/or the mold tool can be moved by the technician without system recalibration (the system self-calibrates) and its compact design enables it to guide manual placement on vertical surfaces and inside enclosed spaces. Further, ply data can be generated by any CAD application. **www.anaglyph.co.uk/Placement.htm**

3-D beam weaving

Biteam (Bromma, Sweden) displayed the first sample, an I-beam demonstrator, made using a new weaving technology capable of directly manufacturing beam-like 3-D profiles in which fiber orientations in the web and flange are, respectively, +θ°/-θ° and 0°/90°. Developed for the motor sports, automobile and building/construction markets, among others, the beam's web and flange fibers intersect in the z-direction (through the thickness), making the preform delamination-resistant. This makes it more capable of bearing shear and tensile loads as well as imparting structural stability during premold handling and impregnation steps. **www.biteam.com**

Economical press molding

Dieffenbacher (Eppingen, Germany) debuted the Compress Lite, its cost-effective compression molding machine designed to process thermoset- and thermoplastic-based composites. The low-height machine features an energy-saving drive and offers what is said to be identical deflection of the table and ram to help provide consistent component thickness and quality.

Access to the table is provided from all four sides, easing tool changes and allowing good automation integration. Press forces in the series range from 4,000 to 12,500 kN.

In the high-pressure resin transfer molding (HP-RTM) market, Dieffenbacher emphasized its fully automated production system for the manufacture of carbon fiber composite components. It includes preform production, the HP-RTM press and equipment for post-mold work. Preforming includes fabric cutting operations, binder application and transfer of preforms to carriers. Dieffenbacher has been cooperating in HP-RTM with KraussMaffei (Munich, Germany), which supplies resin injection systems for many Dieffenbacher presses. **www.dieffenbacher.de**

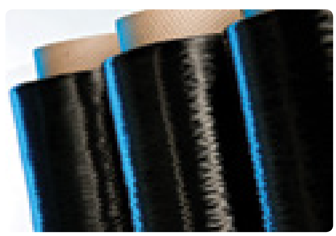
Fast-cure epoxy for HP-RTM

For serial automotive production, **Cytec Industries Inc.** (Woodland Park, N.J.) launched XMTR50, a two-part epoxy resin system developed specifically for the high-rate manufacture of components via high-pressure resin transfer molding (HP-RTM), claiming a cycle time of three minutes at 120°C/250°F for a T_g of 135°C/275°F. Also new, MTM 23, the industry's first application of a volatile-organic compound (VOC)-free thermoset vinyl hybrid resin woven glass reinforced prepreg, enables the manufacture of parts by press molding in five minutes or less. Cytec also introduced FM 3500 EZP peel ply, a resin-rich, fiber-free composite bonding product that reportedly eliminates the need for additional prebond surface preparation. Formulated specifically for one-piece removal, it exhibits handling properties that support manufacturing efficiency. The peel ply's long shop life, durability during extended cure cycles and compatibility with most 177°C/350°F-cure prepregs allow for manufacturing flexibility. **www.cytec.com**

Large, 3-D part machining center

Thermwood (Dale, Ind.) featured its Model 77 5-axis CNC machining center for large-scale composites applications. The M77 is specifically developed for three-dimensional machining. Its stationary table and high-wall enclosure was designed using advanced 3-D software, using finite element analysis. All major weldments are stress-relieved to provide long-term stability. Laser-calibrated to assure accurate absolute positioning and repeatability, it features full, 5-axis simultaneous motion, executes extremely large CAD-generated programs at high speed without pausing and self-performs automatic axis-alignment verification. Available in standard 5-ft by 10-ft (1.5m by 3m) and 10-ft by 10-ft formats, the center's table length can be increased on request in 5-ft increments to a 60-ft/18.3m maximum. **www.thermwood.com**

Carbon fiber, sized for thermoplastics



Toho Tenax Europe GmbH (Wuppertal, Germany) talked about the impending launch of a Tenax carbon fiber filament yarn with a new tailored sizing for thermoplastic and high-temperature applications. The commercialization of Tenax-E HTS45 P12 (12K, 800tex) and Tenax-E IMS65 P12 (24K, 830tex) is planned for 2014. Both types are compatible with polyetheretherketone (PEEK), polyphenylene sulfide (PPS), polyetherimide (PEI) and other high-temp thermoplastics as well as low-temperature polyamide-based systems (PPA, PA 12, PA 6, etc.). The P 12 sizing also allows low-viscosity and in-situ reacting thermoplastics to be combined with Tenax fiber. Both fibers can be processed as woven fabrics, multiaxial fabrics, commingled yarn and 3-D fabrics, and are suitable for pultrusion and prepreg processes. **www.tohotenax-eu.com**

Infusion pressure-control valve

For resin infusion processes, **DD|Compound** (Ibbenbüren, Germany) offered its MTI valve, which addresses a common problem: Prior to infusion, the resin is at ambient pressure. When it enters the mold cavity during infusion, the vacuum compaction is released, resulting in a gradient of higher thickness and lower fiber volume across the part from resin inlet to vacuum outlet. The Boeing Co. (Chicago, Ill.) developed the Controlled Atmospheric Pressure Resin Infusion (CAPRI) process to address this, using an additional vacuum pump to reduce the pressure in the resin feed tank and thus reducing the pressure differential. The MTI valve reportedly accomplishes the same goal by *simulating* a calculated delta in pressure — e.g., 150 mbar for 55 percent fiber volume fraction. The valve automatically shuts off when the pressure equalizes, based on these calculations. **www.dd-compound.com**

New end mills for composites

Cutting tool supplier **Sandvik Coromant's** (Sandviken, Sweden and Fair Lawn, N.J.) highlighted CoroMill Plura, a brazed end mill available in diameters of 6 to 18 mm, with internal cooling and 5° ramping capability. The end mills feature a high-performance grade of PCD optimized for CFRP and developed by Sandvik to deliver maximum possible tool life and offer the potential for end mill reconditioning. For a typical 2-D surface machining application, the end mill design can permit cutting speeds ranging from 200 to 400 m/min (656 to 1,312 ft/min, with 0.03- to 0.06-mm/rev (0.001-inch to 0.002-inch/rev) feed rates for rough cutting, and an 0.02- to 0.04-mm/rev (0.0007-inch to 0.0015-inch) rate for finishing operations. **www.sandvik.coromant.com**

Commercial-grade carbon fiber for thermoplastics

SGL Group's (Wiesbaden, Germany) new Sigrafil C30 T050 TPI is sized specifically for continuous reinforcement of thermoplastics. The 50K tow is designed for high interface performance, particularly with polyamide (PA), in PA 6, PA 11 and PA 12. Key benefits include high tensile strength and mechanical performance in thermoplastic matrices (this specially sized fiber, tested in a PA 6 matrix, yielded a bending strength more than twice that possible with standard sizing — 113 MPa vs. 55 MPa). The product also delivers low levels of twist/false twist, and the potential for low areal weight. Fiber forms include unidirectional tapes and organic sheets, long fiber-reinforced thermoplastics (LFTs), and hybrid yarns. **www.sglgroup.com**

Fabrics for Class A surfaces, and more

FORMAX (Leicester, U.K.) showcased fabrics designed to reinforce automotive composites. The aFORM line of specialized +45°/-45° materials ranges in weight from 150 to 300 g/m^2 and the fabrics are optimized for Class A surface finishes. Alternatively, the company also offers the reFORM line, a variety of highly drapeable recycled materials produced from dry fabric waste. FORMAX also offers a Drape Simulation service that enables customers to optimize the performance of their fabrics by identifying wrinkling and resin permeability issues. FORMAX also announced that it now has the capability to lay multiaxial layers at low angles, ranging from 30° to as small as 22.5°. **www.formax.co.uk**

Binding, toughening agent

EMS-GRILTECH (Domat/Ems, Switzerland) introduced Griltex CE, a combined binding agent and toughener for thermoset resins. Developed for use with epoxies, polyurethanes, phenolics or cyanate esters, it stabilizes fiber structures or tapes and prevents shifting during resin transfer molding processes. As a toughener, it offers an increase in residual fracture strength values in compression after impact (CAI) tests of up to 65 percent. Shear strength also shows an improvement of 33 percent. **www.emsgriltech.com**

Thermoplastics-compatible glass fiber

AGY (Aiken, S.C.) announced in Paris a range of S-2 Glass and E-glass yarns with thermoplastics-compatible sizings. Tailored for optimum fiber/resin bonding, the sizing also facilitates the use of the fibers in conventional conversion processes, such as fabric weaving. AGY says its more narrowly tailored systems improve glass performance vs. fibers sized with multi-use sizing systems, making them more suitable for demanding applications in sporting goods, consumer electronics enclosures and medical devices. AGY says the new sizings are formulated to work with a wide variety of polymer chemistries and are available in a range of fiber diameters. Sizings are said to be suitable for high-temperature resins — polyetheretherketone (PEEK), polyetherketoneketone (PEKK), polyetherimide (PEI) and polyphenylene sulfide (PPS) — as well as engineered polyamides (PA 6, PA 6.6, PA 11, PA 12), polycarbonate and polybutylene terephthalate (PBT). **www.agy.com**

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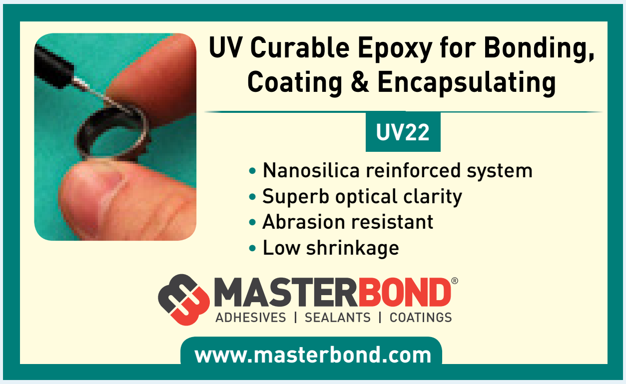

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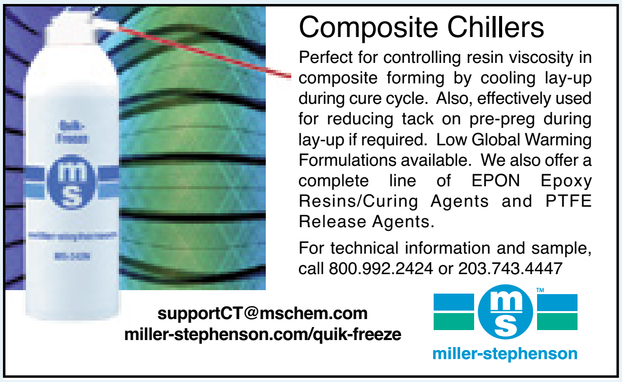


GFRP enables first grid-connected

U.S. FLOATING WIND TURBINE

Composite tower on 1:8-scale system reduces hull size/weight and helps mitigate the overall cost of electric power generation.

Although the business case for offshore wind farms is compelling (see "Learn More"), installing offshore turbines is no easy task. Even in shallow coastal waters, it's expensive. Large turbine installation vessels (TIVs), with jackup technology and massive cranes, transport tower and turbine components to the site, then hammer steel piles into the seabed, assemble the steel tower, and lift and install the turbine and rotor. Deep water along many coastlines, however, precludes the relative simplicity of a steel-pile foundation. As developers confront regions where shallow water is scarce, a different approach is necessary — specifically, *floating* foundations.

Floating turbine concepts, in fact, are abundant, says Main(e) International Consulting LLC's (Bremen, Maine) offshore wind expert Annette Bosler. "This year may become a boom year for various European launches, if projects stay on track," she points out. "Whoever likes to refer to floating offshore wind technology as 'niche' and a long way off may want to reconsider that statement."

In anticipation of this boom, the University of Maine's (Orono, Maine) Advanced Structures and Composites Center (ASCE) headed a consortium of companies called DeepCWind and began to develop the concept four years ago. "When we started work, nothing like this … had been done before," says consortium leader and UMaine professor Dr. Habib Dagher.

DeepCWind plans to field a grid-connected, pilot floating wind farm in coastal Maine by 2017. In its first step toward that goal, ASCE launched a 1:8-scale floating turbine research prototype last year, funded by a 2012 U.S. Department of Energy (DoE) grant and featuring a composite tower built by consortium partner Ershigs (Bellingham, Wash.).


Source | UMaine

The VolturnUS, shown here at its station off the coast of Maine, is a 1:8 scale prototype with a composite tower on a concrete hull.

COUPLED MODELS

Floating foundations presented DeepCWind a complex problem: how to understand, and then design for, the interaction between aeroelastic loads — caused by the wind and rotor movement — and the hydrodynamic loads imposed by the water. Together, wind and water impose different loads on foundations, towers and turbines than those experienced by onshore turbines. And, says Dagher, "The physics of a floating, rotating turbine affected by wave motion are *harder to work out* than for land-based systems."

A computer analysis was undertaken in partnership with the National Renewable Energy Laboratory (NREL, Golden, Colo.), using NREL's open-source *coupled* model, called FAST (see *Learn More*). FAST simultaneously modeled the coupled aerodynamic, hydrodynamic, control system and structural response of offshore wind systems.

The consortium also used experimental data collected from testing the impacts of wind and waves on small-scale (1:50) floating turbines in the experimental wind and wave basin at the Maritime Research Institute Netherlands' (MARIN, Wageningen, The Netherlands). Dagher's group analyzed wave amplitudes/frequencies and passage rates, asking how quickly the waves move past the foundation, how they interact with the floating foundation, and whether those frequencies would mirror the vibration frequencies experienced by the tower as the rotor turns.

The tower design had to account for a variety of loads, including buckling, bending, wind shear and torsional loads. "The FAST model, together with our MARIN data, told us what accelerations

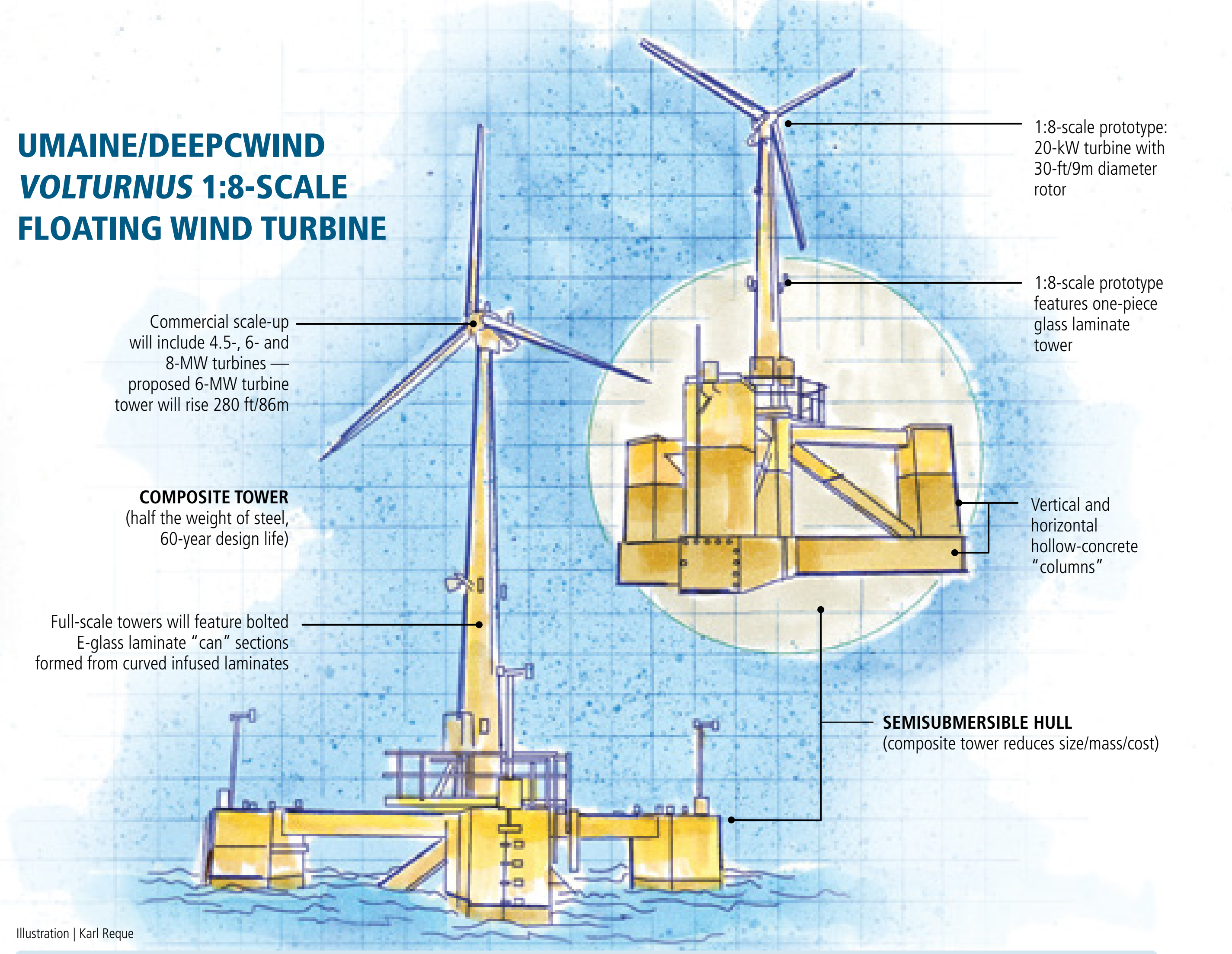


Illustration | Karl Reque

ENGINEERING CHALLENGE:

Design a floating foundation and tower that will minimize the costs of materials, construction and installation of a 1:8-scale prototype wind turbine in a deepwater offshore environment.

DESIGN SOLUTION:

Coupled aeroelastic/hydrodynamic modeling yields a composite tower half the weight of steel, reducing hull foundation weight by two to three times the tower's weight savings.

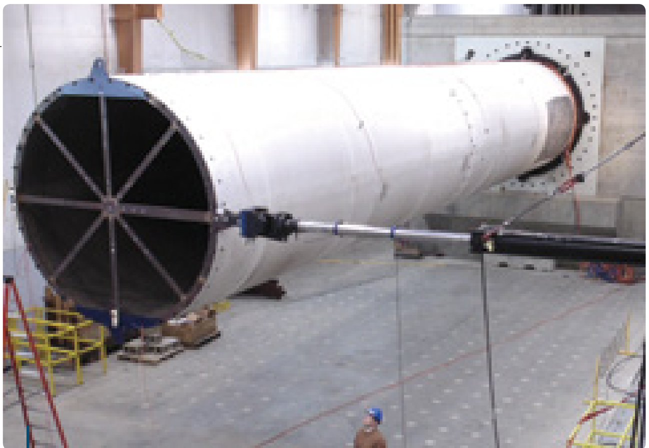
the tower would see, the stresses along its length and helped us size the tower section to withstand the loads," explains Dagher. With noteworthy foresight, Dagher's group modeled not only the 1:8 scale *VolturnUS* system, but future full-scale 4.5-, 6- and 8-MW floating turbine designs as well.

Modeling also exposed the relative merits of mass above and below the water line. "We worked on reducing the system mass above the water as much as possible to reduce the loads that ... would occur on both the tower and the floating foundation," says Dagher, noting that this strategy would "minimize the cost of a platform that could survive." A 6-MW turbine-rotor assembly, for example, can weigh nearly 800,000 lb (364 metric tonnes). To support that at the design hub height of 300 ft/92m, Dagher explains, would require a *steel* tower weighing a whopping 901,690 to 1.2 million lb (409 to 545.4 metric tonnes), with a base about 30 ft/9.2m in diameter, and an exceedingly large hull. But the composite tower proposed by UMaine and Ershigs would support the modeled loads at a little more than *half* the weight of steel. The resulting weight reduction in the floating hull is *two to three times* the tower weight savings. Further, Dagher believes, based on lab fatigue testing, that its corrosion resistance makes a 60-year design life feasible, compared to the typical 20 to 25 years for a conventional steel tower. "Even though composites are more expensive than steel, the value they bring to the entire floating turbine project over its lifetime, and especially the cost savings in the hull design, can pay for the added costs."

"Composite materials offer compelling advantages, particularly for offshore floating wind power," notes Ershigs' VP Steve Hettick.

TOWERING ADVANTAGES

A patent is pending on the consortium's tower design and, therefore, its fiber architecture and fabrication process are deemed proprietary. But Dagher stresses that Ershigs is using "well-established methods and well-known materials" to keep the project's costs as low as possible for the 1:8-scale tower and future full-scale towers. Material suppliers included Ashland Performance Materials (Columbus, Ohio), PPG Industries (Cheswick, Pa.) and ►


Source | UMaine

DeepCWind partners have already tested an Ershigs-built 1:2-scale bolted composite tower (one tower section is shown during testing).

Source | UMaine

The *VolturnUS'* patent-pending concrete semisubmersible hull design can be seen here, prior to the floating turbine system's launch.

VectorPly Corp. (Phenix City, Ala.). He does say that the composite tower's wall thickness is comparable to that of a steel tower sized to meet the floating platform's loads. Hettick adds that the coupled model output also identified frequency harmonics to avoid and other safety factors. These prompted Ershigs' selection of E-glass laminates with considerable axial reinforcement for the *VolturnUS* tower and larger towers to come.

Although the 1:8-scale tower was made in one section, a monolithic design isn't feasible for the proposed 280-ft/86m tall tower that will support 6-MW floating turbines, says Hettick. For it, Ershigs will produce "can" sections similar to those used to assemble a steel tower. Built up from large infused curved panels arranged, according to the patent, around a rotatable mandrel, they'll be joined to form a cylindrical section via a proprietary winding process. Finished cans will be bolted together close to the launch site, avoiding truck transport issues that would be raised by larger assemblies. "It's not a radical concept, it is a proven technology," says Hettick. "The industry is comfortable with bolting steel sections together, and it will work for composites."

The 1:8-scale prototype's tower supports a 20-kW turbine with a 30-ft/9.2m diameter rotor. Broader at the base and more tapered than a land-based tower, it is connected to its hull in a "similar manner to the way land-based steel towers are connected to concrete foundations," says Dagher.

A UMaine patent also is pending on the *VolturnUS* hull, which comprises a three-legged arrangement of hollow, semisubmersed vertical and horizontal concrete "columns" (see drawing, p. 46). Each leg is anchored via mooring line to the seabed. Outfitted with several Webcams and more than 50 sensors that collect wave and wind data as well as tower stress and strain readings, the prototype already has witnessed a wide range of winter storms, says Dagher, and has demonstrated excellent stability and small accelerations even in turbulent seas. Hull and tower performance data have been within 5 percent of the coupled model's predictions, he adds, which validates the design. "The data we've collected has allowed us to understand the platform's, and the tower's, performance in extreme conditions, because its smaller size means that the waves are proportionally larger in comparison," says Dagher. "It is a very effective way to de-risk the full-scale platform design." Consistent with the project's goal of producing electricity at a competitive rate, he contends, "a composite tower supported by a floating concrete foundation actually made the project more economically viable."

For these reasons, the much larger hulls for commercial-scale turbines will be of similar design. Ershigs, in fact, has already fabricated half-scale samples of the 6-MW turbine tower modular sections, which have been tested extensively in the UMaine ASCE laboratory for both ultimate strength and fatigue performance: "We joined sections together by bolting, as they will be on the platform, then simulated a 60-year service life," says Dagher. "The good news is that at the end of the fatigue test, the residual strength still exceeded the initial design strength!"

Fabrication of full-scale, commercial floating turbines is planned to begin in 2016. And when they're installed, TIV cranes and jackup barges won't be necessary. According to Dagher, *VolturnUS*-style hulls, composite towers and turbines can be assembled *dockside*, then be towed to the deepwater farm site by conventional tugboat.

"This is a big deal," Hettick concludes. "It's a win-win situation for composites." | CT |

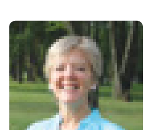
CW LEARN MORE
www.compositesworld.com

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

See a video of the *VolturnUS* launch at www.cianbro.com/NewsMedia/TabId/244/VideoId/178/VolturnUS-Offshore-Wind-Launch-Video.aspx.

Read previous *CT* editorial on offshore wind in "Wind over deep water" | *CT* October 2011 (p. 20) or visit http://short.compositesworld.com/o7Cmv6P4.

For more information about NREL's open-source FAST *coupled* modeling software, visit http://www.nrel.gov/wind/offshore_tools_methods.html.


Technical Editor
Sara Black is *CT's* technical editor and has served on the *CT* staff for 15 years.
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