CW
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Thermoplastic Composites Innovator: INSIDE FOKKER AEROSTRUCTURES

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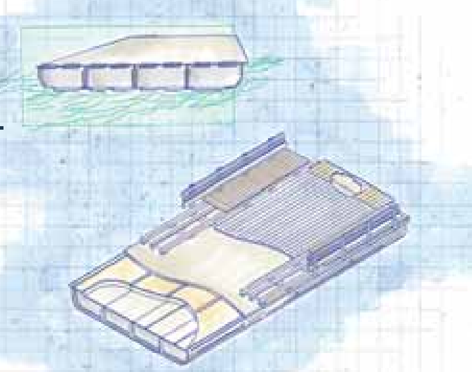
Fokker Aerostructures' (Papendrecht, The Netherlands) contract to manufacture the wing leading edges on the Airbus A380 from *thermoplastic* composites was one of the composites industry's biggest news stories in the first decade of the 21st Century. That program was the biggest, but hardly the only, activity *CW* found on the industry's leading edge during a recent tour of Fokker's Hoogeveen plant (p. 88).

Source / CW / Photo | Jeff Sloan & Sara Black

FOCUS ON DESIGN



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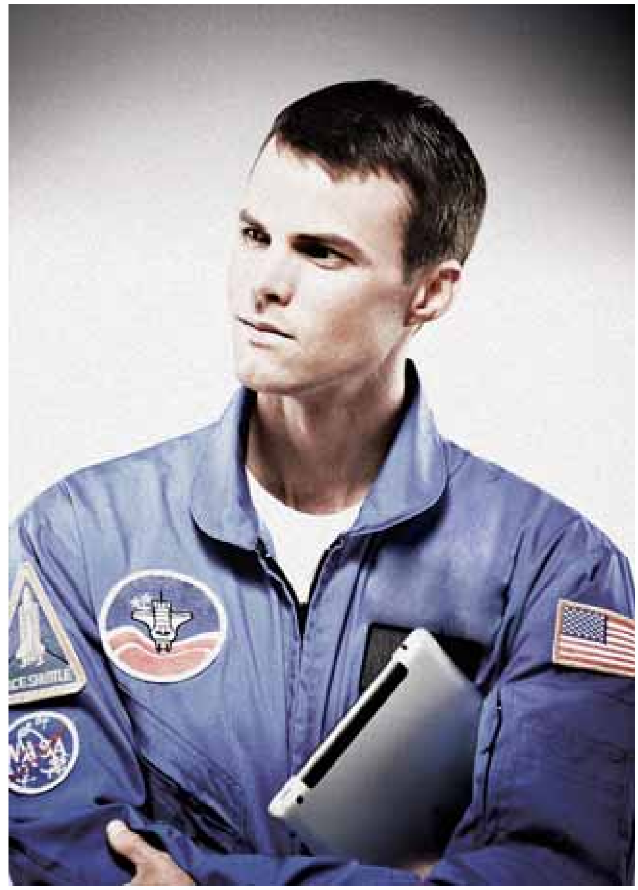
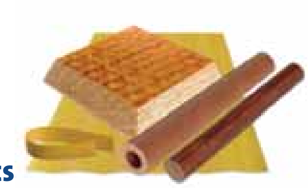
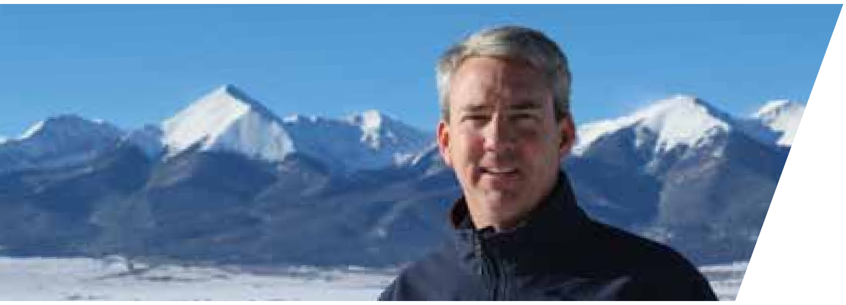






» October is CAMX month, and we here at *CW* are gearing up for the show, Oct. 26-29, at the Dallas Convention Center in Dallas, TX, US. We'll have a booth there, and we're publishing the *CAMX Show Daily* newspaper on site.

> Materials selection for automotive is, in the end, a *meritocracy.*

Preparatory to the show, I was given a chance to conduct a Q&A with this year's CAMX keynote speaker, Dr. Gary Smyth, executive director of Global Research and Development at General Motors (GM, Detroit, MI, US). Doing a Q&A with a high-level corporate executive can be an uncertain proposition; some in this position hew so closely to the company line that getting meaningful and interesting answers can be a challenge. However, it's just as likely that a Q&A will elicit illuminating and informative feedback that actually carries weight. Dr. Smyth, I'm happy to report, falls into the latter category.

I don't have room here to record all he said. You can find the entire Q&A on the *CW* Web site: short.compositesworld.com/GarySmyth. What I can do is share with you some comments he made that elucidated the role composites will play in automotive manufacturing.

First, if you are a regular reader of this column, you know that I have expressed concern that the composites industry, in general, is not well suited to meet the rigorous demands of the automotive supply chain, and I have questioned where composites fabricators will fit in the tier channel should automakers decide to more seriously work composites into cars and trucks.

So, my question on this topic for Dr. Smyth was: The composites industry does not have a history of providing high-volume, just-in-time (JIT) manufacturing services. If GM increases composites use, how will it cope with this challenge?

Dr. Smyth's reply: "This is a significant issue and compounded by the complexity of the composites value chain. In the metal world, we buy sheet metal and stamp it into a part or, in some cases, buy a pre-made assembly. *In the composites world, there can be a resin supplier, a fiber supplier, a molder, and then a component assembler or finisher/painter. This makes it very difficult to manage the whole value chain.* One approach would be to bring the technology in-house; another is to closely partner in the plant, much as we do for the paint shop today. What is clear is that to enable true high-volume implementation, the right decisions need to be made early in part and process design to optimize material use and minimize manufacturing issues."

I added the italics in Dr. Smyth's answer because I think that sentence captures very nicely some of the concerns automakers have when they look at the composites industry: Complexity, uncertainty, multiple materials. And given this uncertainty, it's fair then to ask: What advice do you have for composites fabricators who seek greater involvement in the automotive supply chain?

Dr. Smyth's reply: ".... I would suggest working with Global Purchasing and Supply Chain to *introduce your capability and then become part of the bidding process on future components.* You should also reach out to technical leaders so they are aware of your capability. One key to getting GM's attention is to clearly *communicate the value or uniqueness that you bring as a supplier and to quantify that value.* This often is done through a well-described case study for components you have produced for other industries or OEMs where you demonstrated improved performance or lower cost or better global reach."

Again, I added the italics, which get at the crux of the issue for composites, which is that they must earn their way onto cars. The automaking business model is simple: Make high-quality, safe vehicles for as little money as possible. Materials selection is, in the end, a *meritocracy*, and composites fabricators must prove the value their products have.

This is easier said than done, but if it were easy, everyone would be doing it. However, it is doable. To get started, I encourage you to show up at CAMX, hear what Dr. Smyth has to say, and put to him a few questions of your own.

JEFF SLOAN — Editor-In-Chief

Selling your business, Part 1: The best price with the best deal

» Investors throughout the world have a positive perception of the composites industry. They see growth opportunities across many sectors – aerospace, automotive, wind energy, pressure vessels, oil and gas, rail and mass transport. Overall, margins and return on investment are attractive, especially compared to many other manufacturing segments. And they like the choice that the diverse composites business models offer, with different mixes of capital and margin intensities throughout the supply chain, to match their investment strategies and portfolios.

Relatively young and fragmented, the industry attracts particular attention from three discrete investment communities:

- Mid-market financial investors who seek strong growth opportunities in the manufacturing sector;
- Trade buyers who want to diversify into a higher growth market;
- Industry players looking to expand into new markets, broaden their product portfolio or consolidate.

As attractive as they might be, owners and shareholders who are looking to sell to one of these groups must not neglect the following all-important tasks of preparation if they are to be successful. Planning and timing are key. Toward those objectives, we have developed a comprehensive five-step process:

1) Effective positioning and presentation;
2) Intelligent research;
3) Identification, selection and approach to the right buyers;
4) Creation and management of a competitive process;
5) Avoidance of legal, regulatory and tax pitfalls.

Throughout, there are always requirements for diligence with your planning, awareness of your timing of each action, and an overall approach that concentrates on the end result.

1. Effective positioning and presentation

Define your goals. First, clarify your commercial and your personal objectives. Have you decided on a timeframe? It is rigid or flexible? What about succession planning? Will your children take over the enterprise, or the present management team, or new blood, or a mixture? Will you really leave entirely or will you seek further involvement, possibly over a defined period?

This scenario assumes there's one owner, or a majority shareholding, with others willing and able to tag along with the sale. But most often, businesses have a raft of active, and not-so-active, shareholders, with a distinct lack of alignment between their wishes, hopes and ideas. A lack of orientation makes the business difficult to sell, and certainly hinders external investment.

When a business starts up, the funding — from friends, angels and other sources — and the shareholding and shareholder agreements are often informal, varying in their terms and conditions, and may include other considerations, promises and assurances. The priority at start-up is to get the cash, from wherever and whoever shows a willingness to invest. At FMG, we find that the result is a not unusual mix of investor goals and personal agendas, and a resulting lack of commonality.

Shareholder alignment is essential but can be a bit like herding cats. Nevertheless, it must be dealt with at the earliest opportunity and in place before any exit option is considered or planned. Then a number of questions must be answered:

Who is your likely buyer? For most medium-sized businesses, a buyer comes in two guises:

- *Financial investor.* Usually a private equity group or potentially a 'family office,' their fundamental interest is the financial return on their investment. They look for »

Table 1 A selection of recent acquisitions in the composites industry, illustrating the target company's valuation multiple. Source | Future Materials Group Research

Date	Target	Buyer/Investors	Share bought	Value (million)	Target EBITDA (million)	Target sales (million)	Multiple	Description of multiple
July 2015	Cytec (US)	Solvay (Belgium)	100%	$6,400	–	US$2,000	14.7 (stated) 3.2	EV/EBITDA EV/sales
July 2015	TenCate (The Netherlands)	Consortium led by Gilde Buy Out Partners (The Netherlands)	100%	€675	€84.6	–	8.0	EV/EBITDA
March 2015	CPI Binani (US)	Core Molding Technologies (US)	100%	US$15	–	US$20	0.8	EV/sales
Sept. 2013	Zoltek (US)	Toray (Japan)	100%	US$587	US$30	–	19.6	EV/EBITDA
May 2013	PECO Inc. (US)	Astronics Corporation (US)	100%	US$136	–	US$78	1.8	EV/sales
April 2013	Aldila Inc. (US)	Mitsubishi Rayon Co. Ltd. (Japan)	100%	US$25	–	US$50.6	0.5	EV/sales
Dec. 2012	Glasforms Inc. (US)	PolyOne Corp. (US)	100%	US$34	–	US$50	0.7	EV/sales
July 2012	Umeco (UK)	Cytec (US)	100%	US$411	US$40.9	–	10.0	EV/EBITDA

opportunities where the commercial concept is proven and scaling the business involves developing sales and marketing channels. Any large investment in capacity makes the acquisition less attractive for them.

- *A strategic or trade buyer.* Typically a large business buying up a smaller business, a trade buyer expects to see strong synergy benefits for their business, as well as the all-important return on investment. A large trade buyer often brings an operational capability that can add and efficiently manage capacity.

Alternatively, if you're considering an initial public offering (IPO), you need a very aggressive growth story and/or a very compelling investment hypothesis to appeal to potential shareholders. You must demonstrate a proven commercial concept, the need and opportunity to scale the business, and that the scale-up opportunity is significant.

A financial investor typically wants to partner with existing management over an agreed timeframe. With a trade buyer, there might be an agreement that you continue in management, but that's less certain. (The IPO route is expensive and can be lengthy, but it is possible to maintain control of the business.)

What is your company's actual worth? This is the time to formulate some idea of the company's value. Table 1 (p. 6), for example, lists recent and in-progress deals and the value of the target firms. The composites industry is broad in scope, and so can be the valuations, but there are commonalities. Multiples of revenues, profits, gross profits and more can all be explored and tested with the help of advisers who have up-to-date knowledge of the present and future market indicators and the likely buyers.

What will your buyer actually be buying? A differentiated and compelling proposition is the most valuable sales tool you have to sell your products. Define exactly what your business is: its technology, its markets and its customers. Demonstrate a complete and thorough understanding of your target markets, and why you are competitive in those sectors. Be prepared to show a buyer the realistic growth opportunities for the business — validated, assessed and with evidence. If your assessment forecasts growth that exceeds the expected market growth, then you need a strong argument outlining *why* your firm will perform better.

Fast growth is limited. In manufacturing, you are part of a supply chain. Investment in people, facilities and equipment is required, and it takes time for new composites technologies, materials and processes to prove their utility and quality, as well as the robustness of their delivery and consistency. The growth rates and profitability levels and, therefore, your return on investment, will be more modest than if you were in the IT sector, where firms can spring up and attain high valuations in months. On the plus side, if you have established a strong niche, there is a much-reduced risk of the business failing because the customers who use your products have fewer options. As a result, you can command a higher valuation.

Where do you sit in the value chain? Your position here, and the dynamics of your supply chain, are a core piece of your »

business model. We see numerous business models with serious flaws because the company does not fully understand how its supply chain works, and its position in that value flow.

2. Intelligent research

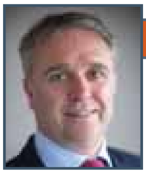
Develop a roadmap. A potential buyer needs to know more than your company. Who are your *customers*, your *competitors* and what is your *geographic reach*? Analyze where the business is today to create a picture of where it could be in the future, and what financing will be needed to enable the transition. A technology/product development roadmap is a good tool here. It must detail the point in time you are expecting to launch a new product and assess the business environment for that product at that time. If there is potential for the business to expand geographically, look at the regulatory environment for your product, geography-by-geography, and show its effect on your competitiveness and value proposition. When you project the company's future position, outline your market growth, market share, geographic expansion, sales volume and capacities. To demonstrate your company's potential to a buyer, we suggest you create a detailed plan for the first three years, followed by a trajectory that shows where the business could be in five years. Once you have a roadmap, identify key milestones that will drive the business over that time period. You can then relate your financial needs to these milestones.

This roadmap, with milestones and financing needs, alongside a very clear value proposition and supporting data, is a very effective way to communicate your business plan to potential buyers. Ideally, you also should be able to distill your three-to-five year plan into a couple of paragraphs. We rarely see this done well, but an external adviser, like FMG, can add valuable insight here.

How much must I invest to get that sale?

When you have decided to sell, you need to agree that you will go ahead with a properly funded and professionally executed plan and engagement with buyers (to be covered in Part 2 of this article). This planning process, including the research outlined above, is expensive in terms of internal and external costs. If you anticipate selling your company for around US$20 million, this process could cost you about 10% of that or US$2 million. But you will have closed your biggest deal ever.

In Part 2: Williams will address the final three stages of the five-step process. CW



ABOUT THE AUTHOR

Adrian Williams is co-founder and managing director of Future Materials Group (Cambridge, UK), an independent strategic advisory firm. Its services include growth strategies, mergers and acquisitions, strategic partnerships and growth capital.

Is a composites technical talent shortage looming?

» If you are a proponent of composites (and as a reader of this magazine, I assume you are), you have to be encouraged by all the developments underway and the growth potential of the industry. Examples abound: The need for lighter weight automobiles, to meet fuel economy and CO_2 emission targets, is stimulating innovation and investment across the globe in advanced composites. Clean energy sources, such as wind turbines, are becoming increasingly competitive with fossil fuels, and are creating enormous demand for resins, fiberglass *and* carbon fiber. Forecasts in these key applications call for double-digit growth for many years as composites become more ubiquitous.

If the forecasts are accurate, there also will be a huge demand for trained composites technicians, manufacturing engineers and designers able to avoid the "black metal" approach to structural analysis. *Where will we find the people to design the components and assemblies, run the manufacturing equipment, and repair the resulting parts when they are damaged?* More than the need to add manufacturing capacity, it's concern about finding talented *people* that keeps composites industry owners and senior managers awake at night. And the skills required today and in the future aren't the same as those that sufficed 20 years ago, when buckets, brushes and manual chopper guns dominated fiberglass shops, and hand layup dominated composite aircraft part making. With the advent of resin infusion and RTM for continuous glass fiber (and many carbon fiber) parts, and automated tape layup or fiber placement for prepregs, today's (and tomorrow's) technicians and engineers require a higher level understanding to diagnose issues and keep production rates high.

> We need more schools to create curricula that mint … engineers with *undergraduate* degrees in composites.

In July, *CompositesWorld* editor-in-chief Jeff Sloan opined that the composites industry has too many "old" people and not enough "young" people to replace those retiring with many years of composites experience. As one of the "old" people with 30-plus years of experience — but *not* yet ready to retire — I think we run the risk of not having enough trained workers at *all* ages.

There is no doubt we need to attract young people. Within professional societies, such as SPE and SAMPE, the average age continues to rise. Although we expend a lot of financial resources on scholarships and support of student activities, these don't translate to membership growth at the rate we need to see, let alone the industry's growth rate. One reason for the lack of attraction is that younger generations connect through social media rather than face-to-face, so we must think about our *messaging* — how do deliver our appeal more effectively using these new tools?

Part of the message is that the composites industry is a *high-tech* industry, with an increasing reliance on modeling and simulation tools, and automated equipment for fabrication and assembly of composite structures. We also need to emphasize the *sustainability* aspects of composites: Our products, in fact (and despite the use of some, when cured, absolutely inert petroleum-based materials), *reduce* global warming and *support* green-energy solutions — the wind energy industry and fuel-cell technology, for example — concerns increasingly important to younger generations.

Although many of our universities have done an excellent job with graduate-level degree programs focused on research in composites, we still need more schools to create curricula that mint manufacturing and design engineers with *undergraduate* degrees in composites, especially in the US. I am always impressed when I go to Europe, particularly Germany, where I see a lot of young engineers obtaining credit toward an advanced degree by *working full time* in a composites manufacturing environment, rather than in a research setting. This kind of real-world experience today creates the manufacturing managers of tomorrow.

The initiatives we need aren't only for the young; *retraining* of workers in stagnant industries as composites technicians is also on the radar — not just for the companies that will employ them, but also for state economic development organizations, hoping to attract companies to take advantage of such talent. The American Composites Manufacturing Assn. (Arlington, VA, US) has made a good start with its Certified Composites Technician (CCT) program in the US, and this could be accelerated with help from workforce development efforts in each state and by focused composites institutes, such as the Institute for Advanced Composites Manufacturing Innovation (IACMI, Knoxville, TN, US). Similar efforts of which I am aware are underway in the UK, France and Germany.

Engineers are trained to solve real-world problems, and the potential shortage of talent in the composites industry is just such a problem, seeking a solution. Collectively, industry, government and academia can — indeed, *must* — effectively address this issue to keep the composites industry on its upward trajectory. CW

ABOUT THE AUTHOR

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

V-notched shear testing of composites

» Many test methods are available for measuring the shear properties of composite materials. The V-notched methods are currently among the most popular, in part because they can produce a relatively pure and uniform shear stress state in the test specimen, and they can measure the shear modulus and shear strength for the in-plane and interlaminar material orientations. The original V-notched shear test for composites, commonly referred to as the Iosipescu shear test, was introduced in the early 1980s[1] and became an ASTM standard (ASTM D 5379[2]) in 1993. In more recent years, the V-notched rail shear test was developed and standardized (ASTM D 7078[3]); a V-notched, combined loading shear test has been developed as well.

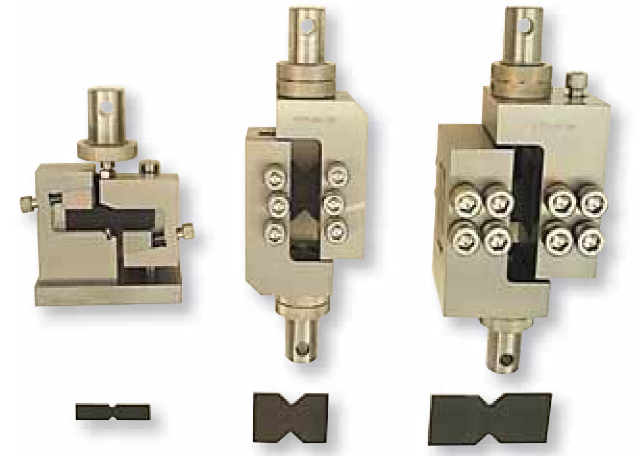
> The original V-notched shear test for composites, the Iosipescu shear test, was introduced in the 1980s.

The test fixtures and specimens used for the three methods are compared in Fig. 1. All three apply an asymmetrical four-point bend loading to the specimen. As illustrated in Fig. 2, this type of loading can be visualized (and experienced) by the reader using a pencil or pen as the specimen, and applying the load, using the index finger and thumb on both hands. For starters, if the index fingers are placed on the outer bottom surfaces of the specimen and the thumbs placed at the inner top surfaces (Fig. 2a), significant bending stresses are produced in the central section between the reader's thumbs. This is the loading method used in conventional four-point flexure testing. However, if the reader simply rotates one hand by 180°, such that the thumb loads the bottom and the index finger loads the top of the specimen (Fig. 2b), the resulting asymmetric four-point loading changes from bending to shear in the central section.

The 90° V-notches machined into the specimens are used to produce a uniform state of shear stress in the central test section between the notch tips. Without notches, the shear stress distribution varies parabolically across the width of the specimen, ranging in magnitude from zero at the top and bottom specimen edges to a maximum at the horizontal midplane. The V-notches effectively remove the outermost regions of the specimen under relatively low shear stress, leaving the central section between the notches with a surprisingly uniform state of shear stress. Using V-notches to produce a uniform stress state may seem counterintuitive for readers who are unfamiliar with this type of shear test, because notches are known to produce large stress concentrations and nonuniform stress distributions in axially loaded specimens. However, the 90° V-notches in the shear specimens, with depths of 20-23% of the total specimen width, produce minimal stress concentrations.

FIG. 1

V-notched shear testing of composites test fixtures/specimens.



a) Iosipescu shear test (ASTM D 5379) b) V-notched rail shear test (ASTM D 7078) c) Combined loading shear test

FIG. 2

Four-point loading configurations of beam specimens.

a) Symmetric four-point flexure loading. b) Asymmetric four-point shear loading.

Although the same asymmetrical bend loading (Fig. 2b) is used in all three V-notched shear tests, the specimen surfaces where the load is applied and the size and shape of the test specimens differ between them. In the Iosipescu shear test method (Fig. 1a), the fixture loads the top and bottom edges of the 76-mm long by 19-mm wide specimen. Although limited load can be applied through the specimen edges without causing crushing, it is adequate to produce failure in unidirectional or cross-ply composite specimens, such that the shear strength and shear modulus of the composite material can be measured.

Although it is still common practice to test 0° unidirectional composite specimens with fibers oriented lengthwise, there are significant advantages to using a $[0/90]_{ns}$ cross-ply laminate for in-plane shear testing. Cross-ply specimens are not only less fragile, but also produce a more uniform state of shear stress and »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The water is fine.

strain in the notched test section of the specimen. The latter has important implications for accurate shear modulus determinations. To calculate the shear modulus, the average shear stress τ_{ave} (calculated as the applied force divided by the specimen cross-sectional area between the notches) is divided by the measured shear strain γ, or

$$G = \tau_{ave}/\gamma.$$

Because the average shear stress is used in the shear modulus calculation, the average shear strain between the notch tips, γ_{ave}, also must be used to obtain the correct shear modulus. When relatively small strain gages are centered between the notches, the measured shear strain can be 5-10% lower than γ_{ave} when testing 0° unidirectional specimens. Therefore, the measured value of shear modulus will be 5-10% too high. The use of cross-ply specimens results in greater shear strain uniformity and more accurate measurement of shear modulus. Note that if 0° unidirectional specimens are to be used, specialized shear

The use of cross-ply specimens results in greater shear strain uniformity and more accurate measurement of shear modulus.

strain gages[4] that extend the entire distance between the notch tips may be used to record accurate values for the average shear strain, γ_{ave}, and thus the shear modulus, *G*.

The V-notched rail shear test fixture (Fig. 1b) loads the specimen through its faces, allowing for greater load transfer and the testing of higher shear strength composite laminates. Face-loading of the 76-mm long by 56-mm wide V-notched specimens is accomplished by gripping the outer 25 mm of each specimen end, using clamping bolts. Up to 500 MPa shear strengths have been obtained from $[0/\pm45/90]_{ns}$ quasi-isotropic and $[\pm45]_{ns}$ laminates[5], but specimens must be kept relatively thin to avoid slipping in the grips. The V-notched rail shear specimen also has a central test section that is three times larger than that of the Iosipescu specimen, allowing proper shear testing of relatively coarse textile composites with large unit cell sizes. The test method also is suitable for unidirectional and cross-ply composite laminates. As with the Iosipescu shear test, the use of cross-ply laminates is recommended to produce a robust specimen and a more uniform state of shear strain between the notches.

Although the V-notched rail shear test fixture is capable of higher specimen loadings than the Iosipescu shear test fixture, there is increasing interest in testing the thicker, high-shear-strength laminates used in structural applications. For such »


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cases, the combined loading shear test fixture provides even higher shear load capacity. Shown in Fig. 1c (p. 14), this method combines the edge-loading method of the Iosipescu test and the face-loading method of the V-notched rail shear test. Although the central V-notched region of the specimen is the same as the V-notched rail shear specimen, the gripping region on either end is elongated by 25 mm to provide twice the length for edge and face loading. The resulting 127-mm long by 56-mm wide specimen has been shown to produce acceptable gage-section failures of relatively thick laminates that require failure loads above 100 kN[6]. Note that the fixture body is much heavier and contains larger-diameter bolts on each side, compared to the V-notched rail shear test fixture.

In summary, the choice of V-notched shear test method is best made with the composite to be tested firmly in mind. To obtain the in-plane or interlaminar shear properties of composite materials, all three test methods can be used. However, the Iosipescu shear test, which uses a smaller specimen and a smaller, less expensive fixture, is the preferred method for most users. The V-notched rail shear test provides a significantly larger test section required for testing relatively coarse woven or braided textile composites, as well as an increased loading capacity to enable the testing of multidirectional composite laminates. Finally, the combined loading shear test offers the greatest shear load capacity, permitting the shear testing of relatively thick specimens from high-shear-strength laminates used in structural applications. CW

REFERENCES

[1] D. E. Walrath and D. F. Adams, "The Iosipescu Shear Test As Applied to Composite Materials," *Experimental Mechanics*, Vol. 23, No. 1, 1983, pp. 105-110.

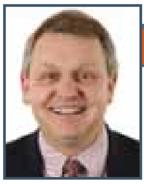
[2] ASTM D 5379/D 537M-12, "Standard Test Method for Shear Properties of Composite Materials by the V-Notched Beam Method," ASTM International (W. Conshohocken, PA, US), 2012 (first issued in 1993).

[3] ASTM D 7078/D 7078M-12, "Standard Test Method for Shear Properties of Composite Materials by the V-Notched Rail Shear Method," ASTM International (W. Conshohocken, PA, US), 2012 (first issued in 2005).

[4] "Plane-Shear Measurement with Strain Gages," Vishay Precision Group Tech Note TN-512-1, Document No. 11062, September 2010, www.vishaypg.com/docs/11062/tn5121tn.pdf

[5] D.O. Adams, J.M. Moriarty, A.M. Gallegos, and D.F. Adams, "The V-Notched Rail Shear Test," *Journal of Composite Materials*, Vol. 41, No. 3, 2007, pp. 281-297.

[6] D.J. Litz, "Development of the Combined Loading Shear Test Method and Shear Strain Measurement in the V-Notched Rail Shear Test," MS Thesis, Department of Mechanical Engineering, University of Utah, 2012.



ABOUT THE AUTHOR

Dr. Daniel O. Adams is a professor of mechanical engineering and has been the director for 18 years of the Composite Mechanics Laboratory at the University of Utah and vice president of Wyoming Test Fixtures Inc. (Salt Lake City, UT, US). He holds a BS in mechanical engineering and an MS and Ph.D in engineering mechanics. Adams has a combined 35 years of academic/industry experience in the composite materials field. He has published more than 120 technical papers, presents seminars and chairs both the Research and Mechanics Divisions of ASTM Committee D30 on Composite Materials and the Testing Committee of the Composite Materials Handbook (CMH-17). He regularly provides testing seminars and consulting services to the composites industry.

CW Business Index at 42.9 – Lowest since December 2012

» With a reading of 42.9, the *CompositesWorld* Business Index for August showed that the US composites industry had contracted for the fourth time in five months. Further, the rate of contraction had accelerated in June, July and August. And the Index fell to its lowest level in August since December 2012. Compared with one year earlier, the Index had contracted for eight consecutive months.

New orders contracted in August for a second month. The drop in that subindex was so steep that in August, it fell to its lowest level since the CWBI survey began in December 2011. Likewise, the production subindex had contracted two months in a row but its decline wasn't as sharp. Because production had shown relatively greater strength than new orders, however, the backlog subindex plunged. In August, backlogs contracted at their fastest rate since the survey began. The trend in backlogs indicates that factory capacity utilization will fall heading into 2016. Employment contracted for the first time since February 2013. Because of the strong dollar, exports continued to contract. And in August, supplier deliveries continued to lengthen at about the average rate for 2015.

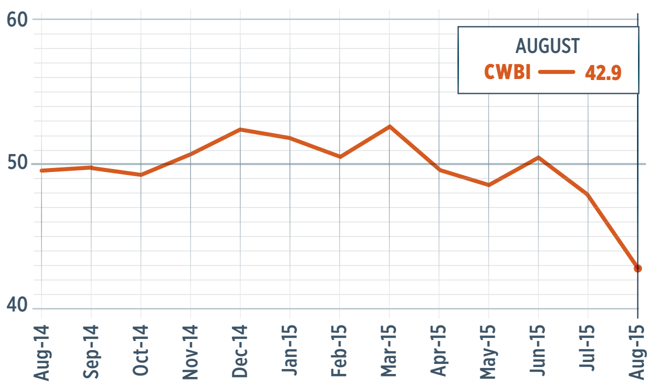
After going up at a steadily accelerating rate, the increase in material prices slowed in August. The rate, in fact, was below the rate of increase for 2013 and 2014. Prices received increased for the second month in a row. However, the rate of increase was minimal. Future business expectations had been trending lower since February of this year, and they hit their lowest level in August since October 2014. In August, expectations fell below their average level for the first time since October 2014.

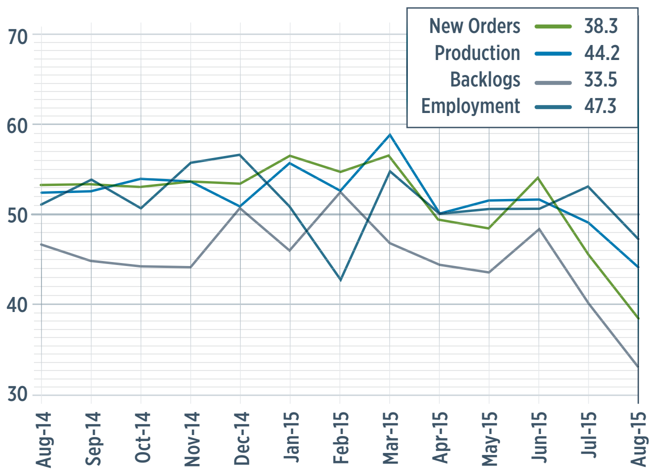
The subindices at manufacturing plants of all sizes were below 50.0 in August. Plants with more than 250 employees performed significantly better than the other categories, however: the subindex for this largest facilities category was just under 50.0 at 49.4. All of the other plant sizes had posted numbers of 45.0 or less. Fabricators with fewer than 20 employees contracted for the sixth straight month. Companies with 50-99 employees contracted for the fourth time in five months. Plants with 100-249 employees contracted for the second time in four months. Facilities with 20-49 employees have contracted every month but two during the past 12 months.

All regions in the US contracted in August, too. The North Central-East contracted at the slowest rate, with an subindex of 47.7. This was the second month in a row this region contracted. The North Central-West contracted at a similar rate. It had contracted in two of the preceding three months. The subindex in the South Central dropped to 44.0 from 60.4 in July month. The Southeast contracted for the first time since February of this year. Both the West and the Northeast had an subindex below 40.0 in August.

Despite the negative trends in the August data, future capital spending plans for the 12-month period ending in August actually increased significantly. In fact, the month's future capital spending plans figures were nearly double the July numbers, putting that category at about the average level recorded since December 2011. Compared with one year earlier, future spending plans increased 21.2% — the first month-over-month increase since June 2014. CW

A CWBI reading of >50.0 indicates expansion; values <50.0 indicate contraction.





ABOUT THE AUTHOR

Steve Kline, Jr. is the director of market intelligence for Gardner Business Media Inc. (Cincinnati, OH, US), the publisher of *CompositesWorld* magazine. He began his career as a writing editor for another of the company's magazines before moving into his current role. Kline holds a BS in civil engineering from Vanderbilt University and an MBA from the University of Cincinnati.
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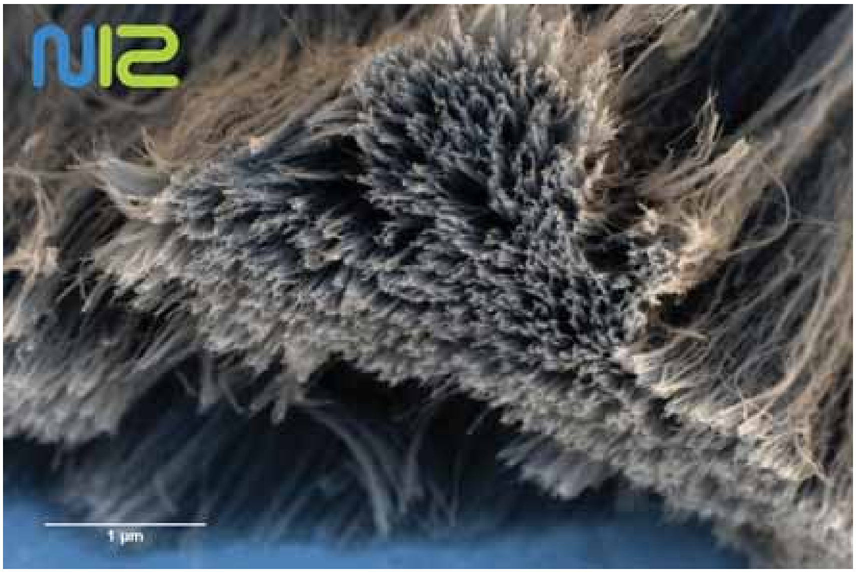
Commercial carbon nanotube-enhanced prepregs and atmospheric plasma carbonization ovens for carbon fiber manufacture top the trends, Europe's 2015 offshore wind growth figures top all, and Brazil tops South American neighbors in wind energy progress.

CNT-enhanced prepregs: commercial & production-capable

Carbon nanotubes. They've have been around for 20 years, with attempts at commercialization for a decade. But until now, says Dr. Ryan Williams, senior scientist for N12 Technologies (Cambridge, MA, US), "companies have not seen the performance or scale promised." Selected as a 2015 Top Start-up by the Silicon Valley-based non-profit TIE50 global annual awards program, Williams' Massachusetts Institute of Technology (MIT, Cambridge, MA, US) spin-off firm aims to change that. "Our goal is to make sure our technology delivers on its promise," he says.



Source | N12 Technologies Inc. / Photo | Dina Deresh

N12 Technologies' NanoStitch and Surface Layer System (SLS) products are part of a new generation of nanomaterials aimed at delivering macro-level benefits in products produced at commercial scale. N12 also focuses on the reinforcement, rather than the resin. Mixing CNTs into resin has presented real challenges, Williams claims, both to performance and part production scale up, because CNTs agglomerate, hindering optimal dispersion and orientation. "We put vertically aligned carbon nanotubes (VACNTs) at the interface of each laminate ply and align them so that the user doesn't have to do this," Williams explains, giving the analogy of chopped carbon fiber vs. unidirectional prepreg. "You need not only the nanomaterial, but also placement and alignment in order to achieve high performance and light weight," he says. "We do this at the nano scale, but with a completely drop-in product. We don't expect the composites industry to modify its methods to use our products." (The photo shows a scanning electron microscope image of a NanoStitch vertically aligned CNT "forest.")

Williams says that users can roll, cut and handle N12 NanoStitch prepreg during layup or on an automated tape laying machine just like other prepregs. Further N12 has, he says, "capacity now to deliver thousands of square meters of NanoStitch materials per year and have completed another round of financing to expand this capacity to *millions* of square meters within the next 3-4 years." N12 has commissioned a production-rate reactor for the aligned CNTs and has a plan for scaling production at reasonable cost to support expanded industrial-scale supply. "We are working with a number of the large prepreg manufacturers to deliver NanoStitch-enhanced products — basically the prepregs already widely used in the industry — but with NanoStitch applied," Williams explains. "We are also developing a resin film delivery strategy, which gives the industry design freedom in what they do with the technology." For example, some companies want to apply the NanoStitch globally, while others want to locally reinforce a line of rivet holes or in a particular spot on a golf club shaft.

N12 also aims to be as close to cost-neutral as possible. He explains, "For example, if you have a 64-ply laminate to meet performance requirements, our NanoStitch technology might achieve a 10% weight savings by boosting the performance, which then balances the additional cost of adding in the technology." He says the company has worked mostly with epoxies but also with phenolics, bismaleimide *and* thermoplastics. It is already testing products with dozens of companies and has more than 100 different relationships established with potential customers, some in the very initial stages and others in physical component testing.

N12 will exhibit its NanoStitch technology in Dallas at CAMX 2015. See *CW's* "CAMX 2015 Preview" on p. 44.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BIZ BRIEFS

Renishaw (Gloucestershire, UK) recently marked a major growth milestone with the opening of its new 14, 214m^2 Innovation Center in the UK. The US$31 million facility, located at the company headquarters near Wotton-under-Edge, Gloucestershire, was formally opened in July. The additional space will house R&D and corporate services staff, as well as demonstration, training and conference facilities, and enable relocation of Renishaw's spectroscopy and laser calibration product lines to the site. The Center's investment program also encompassed the opening of a new R&D operation at the University of Ljubljana in Slovenia, as well as other new construction in the UK.

Airbus (Toulouse, France) inaugurated in Mobile, AL, US, on Sept. 14 its first-ever US manufacturing facility. The plant, which assembles the family of A319s, A320s and A321s, is officially open for business, with a team of more than 250 Airbus manufacturing employees now at work on the first U.S.-made Airbus aircraft. Airbus announced plans for the $600 million facility in 2012, and construction began at the Mobile Aeroplex at Brookley the following year. The first U.S.-made Airbus commercial aircraft, an A321, is scheduled for delivery in early 2016. By 2018, the facility is expected to produce 40-50 single-aisle aircraft per year. Airbus' market forecast indicates a demand over the next 20 years (directed to *all* manufacturers) for some 4,700 single-aisle aircraft in North America alone.

ENERGY

European 2015 offshore wind mid-year growth tops previous full-year record

According to the European Wind Energy Assn.'s (EWEA, Brussels, Belgium) mid-year report, "The European Offshore Wind Industry — Key trends and Statistics, 1st Half 2015," wind farm operators there installed more new capacity in the first half of 2015 than in *all* of 2014. EWEA credited the spike to completion of several large projects and to use of much larger turbines that feature longer composite blades, which enable the rotor to capture more energy via a significantly greater swept area. Average turbine capacity, therefore, rose, says EWEA, from 3.5 MW in 2014 to 4.2 MW, thus far, this year.

Offshore installations in Europe through June 30, 2015 totaled 2,342.9 MW — *tripling* the grid-connected capacity installed in the first half of 2014. As a result, total installed European offshore wind capacity hit 10,393.6 MW (82 wind farms in 11 countries). Germany accounted for the majority, with 406 turbines (1,706 MW), the UK followed with 140 (522 MW) and The Netherlands brought up the rear with 38 (114 MW). Kristian Ruby, EWEA's chief policy officer, says, "It has taken the offshore wind industry just six months to set the best year the sector has ever seen."

BIZ BRIEF

Russia-based invest/holding company GS Group has launched **GS Composite**, a pilot production plant for wood-plastic composites (WPC) in Ulyanovsk, Russian Federation. Its flagship products, granulated wood-plastic composites and finished products are made by extrusion and injection molding. Nominal WPC pellet output is 500 kg/hr. The plant will be the first in Russia to produce composites with a significant proportion of polyethylene terephthalate (PET). WPC pellets using PET will feature the higher strength, elasticity, moisture resistance, UV-stability and decay-resistance necessary for packaging, construction and furniture parts, along with elements of construction formwork. Pilot plant capacity is reportedly as high as 2,150 metric tonnes of finished products per year. Developed in the GS Group in-house laboratory, based on the Russian academy of sciences A.N. Frumkin Institute of Physical Chemistry and Electrochemistry RAS (IPCE RAS) in Moscow, the GS Composite process will use sawdust from local woodworking companies as raw material, and in future, will recycle waste from the GS Group's Sudoma sawmill in the Pskov region. Reportedly, the Russian WPC market is near 20,000 metric tonnes per year and growing at 8-9% per year, with more than 40% of products imported. Moreover, this growth is expected to continue. Therefore, by 2020, annual consumption of WPC in Russia could exceed 30,000 metric tonnes. Given the project's potential, GS Composite expects to reduce industry's dependence on imports.

CORRECTION

CompositesWorld published in its September 2015 issue a story by *CW* technical editor Sara Black about the development of fast-cure epoxy resin systems for use in automotive composites fabrication. The story, titled, "Automotive Composites: Thermosets for the Fast Zone," appears on p. 46 of that issue. The article included a reference, on p. 49, to Toray Composites (America) Inc.'s (Tacoma, WA, US) G83C epoxy prepreg. Included with this reference was a parenthetical note stating that this prepreg was "used on the Boeing 787 program."

The parenthetical reference, however, was based on incorrect anecdotal information, and a Toray representative, when given the opportunity to review the story for factual accuracy prior to publication, noted in the review text that the reference connecting G83C to the Boeing 787 program was *not* factual and should be stricken from the article.

Unfortunately, that request was overlooked during the subsequent editing process and, as a result, the reference went into print. *CW's* editorial staff has since been informed of the misstep, has omitted the incorrect reference in the article's online and other digital formats, and here apologizes for the oversight. The Toray G83C prepreg material in question is for automotive use only, and it is not used in aerospace applications. *CW* regrets the error.


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IN VIEW

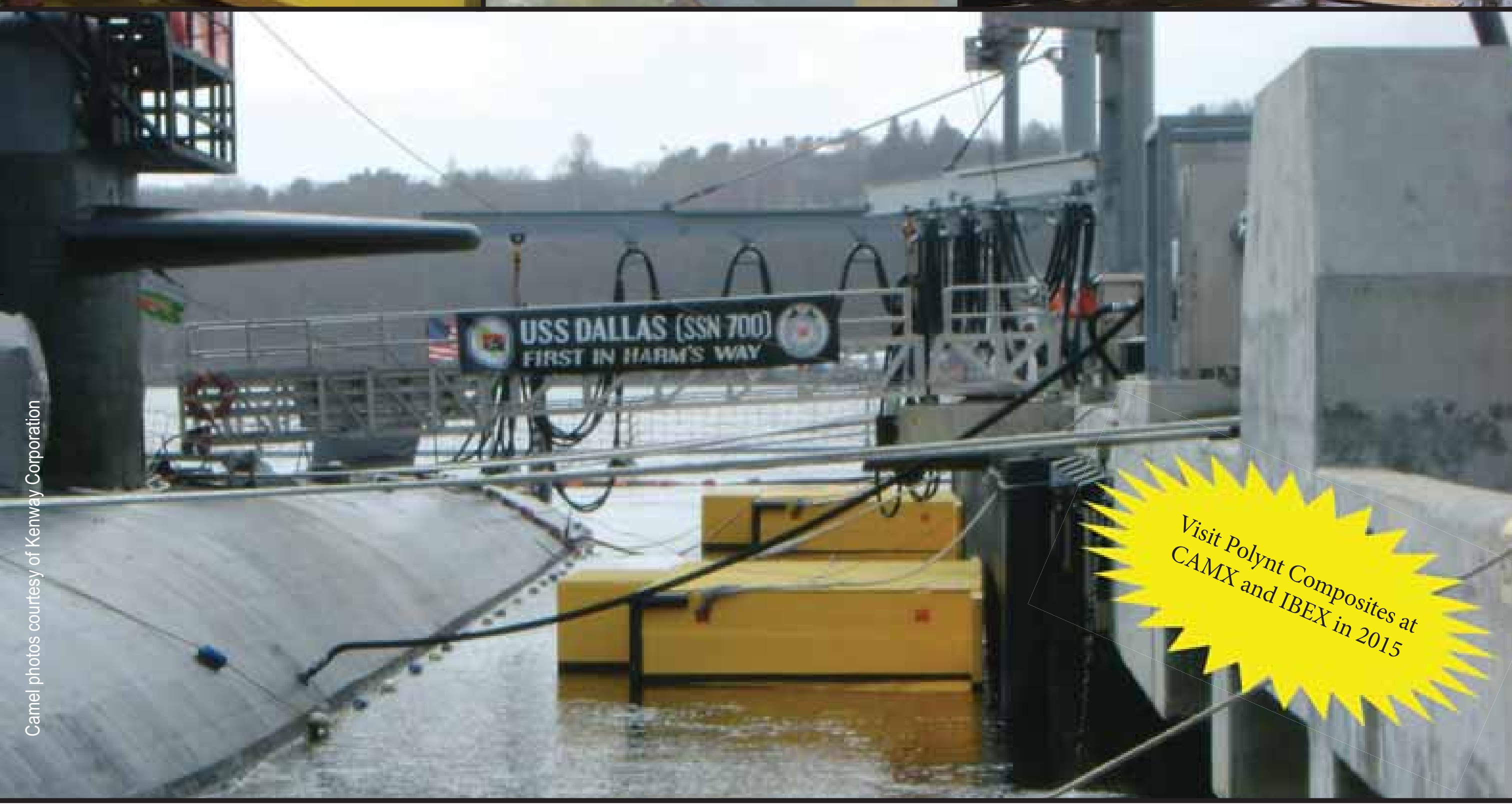
Dielectric properties measurement drives this NDT system to composites market

Material-Wave Interactions Laboratories (MWI Lab, Tempe, AZ, US), a 2010 spin-off of nondestructive material inspection technology developed at Arizona State University (Tempe), is coming off a period of substantial R&D and is preparing to put its product into the composites fabrication and maintenance and repair market.

Using MWI Lab's patented radio frequency (RF) and microwave (MW) antennas, MWI provides testing services or customized manufacturing solutions using Gaussian Beam technology. These antennas and systems are used to measure the anisotropic/dielectric/magnetic material properties in advanced composites, such as honeycomb, resistive films and radome materials. Reportedly, MWI Lab's technology can detect defects, such as subsurface voids, delaminations, faulty repairs or RF and MW leakage, in composite structures.

The technology is the brainchild of Rudy Diaz, an engineering professor at ASU, and Jeff Peebles, MWI Lab president and formerly of ASU. The two hatched the plan to measure dielectric values as a means to evaluate

(*Continued on p. 34*)



Camel photos courtesy of Kenway Corporation

(*Continued from p. 32*)

material properties while working together for a time in the aerospace industry 20 years ago, but the computing power to drive the technology was lacking until they reconnected at ASU in the 2000s. More powerful computers then enabled the design of new-generation antennae and near-field sensors. Computing speeds today enable MWI Lab's Gaussian Beam system's unusually high speed of interrogation — as few as 2-3 minutes, compared to hours for comparable systems.

MWI Lab's noncontact Gaussian Beam antennas have a planar-wave, broadband, narrow beam (without focus points) spot sizes and offer relatively large dynamic ranges when used in insertion loss, reflection loss, composite repair and RCS applications. Data collection and signal processing is provided by analyzers manufactured by Keysight Technologies (Santa Rosa, CA, US).

Matthew Witte, chief commercial officer at MWI Lab, says potential applications range from in-line/in-process analysis during manufacturing to prepreg manufacturing to composites repair. MWI Lab is focused on a handheld unit (due out yet this year), which can provide high-speed composites surface interrogation at a variety of depths and sensitivities, as well as *rental* scanners to assess a variety of parts, particularly for aerospace applications.

MWI Lab is seeking channel partners to help it move its dielectric-measuring technology into the composites marketplace. Interested parties are encouraged to contact Witte | mattwitte@mwilab.com

Atmospheric plasma heading toward commercialization for carbon fiber manufacture

RMX Technologies (Knoxville, TN, US) reports that its atmospheric plasma technology, in development for four years, is close to commercialization and could reduce oxidation energy consumption during carbon fiber manufacture by as much as 75%, and overall carbon fiber production costs by 20%. Rod Grubb, president, and Truman Bonds, VP of R&D, say that the technology, when used instead of conventional oxidation ovens to oxidize polyacrylonitrile (PAN) precursor, generates *unique* reactive chemistry. Bonds explains that conventional ovens require a great deal of energy to use molecular oxygen in air to thermally and chemically stabilize PAN for the carbonization process. Instead of molecular oxygen, the RMX system creates "other chemistries" from air as well as heat, to speed oxidation. "Our system is, basically, a chemistry generator."


Source | RMX Technologies

RMX has proven the technology in its lab over the past 18 months, using an oven with a 1-metric tonne/yr nameplate capacity. Grubb says RMX has worked with several unidentified carbon fiber manufacturers to test its process and reports that "good product" resulted — in some cases, properties exceeded those achieved with conventional ovens.

Grubb says RMX now has an industrial partnership with an established oxidation oven manufacturer (also unidentified), which will help RMX scale up the technology to a multi-hundred-metric-tonne model for commercialization. This, Grubb expects, will happen in the next 18-24 months.

Bonds says the cost and energy savings are achieved primarily because the atmospheric plasma process is faster (20-30 minutes total) than conventional thermal systems. Further, the RMX oven, as designed, will be one-third to one-half the length of a conventional oxidation oven, he notes, which will help reduce a carbon fiber line's footprint.

While RMX is scaling up its oven, it will work with a European partner to develop a textile-grade PAN precursor optimized for plasma oxidation and targeted to manufacture a 500-ksi, 50K carbon fiber. This effort, Grubb says, might be commercial near the full-scale oven's launch time.

Bonds credits Oak Ridge National Laboratories (ORNL, Oak Ridge, TN, US) for early R&D help, but emphasizes "we are in sole control of commercializing this technology and we want to make sure the marketplace understands that."

For more information, contact RMX Technologies' Rod Grubb | rgrubb@rmxtechnologies.net

CW MONTH IN REVIEW

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

CST Composites obtains US$1 million government funding
This will enable the Australian company to continue its push into new larger markets including automotive, oil and gas, mining and defense.
09/18/15 | short.compositesworld.com/CSTFunds

NASA's first flight of *Orion* with crew might not launch until 2023
Scheduled for 2021, the mission departure date was reset, following a rigorous technical and programmatic review by the agency.
09/16/15 | short.compositesworld.com/Orion1st

AIAA Space and Aeronautics Forum: Mars on their mind
The American Institute's Forum featured robust discussions about missions to low-Earth orbit and as far away as Mars.
09/14/15 | short.compositesworld.com/AIAAForum

Automated Dynamics to work on NASA research program
The company's composite production and laser-based fiber placement technology was chosen by NASA for continued research and development.
09/14/15 | short.compositesworld.com/AutoDyNASA

Fives acquires Lund Engineering
The move expands its automation offerings for composite parts manufacturing, enlarging its range of equipment and process expertise.
09/14/15 | short.compositesworld.com/Fives-Lund

Haydale, Huntsman to team on graphene-enhanced polymer resins
The ultimate objective: Commercialize graphene-enhanced ARALDITE resins for a range of applications in the composites market.
09/14/15 | short.compositesworld.com/HHgraphene

Kaman Composites receives MBDA contract worth US$4.4 million
The company will produce composite components for European missile developer and manufacturer MBDA's missile programs.
09/14/15 | short.compositesworld.com/KamenMBDA

Toray Composites to supply carbon fiber prepreg for Bell *525 Relentless*
Toray Composites America (Tacoma, WA, US) sees the program as a base from which to build its technology portfolio with Bell Helicopter.
09/14/15 | short.compositesworld.com/Toray-Bell

San Diego Composites canisters complete two successful launches
The San Diego, CA, US-based manufacturer's Lightweight Low-Cost Canister is part of a US Army-sponsored SBIR program.
09/08/15 | short.compositesworld.com/SDC-SBIR

GKN Aerospace will work on Clean Sky 2 aeroengine projects
The company will employ a number of processes and technologies to create the parts, with the goal of lowering weight by 15-30%.
09/08/15 | short.compositesworld.com/GKNCSky2

Bayer MaterialScience officially becomes Covestro
It will remain a Bayer AG subsidiary, but legally and economically independent; Bayer hopes to float Covestro stock by mid-2016.
09/08/15 | short.compositesworld.com/Covestro

AEROSPACE

Largest-ever civil aircraft composite part: A350-1000 wingskin

The wings for the first Airbus A350-1000 commercial aircraft have entered the assembly stage at the Airbus (Toulouse, France) manufacturing site in Broughton, North Wales, UK.

Source | Airbus

Although the Airbus A350-1000 wing has the same span as the A350-900 aircraft that is already in service, 90% of the parts that make up the A350-1000 have been modified, and its trailing edge has been extended to resize the wing for the plane's additional payload and range. At 32m long by 6m wide, therefore, the largest A350 XWB aircraft's upper wingskin is also the largest single part made from carbon fiber composite material currently in use in civil aviation today.

The upper wingskins for the A350-1000 were designed and developed at the Airbus facility in Filton, near Bristol, where a number of other systems are designed and tested, including the plane's fuel systems and landing gear.

The high-performance wings of the A350 XWB aircraft family reportedly make the plane faster, more fuel-efficient and (for the passengers) quieter. The wing design includes several streamlined features. Among these are droop-nose leading edge devices and new adaptive dropped-hinge flaps, which increase the jetliner's fuel efficiency at low speeds.

To improve fuel efficiency at higher speeds, the A350 XWB reportedly can deflect its wing flaps differentially, optimizing the wing profile and, thus, providing better load control.

ENERGY

US wind energy: Offshore promise remains unfulfilled, onshore strong

On the occasion of the laying of the first foundation for the first turbine in the first-ever offshore wind farm in the US, located three miles southeast of Block Island, RI, US (5 turbines, 30 MW, expected online in 2016), an article published by the US Energy Information Admin. (Washington, DC, US) by authors Rachel Marsh and Cara Marcy noted that this small beginning presages what could be profoundly significant opportunities to harvest wind energy off the US coast and ensure a long and steady demand for the composite materials and equipment necessary to build the massive blades that turn the turbine rotors. The authors note that The National Renewable Energy Laboratory (NREL, Golden, CO, US) estimates the US has 4,200 GW of developable offshore wind, compared to its estimate of 11,000 GW of onshore potential. Wind resources are classified on a scale of 0 to 7 (7 is best) based on power *density,* and more than 66% of offshore wind in the US is in class 6 or 7.

Marsh and Marcy note that wind turbine technology has grown steadily in Europe, and, to a lesser extent, in Asia. By 2014, Europe accounted for 90% of the estimated 8.8 GW of installed global offshore wind turbine capacity (see p. 26).

In the US, developers have proposed nearly 4.9 GW of offshore wind capacity off the coasts of nine states, but challenges remain even for projects that have advanced through key regulatory/market milestones. For example, Cape Wind, a 486-MW project proposed in 2001, faced litigation that halted its progress. Marsh and Marcy put the difference in European and US attitudes toward offshore wind down, in part, to the abundance of *on*shore wind opportunities in the US, many in relatively unpopulated areas, where challenges such as those that have delayed/cancelled projects in densely populated New England are less likely to crop up.

AEROSPACE

Scaled Composites/ Vulcan Aerospace predict 2016 debut for LEO launch aircraft

A year ago this month, at the inaugural Composites & Advanced Materials Expo (CAMX) event in Orlando, FL, US), Scaled Composites' (Mojave, CA, US) affable president Kevin Mickey spoke on a range of fascinating subjects, one of which was

Source | i.space.com

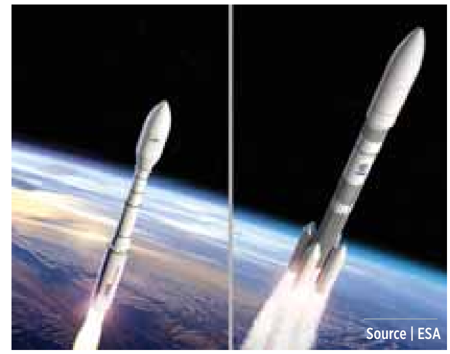
the massive *Stratolaunch* aircraft project his company is involved in, funded by billionaire Paul Allen in collaboration with Scaled Composites' founder Burt Rutan. In a recent *Aviation Week & Space Technology* magazine (Aug. 3-16, 2015), a story by Guy Norris and Amy Butler reviews progress on the massive air launch system.

The carbon composite *Stratolaunch* carrier vehicle is under development by Scaled Composites, and the launch vehicle it will carry is in progress at Vulcan Aerospace Corp. (Seattle, WA, US, the space-focused business of Vulcan Inc., which holds Paul Allen's assets). The massive carrier vehicle has six jet engines and a 118.5m wingspan and is designed to carry a rocket-powered orbital vehicle with payload, weighing up to 6,136 kg, to a launch altitude of around 10,800m, where the vehicle is released for self-propelled flight into low-Earth orbit.

The carrier-vehicle concept can save considerable fuel and launch costs entailed in a conventional vertical launch vehicle take-off and, according to Vulcan Aerospace, the concept "decouples launch service from its dependence on traditional ground launch ranges" by providing the flexibility of launching from many different locations, thus optimizing orbits. Rollout is expected in early 2016. Watch a YouTube video of the *Stratolaunch* concept here | **www.youtube.com/watch?v=YgJFKUiuDBE**

AEROSPACE

European Space Agency authorizes new *Ariane 6*, *Vega C* launch vehicles development


Source | ESA

The European Space Agency (ESA) has signed contracts for the development of the *Ariane 6* new-generation launcher, its launch base, and the *Vega C* evolution of the agency's current small launcher.

The contracts were signed at ESA's Paris head office with, respectively, Airbus Safran Launchers (ASL, Issy-Les-Moulineaux, France), France's CNES space agency (Centre National d'Etudes Spatiales, Paris) and the *Vega C's* prime contractor, ELV SpA (European Launch Vehicle, Colleferro, Italy), a 70/30 joint venture of Colleferro-based Avio and the Italian Space Agency (ASI - Agenzia Spaziale Italiana, Rome) that is *Vega's* current prime contractor. Those agreements cover all development work on the *Ariane 6* and its launch base for a maiden flight in 2020, and the same on the *Vega C* for its 2018 debut.

"These contracts will allow the development of a family of European launchers, highly competitive in the world market and ensuring autonomous access to space at fully competitive prices for ESA's Member States," says Jan Woerner, director general of ESA. "They are an important change of governance in the European launcher sector, with industry being the design authority and taking full responsibility in the development and exploitation of the launchers, and committing to deliver them to ESA and the European institutional actors at specified competitive prices."

ESA is overseeing procurement and the architecture of the overall launch systems, while industry is developing the rockets, with ASL as prime contractor and design authority for *Ariane 6*, and ELV serving in those capacities for *Vega C*.

ASL and ELV are working closely together on the P120C solid-propellant motor that will form *Vega C's* first stage and *Ariane's* strap-on boosters. *Ariane's* modular approach will offer either two boosters (*Ariane 62*) or four boosters (*Ariane 64*), depending on the required performance. The boosters feature the largest filament wound composite motor cases ever produced in Europe. Additionally, RUAG (Zurich/Emmen, Switzerland) will fabricate the *Ariane 6* fairings from aluminum honeycomb-cored sandwich panels with carbon fiber-reinforced facesheets.

The site of the launch base for *Ariane 6* at Europe's Spaceport in Kourou, French Guiana, has been chosen, and prime contractor CNES is already excavating the site. The three contracts follow the decision taken at the ESA Council meeting at Ministerial level held in Luxemburg in December 2014 to maintain Europe's leadership in the fast-changing commercial launch service market. "With the signing of these contracts we are on track on building a new family of launchers featuring common building blocks, in line with the decisions and schedule set at the Ministerial Meeting in 2014," says Gaele Winters, ESA's director of launchers.

The contracts were signed by Gaele Winters, ESA's director of Launchers; Jean-Yves Le Gall, president of CNES; Alain Charmeau, CEO/president of ASL; and Pierluigi Pirrelli, CEO of ELV.

The contract amounts are €2.4 billion (US$2.77 billion) for *Ariane 6* (ASL), €600 million (US$691.7 million) for the launch base (CNES) and €395 million US$455.4 million) for *Vega C* (ELV).

ENERGY

Brazil #1 in South American wind energy market

GE Wind Energy (Fairfleld, CT, US) will soon supply 156 wind turbines (worth about US$427 million) to Brazilian renewable-energy developer Casa dos Ventos Energias Renovaveis SA, for its Ventos do Araripe III wind complex, scheduled to begin commercial operation in April 2017, according to a *BloombergBusiness* article authored by Vanessa Dezem, Aug. 2. Casa dos Ventos will use the equipment for a huge 360-MW wind farm in Brazil's northeastern states of Piaui and Pernambuco, said Jean-Claude Robert, GE's general manager for renewable energy in Latin America.

"Brazil is a huge country and if you want to be the number one in Latin America, you need to be big in Brazil," Roberts told Dezem in a telephone interview from Sao Paulo.

Brazil is, in fact, Latin America's biggest wind market. In August, the Brazil Wind Energy Assn. (Abeeolica, São Paulo, Brazil) reported that Brazil now has more than 7 GW of installed wind power capacity, growing by about 1 GW in seven months. That according to *SeeNews Renewables* reporter Lucas Morais, in an Aug. 10 article. The 7-GW mark was reached after three new wind farms started up in Rio Grande do Norte state. Currently, Brazil's wind capacity provides 5% of the Brazilian power mix. In total, there are 281 wind farms in 11 states. The Brazilian government expects the wind sector to reach 23 GW of installed capacity by 2023 but Abeeolica's forecast is more optimistic at 27 GW.

Bloomberg's New Energy Finance says the Brazilian wind industry will attract as much as US$84 billion in investment through 2040. Installations are expected to top 22 GW in the coming 10 years.

Wind power, notably, was GE's fastest growing business in Brazil last year. The company sold ~500 MW of turbines and expects about 40% growth this year, with sales surpassing 700 MW. GE's Brazilian turbine factory is near capacity, and service centers are in progress.

Building on success

As this attendee-packed conference auditorium photo attests, last year's Composites and Advanced Materials Expo in Orlando, FL, US was the timely beginning of a fitting new tradition. In 2015, expo organizers firm up that foundation with a move to Dallas, TX, US, hosting its second conference and exhibition in a strong area of concentrated aerocomposites activity.
Source | CW

CAMX 2015 Preview

ACMA's and SAMPE's 2nd combined event promises a US conference and exhibition of unprecedented scale and value to manufacturers from all corners of the composites world.

What: CAMX 2015
When: Oct. 26-29, 2015
Where: Dallas Convention Center, Dallas, TX, US
Info: www.thecamx.org

» For many years, the North American composites community has been ably served by two major trade organizations: the American Composites Manufacturers Assn. (ACMA, Arlington, VA, US) and the Society for the Advancement of Materials and Process Engineering (SAMPE, Covina, Calif.). Each served a different segment of the market — ACMA covered what is often called "industrial" composites while SAMPE focused on "advanced" composites. In 2014, the debut of the Composites and Advanced Materials Expo (CAMX 2014) at the Orange County Convention Center in Orlando, FL, US, a joint ACMA/SAMPE undertaking, brought those previously separately served communities together in a new North American conference and trade show.

In the light of hindsight, it's clear that CAMX 2014 very successfully united these increasingly complementary technological streams in a educational and marketing/networking event that, by all accounts, is setting the trend for the industry's future on this side of the Atlantic. For year two, CAMX organizers are — no surprise — building on that success.

What you will find

CAMX 2015 will feature four full days of conference sessions (Oct. 26-29) united under the fitting thematic banner "Combined Strength. Unsurpassed Innovation." The conference sessions, again, will combine the best of what ACMA and SAMPE once offered separately, in a variety of educational options — technical paper presentations, education sessions, panel discussions and tutorials. The conference activities will run concurrently with a three-day exhibition (Oct. 27-29).

Given the great debate about the place of composites in the future of volume automotive production, the keynote address (Oct. 27 at 9:00 a.m.) by Dr. Gary Smyth, executive director of Global Research and Development at General Motors (Detroit, MI, US), should be a popular attraction. Smyth's insights into the future of autocomposites will include lessons learned from use of composites on GM's Chevy *Corvette* as well as a high-level perspective on transformational change now going on in the automotive industry. (*CW* editor-in-chief Jeff Sloan caught up with Dr. Smyth for a pre-show interview and shares some intriguing advance observations in "From the Editor," on p. 4.)

For conference info, pricing and registration procedures, visit the CAMX Web site | www.thecamx.org

On the show floor

The CAMX 2015 show floor, at CW press time, was almost entirely reserved. The following is a suggestion of what's in store:

Abaris Training Resources Inc. (Reno, NV, US) will showcase its updated engineering, manufacturing and repair courses, covering the latest in advanced composite technologies. In addition, Abaris is now offering carbon fiber automotive structural repair training at its Reno facility, with two intensive courses designed to meet the specific needs of the emerging automotive composites industry. Also at CAMX, Abaris' senior engineering instructor, Dr. Rikard Heslehurst, will give a pre-conference tutorial on Monday, Oct. 26, titled "Composite Structures Joint Design Technology." Lou Dorworth, Abaris direct services division manager, will participate in the Workforce Development & Technologies session panel on training, lifelong learning and the next-generation workforce. www.abaris.com

Airtech Advanced Materials (Huntington Beach, CA, US) will show several products for infusion-based molding processes: Its Premium Multi-Valve 408, with a solid body design that combines the male quick-disconnect and thru-bag connector, eliminates threaded connections and potential leak paths. Stainless steel construction ensures corrosion resistance and long life. High-temperature O-ring and platinum cured silicone gasket give a long service. It is interface-

compatible with Parker Snap-Tite 6.35-mm quick disconnects. The valve mechanism and O-ring seals can be replaced to extend life. BBH 1080 Hose, a durable high-temperature and high-pressure autoclave hose, consists of an inner flexible stainless steel conduit overwrapped with a stainless steel braid. A stainless steel armor jacket covers the hose and protects it from the harsh autoclave and production environment.

Airflow 100 Armor Sleeve is a durable high-temperature and high-pressure autoclave vacuum hose. Its construction features an outer steel armor jacket protecting the braided steel, which holds a PTFE inner tube supported by a flexible steel spring conduit. This design prevents collapse from vacuum or autoclave pressures. It is also available with a 90° fixed end-fitting on one or both ends.

Econobreaker 2R is an inexpensive, multi-purpose, rubber adhesive pressure-sensitive tape. Reportedly ideal for holding down vacuum-bagging materials, thermocouples and other layup items, the tape is suitable for room-temperature applications and heat cures to 177°C.

Vac-Gauge 40D is a versatile digital vacuum gauge used for leak detection and vacuum determinations under the vacuum bag. The gauge offers vacuum readings in four selectable units: mBar, mmHg, inHg, and Kpa.

The Airtech Vacuum Test Unit is a compact, lightweight and easy-to-use device that can be used to test in-service equipment or to check equipment that has undergone maintenance like seal replacements on vacuum valves or end-fitting replacements on vacuum hoses. www.airtechonline.com

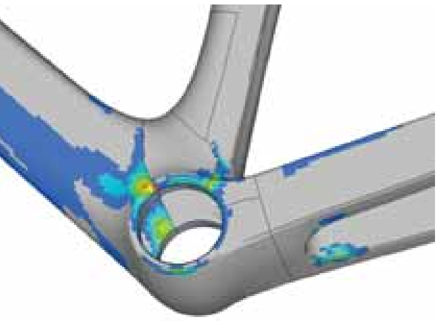
Airtech Inc. (Rutherford, NJ, US) — not related to California-based Airtech Advanced Materials — is a global manufacturer and supplier of vacuum pumps, blowers, compressors, and systems. It will feature its L-Series and ATV-Series of rotary vane vacuum pumps. Systemization of these products is also available. These vacuum pumps are used in the composite industry in autoclaves, vacuum hold down and vacuum infusion. In addition to a range of ready-to-ship products, Airtech offers customized solutions. www.airtechusa.com

AkzoNobel (Chicago, IL, US) will showcase Perkadox 16-40XPS, characterized by AkzoNobel as the only safe alternative to Perkadox 16. The latter, an initiator for cured-in-place pipe, pultrusion and low-temperature molding compounds, is being re-classified by the National Fire Protection Assn. as a Class I material. This severely restricts storage/handling to the point where it is difficult to justify the expense of updating storage facilities, adding to already expensive shop practices necessary for safe use of Perkadox 16. Perkadox 16-40XPS is said to be the only alternative on the market that is safer to use with minimal investment in storage and handling. The thixotropic paste delivers a safer, dust-free form of Perkadox 16 in larger containers without the need for premixing or potentially dangerous heating and cooling. The fine particle size suspension delivers the same activity as the original Perkadox 16 and is stored in the same NFPA Class III storage facilities currently used.

Anthony Bennett, AkzoNobel's technical development manager, polymer chemistry, will present at two informational sessions. The first, Thursday, Oct. 29, 2:00 p.m., is titled "Novel Water-insensitive Curing Systems for Biofiber Reinforced Unsaturated Polyester Resin Composites." The second, also on Thursday, Oct. 29, 3:00 p.m., is titled "A Paste of Di(4-Tertbutylcyclohexyl)Peroxydicarbonate (Commonly Known as Perkadox 16) Provides NFPA Class III Storage and Novel Use Options for CIPP and Pultrusion Applications." www.akzonobel.com/polymer

Altair Engineering (Troy, MI, US) will emphasize its tools and expertise for analyzing and optimizing composite structures. Case studies will be highlighted, including carbon fiber bicycles, America's Cup racing yachts, automotive composites, prosthetic devices, and aerospace composites. Altair also will present a paper authored by Jeffrey Wollschlager on the application of Altair's design optimization technology in OptiStruct to create a super lightweight but strong composite beam. In addition, Altair will introduce its newly acquired technology from MultiScale »

Design Systems (MDS), which includes solutions for micromechanics, microstructural optimization and life prediction of complex materials. The company's technology integrates modeling, simulation, testing, uncertainty quantification and optimization of composite materials and structures at multiple spatial and temporal scales. Altair also will highlight its Altair Partner Alliance (APA) composites analysis and design tools, offered by third parties and accessible under the Altair HyperWorks licensing system. These include solutions for structural analysis, micromechanics modeling, failure modeling, complex stress analysis, material databases, injection molding analysis and mapping of material data from injection molding simulation of fiber-reinforced plastics. www.altair.com



Armacell Benelux SA (Thimister-Clermont, Belgium) will showcase its two product lines: The first, ArmaFORM PET Core, is polyethylene therephthalate-based structural foams used in sandwich constructions for the building and construction, rail and road transportation, marine and wind turbine markets. They offer excellent fatigue properties (threshold >60%), high mechanical strength, very good temperature stability (with curing temperature up to 180°C), as well as process compatibility with all resins and manufacturing methods. In addition, the foam is thermoformable (3D shape) without property degradation in the case of grid scoring and without adding weight and costs because of corresponding resin intake. New to the ArmaFORM PET range are thin PET sheets made from 100% recycled PET material, called ArmaFORM PET Foil. Available in thicknesses starting at 1 mm, and at densities from 70-300 kg/m^3, and customized formulations, ArmaFORM PET Foil is designed to provide a sustainable and improved alternative to crosslinked, extruded polyethylene and extruded polypropylene products. Particularly, its improved stiffness and compression properties in combination with thermal and chemical stability reportedly differentiate ArmaFORM PET Foil from other thermoplastic foil products. The closed and fine cells provide a smooth surface structure for better laminating, die cutting and forming. It is temperature-tolerant (-40°C to 180°C) and its heat resistance is said to provide a significantly broader thermoforming window than comparable XPE and XPP products, simplifying processing and shaping. www.armacell-core-foams.com

Autometrix Inc. (Grass Valley, CA, US) will emphasize its entire cutter lineup, including several static cutting tables and a newly released conveyor system called Catalyst. PatternSmith, a full 2D CAD software package, includes machine control features, developed in-house at the Autometrix facility in northern California. The company will demonstrate the cutting of composite materials on the new Catalyst conveyor system in the booth. Software demos will be available as requested on site, as well. www.autometrix.com

Axia Materials Co. Ltd. (Seoul, South Korea) will introduce its new LiteTex, LitePan and LitePreg products to the US market. This new continuous fiber-reinforced thermoplastic composite material was developed by using Axia's own polymer matrix resin and process technology and offers thermoforming capabilities. Axia can produce 3m-wide

continuous rolls of LiteTex, coiled in rolls of 190m or greater length. LiteTex can be produced in a variety of thicknesses, reinforced with carbon fiber, aramid fiber, glass or other fiber according to customer needs. Single-structure LitePan composite sandwich panels are available in sizes up to 3m wide by 12m long in customer-specified thickness. All of Axia's products are VOC-free and will be distributed by **Bercella USA Inc.** (Stamford, CT, US) out of its warehouse in Midlothian, TX, US. Target markets include temporary housing, frameless buildings and mobile storage for the construction, mining and oil and gas industries. Bercella, a subsidiary of Bercella SRL Italy, a leader in the field of composite materials for automotive, aerospace and defense, will show parts such as a race car body, a radar antenna and other solutions. LiteTex and LitePan will be used in the CAMX 2015 Axia display construction to demonstrate its performance and advantages. www.bercellausa.com

Becker Pumps Corp. (Cuyahoga Falls, OH, US) is emphasizing its full line of rotary vane pumps, dry rotary screw pumps, central vacuum systems, regenerative blowers and radial blowers. Featured will be the company's VariAir patented intelligent speed technology. www.beckerpumps.com »

BGF Industries (Greensboro, NC, US) is featuring its line of woven carbon, glass, aramid, aluminized glass, thermoplastic glass fiber and other reinforcement fibers.

Carbon: BGF offers a variety of polyacrylonitrile (PAN)- and pitch-based carbon fabrics, using 3K, 4K 6K, and 12K tow carbon fibers. BGF says they offer high strength, high modulus, light weight, high thermal conductivity and electrical resistivity in primary and secondary aircraft structures, including engine components, rotor blades, radomes, ducting, brake linings and tooling.

Aramid: BGF's woven materials for aerocomposites are made from high-strength DuPont Kevlar fiber. BGF notes that aramid fabrics have excellent thermal and dimensional stability, perform with no strength loss up to 160°C for extended periods, weigh less than E-glass with higher specific strengths, demonstrate little or no change in a composite when indirectly exposed to UV light, and will not melt or support combustion.

Glass: BGF's E-glass and high-strength S-glass fabrics for composites applications use a heavier construction with complex weave patterns to produce a high-strength, high-performance, lower cost fabric than carbon or aramid. BGF's Aerialite fabrics (E- and S-glass), for snowboards, are specifically designed to provide superior handling and cleanliness to insure a smooth manufacturing process. Aerialite fabric reportedly exhibits improved wetout and clarity, which increases laminate strength and provides a smoother, whiter surface to make graphics stand out. Aerialite X (see photo) is designed with a range of fiber combinations, from 100% Innegra fiber to Innegra hybrid designs. The latest advancement comprises Innegra fiber commingled as part of the fiber matrix in both glass and carbon. Used for high-impact applications in surfboards, SUP boards, auto racing and protective sports equipment, Aerialite X delivers impact resistance, damage tolerance and vibration reduction.

Aluminized glass: Barracuda aluminized glass fabric reportedly looks like metal but has the functionality of high-performance fabrics. Applications include sporting goods, luggage, motorcycle helmets, kitchen appliances, dashboards, umbrella shafts and more. When combined with the proper resin, products made with Barracuda emulate the silver sheen of 3D steel, and beneath their surfaces, offer the same high-performance characteristics of conventional fiberglass fabrics.

Thermoplastic glass: PolyPreg is a woven commingled glass/polypropylene fabric, available in weights of 750 g/m^2 and 1,500 g/m^2 in natural or black colors. It can be directly consolidated, with the addition of heat and minimal pressure, into a high-strength composite part. PolyPreg has high glass content, high impact properties, unlimited shelf life, no emissions, recyclability and is said to be easy to process. **www.bgf.com**

CGTech (Irvine, CA, US) will present a software developer's perspective on implementing programming and simulation software for automated layup equipment. CGTech will demonstrate VERICUT Composite Applications: VERICUT Composite Paths for Engineering (VCPe), VERICUT Composite Programming (VCP) & VERICUT Composite Simulation (VCS). Booth visitors will have the opportunity to receive an overview of the steps necessary to get from a CAD-designed composite part to the CNC programs that drive an automated fiber placement (AFP) or automated tape laying (ATL) machine. Additionally, there will be news about new projects that will implement machine-independent offline NC programming software for AFP and ATL machines, such as ongoing work at NASA's Langley Research Center (Hampton, VA, US), using a 16-tow AFP machine from **Electroimpact** (Mukilteo, WA, US). CGTech also will exhibit its latest version of VERICUT software for machine simulation, verification and optimization software that enables users to eliminate the process of manually proving out NC programs. VERICUT simulates drilling and trimming of composite parts, waterjet, riveting, robotics, mill/turn and parallel kinematics. www.cgtech.com

Chemique Adhesives Inc. (Kennesaw, GA, US) will spotlight adhesives and sealants. Solfre 2, its rollable, beadable (see photo) and sprayable adhesive, is said to provide a strong, yet versatile solvent-free solution for bonding demanding lightweight composite panels, including architectural and structural insulated panels, hygienic wall cladding and cleanroom panels, to name a few.

In applications where instant grab and long tack life are needed, Chemique's Bondseal reportedly excels at joining metals, composites and thermoplastic substrates.

When a flexible but strong bond is needed, its Sabatack line provides simple and advantageous processing, speed and reliability of adhesive joints, improved construction rigidity, and superior acoustic and vibration absorption. www.chemiqueadhesives.com

Chem-Trend (Howell, MI, US) is emphasizing the continued evolution of its Chemlease and Zyvax mold release brands with the development of water-based release systems that perform as well or better than customary solvent-based products. Chem-Trend's water-based release systems are said to provide significant environmental and workplace advantages and boost performance for composite manufacturers. Reported advantages include increased throughput by minimizing mold fouling, as well as improved part cosmetics and reduced part rework. Chem-Trend's water-based alternatives can be applied by wipe or with spray equipment onto ambient or hot tooling. www.chemtrend.com »

Pigment and chemical dispersions supplier **Chromaflo Technologies** (Ashtabula, OH, US) will showcase several recent advances: Its Accumag dispersions, says Chromaflo, are the most consistently reactive thickener dispersions available to the market. Manufactured using a technology recently reformulated to improve reactivity and shelf stability of the dispersions, the result has been enhanced consistency and predictability of thickening for SMC, BMC and TMC systems, enabling customers to better manage and supply inventory logistics.

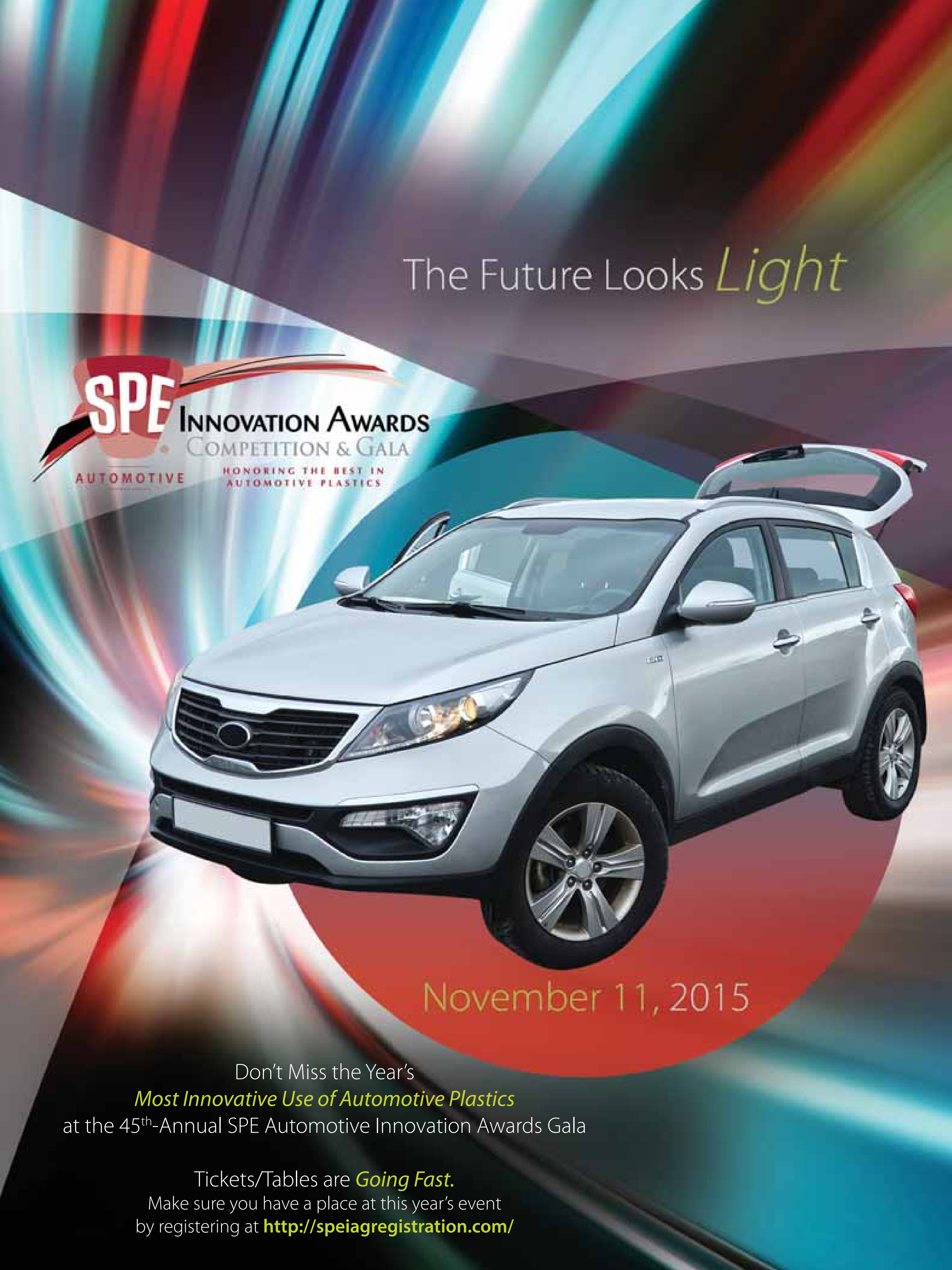
Chromaflo's IN-Series of inhibitor solutions have been designed for use in the thermoset industry to manage shelf stability and to retard premature gelation.

The UVSolutions line of pigment dispersions for weatherability employs a "total compound systems" approach that is tailored to the resin system and color space.

Chromaflo's new GTS line of colorants, designed for polyester SMC, BMC and pultrusion, contain a heavy metal-free, exterior-grade pigment dispersed in monomer-free, low-viscosity unsaturated polyester resin. They are suitable for volumetric and gravimetric pumping and metering, and can be used for in-plant tinting applications. www.chromaflo.com

Coastal Enterprises (Orange, CA, US), a manufacturer of Precision Board high-density urethane tooling board, will feature two new products: Its updated Precision Board, with superior physical properties and machining characteristics is said to hold edges better and provide smoother tapers. Chip loading also has been reduced, allowing concise speed and feed control. Samples will be available at Coastal's booth. New custom, machinable, Precision Board filament winding mandrels (pictured) are now available in any square size. These custom mandrels enable producers of filament-wound tanks and cylinders to more easily accommodate last-minute design changes and help reduce machining time on prototype or low-volume projects. The center shaft is molded into the mandrel during manufacture, which Coastal says eliminates twisting or turning of the shaft during winding. Coastal does not charge for engineering the mandrel design. See a small-scale example of a custom-made mandrel in Coastal's booth. www.precisionboard.com

Composites One (Arlington Heights, IL, US) and the Closed Mold Alliance will present its now well-known demonstrations live on the CAMX exhibit hall floor. This year, the "Lean Mean Process Machine ... REDUX" will »


The Future Looks Light
SPE
INNOVATION AWARDS
COMPETITION & GALA
AUTOMOTIVE
HONORING THE BEST IN AUTOMOTIVE PLASTICS
November 11, 2015
Don't Miss the Year's
Most Innovative Use of Automotive Plastics
at the 45th-Annual SPE Automotive Innovation Awards Gala
Tickets/Tables are Going Fast.
Make sure you have a place at this year's event
by registering at http://speiagregistration.com/

extend over three days, with more than 20 process demonstrations, carried out in a massive enclosed staging area. Reportedly, real-world parts will be built, ranging from aerospace nosecones and mini-nacelles to marine dashboards and longboards.

Booth exhibits will include a light resin transfer molding (LRTM) workcell and a time-lapse video showing a 3D-printed mold transition

from concept to reality in just hours, plus vacuum infusion, reusable silicone bag molding, and prepreg solutions. The prepreg parts will be cured using a large oven supplied by **Wisconsin Oven** (see p. 63). Products featured in the demonstration are provided by partners 3A Composites, AOC, Airtech International, Arkema, Ashland, Chem-Trend, Chomarat, ITW Plexus, Huntsman, Magnum Venus Plastech, Owens Corning, Polynt Composites, Scott Bader, Stratasys, Sworl, United Initiators, Vectorply, Roush Performance, Janicki Industries and RTM Solutions. **www.compositesone.com**

Dow Polyurethanes (Midland, MI, US) will introduce the VORAFORCE TP 1200 series, a novel polyurethane solution that enables fast, energy-efficient pultrusion fabrication with low volatile organic compound (VOC) emissions. Dow says its new solution supports pultrusion of composites for a number of applications, including building profiles, such as pilings, panels and window profiles, as well as utility poles, plus heavy-duty polyurethane pallets for logistics and transportation applications, and ladder rails for consumer use. The Dow pultrusion system also is said to provide low pull-through forces during processing, enabling greater productivity for fabricators. **www.dow.com**

EconCore (Leuven, Belgium) is emphasizing its patented ThermHex technology for continuous production of thermoplastic honeycomb-cored sandwich materials. The ThermHex process consists of integrated steps: vacuum forming extruded film to a pattern, mechanical folding to create honeycomb core structure, and lamination of skin material to the core. The process accommodates a wide range of thermoplastics to produce honeycomb core. PP is the most used, but PET, PA, PC, PLA, PPS, PVC, PMMA and others are possible. Faceskin options are equally broad, including both thermoplastics and thermoplastic composites reinforced with glass, carbon or natural fibers, as well as thermoset composites, steel, aluminum, wood and more. EconCore will showcase a number of sandwich materials produced today by its licensees. Applications include reusable packaging, graphical displays, and building and construction, marine and transportation (including automotive) components. Among the latter are interior door panels (see photo, p. 52) made with the ThermHex process by converting pellets to film, film to core, and in-line laminating of natural fiber skins to make the sandwich panel. Decorative textile layer and thermoforming to final part shape may be integrated on a commercial scale. EconCore will stress the ability to integrate finishing steps, such as decorative or UV protection layers. Post-processing operations, such as thermoforming, can be integrated. **www.econcore.com**

Elliott Co. of Indianapolis (Indianapolis, IN, US) is featuring its line of rigid polyiso/urethane foam core materials. Supplied as blocks, sheets and also in custom shapes, ELFOAM products are said to offer excellent insulating, fire resistance and structural physical properties. Depending on performance requirements, ELFOAM's ability to save weight, resist chemicals and handle temperatures of ±149°C can be of value in a variety of panel, tank, slope, insert and equipment applications. The company now also offers fabrication options to complement its sheeting, scoring, perforating and profiling capabilities. **www.elliottfoam.com**

Globe Machine Manufacturing Co. (Tacoma, WA, US) will showcase ongoing advances in effectively accelerating and automating composite parts manufacturing. Drawing on almost 100 years of custom machinery design/build experience, Globe offers customer-focused solutions to production efficiency, cost-control and material-handling problems. Its RapidClave curing systems are designed to enable parts-makers to attain autoclave-quality thermoset resin cures in minutes instead of hours. New concepts in unidirectional thermoplastic composite tape layup, and processing of tailored blanks, reportedly offer successful 1-minute part cycle times for automotive part workcells. **www.globemachine.com**

Visitors to the **Hennecke** (Lawrence, PA, US) exhibit will learn about the latest developments in its line of polyurethane composite fabrication technology. Of particular interest will be a high-performance carbon fiber/aluminum hybrid automobile wheel rim, manufactured with the aid of Hennecke's STREAMLINE high-pressure metering system for high-pressure resin transfer molding (HP-RTM) applications. Apart from a high-end surface structure, such rims offer enormous 25-30% weight reductions vs. conventional forged-aluminum rims. The result is not only lower fuel consumption, but also noticeably improved driving dynamics. Its HP-RTM process, says Hennecke, offers greater efficiency and product quality, and the option of processing large volumes economically. Also on display: An Audi *R8* automotive dashboard shell made with reaction » injection molding (RIM) and composite spraymolding (CSM); honeycomb composite automotive load floors; a CLEARMELT demonstration part; a polyurethane spray skin foam seat cushion; a Varysoft composite automotive part made via HP-RTM; long-fiber siding panels; an automotive leaf spring made via the STREAMLINE RTM process; the MN 10 mixhead for high-pressure spray; an MN 6 mixhead for polyurethane spray; and constant pressure injectors. www.henneckeinc.com

Hexcel (Stamford, CT, US) will highlight several products: HexSHIELD, its new honeycomb core, provides high temperature resistance in aircraft engine nacelles by means of a thermally resistant material inserted into the honeycomb cells. Its unique heat-shielding capabilities reportedly allow for the potential re-use of material after a fire at 1093°C. This product builds on Hexcel's history of heat-resistant honeycombs, including HexWeb HRH-327, with temperature resistance up to 260°C.

Acousti-Cap, Hexcel's broad-band noise-reducing honeycomb, has resulted in multi-degree of freedom (MDOF) liners that bring significant improvements in acoustic absorption capabilities in aircraft engine nacelles. The acoustic treatment may be positioned at a consistent depth and resistance within the core, or can be placed in a pattern of varying depths and/or resistances, offering an acoustic liner that is tuned to engine operating conditions. Tested at NASA on a full engine test rig, it met all 16 design conditions without trade-offs. An example of this new technology will be on display at CAMX.

Hexcel will display tooling made from HexTOOL M61, which is used to make CFAN fan blades for the GE90 and GEnx engines and is manufactured by Sawyer Composite (Ft. Worth, TX, US). Visitors also will see carbon fiber composite automotive body-in-white (BIW) parts made with HexPly M77 preforms from Hexcel's automated process (see photo, p. 54). The preforms' low tack allows for automated handling by the customer. They require no surface preparation and are designed for one-step bonding and curing in a press, requiring no finishing operations. Common BIW part joining technologies such as welding can be used, and the parts are compatible with e-coating processes.

Building on the attributes of HexPly M77, Hexcel reports that it has now installed a fully automated production line in Austria that converts UD prepreg into 2D preforms in seconds. The process allows prepreg plies of different weights and orientation to be combined in the same plybook and includes automated cutting, camera-assisted ply positioning and integration of adhesive and automated packing.

Hexcel also will promote its new Prepreg Resin Selector app, focused specifically on the prepreg products it develops and supplies for aerospace and industrial markets. The app enables users to select the best prepreg resin, based on market and application, cure temperature and maximum service temperature (T_g), and enables the user to view the full range of Hexcel's prepreg resin data sheets. The app is available for download free through the Apple iTunes Store (search Hexcel Prepreg Selector). www.hexcel.com

Innegra Technologies (Greenville, SC, US) will feature its full line of olefin-based Innegra fibers and discuss how to integrate Innegra materials into composite products. Proven as reinforcements in the sporting goods industry (in canoes, kayaks, paddles, hockey sticks, tennis rackets and helmets), Innegra's fiber products are being deployed in other composites markets, such as automotive, marine, industrial and travel (luggage and cases). During the summer, Innegra fiber was featured during a three-day demonstration at the EAA AirVenture Show (Oshkosh, WI, US). The demonstration consisted of using TeXtreme fabric reinforced with Innegra fiber to build an 82% scale F4 U *Corsair*, a replica Chance Vought fighter from WWII. At CAMX, the company will feature Innegra S and award-winning Innegra H fibers. Innegra S fiber is an olefin-based, multifilament fiber available in black and white; Innegra H fibers are hybridized, multifilament fibers that contain Innegra S and other high-performance fibers, including but not limited to carbon, glass, basalt and aramid. Technical sales representatives will be on hand at the show to answer questions about Innegra fiber and offer assistance in using Innegra products in composite and rope applications. Innegra » reinforcement materials can be found through the following suppliers: A&P Technology, Sigmatex, Oxeon, Texonic, Adfors, Textum, G. Angeloni, Composites Fabric of America (CFA), BGF, SAATI, Highland, Absecon, Axiom, Composites One, TexTech, TEAM Textiles, Vectorply, V2, Saertex, AEC, Carolina Narrow, Flotex and more. www.innegratech.com

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Janicki Industries (Sedro-Woolley, WA, US) will highlight its capabilities in tooling, prototyping and fabrication of parts for aerospace, marine, energy, architecture, military, space and transportation markets. Janicki has experience with many composites-related products, including syntactic putty; 71°C fiberglass composites; 121°C carbon fiber tools; 121°C carbon/fiberglass hybrid molds; and 121°C Invar and steel molds. Of special note, says Janicki, are the following:

- Carbon/JBXA layup molds that cure at 182°C and support more than 100 cycles.
- Carbon/BMI layup molds that cure at 182°C and support more than 200 cycles.
- Invar/steel layup molds that cure at 182°C and support more than 1,000 cycles.
- Aluminum layup molds that cure at 121°C and support more than 250 cycles.

www.janicki.com

L&L Products (Romeo, MI, US) will feature a range of room temperature-curing two-component fire, smoke, toxicity (FST)-compliant adhesives for simple assembly of composite parts. They're supplied in a two-component cartridge, and (as separate components) in pails or drums.

One of the components contains an epoxy-based adhesive, while the other contains an amine-based curing agent. L&L says its adhesives hold a high-strength bond and are designed to meet the stringent requirements of the aerospace industry. The company notes that a 12-second vertical burn is the minimum specification to meet FAA *FAR 25* requirements; L&L's adhesives reportedly exceed the requirement by passing the most stringent of the tests at 60 seconds. All of the two-component adhesives have a 1:1 or 2:1 mix ratio, enabling easy working conditions, using standard applicator gun sizes. Typical gel times are 5-90 minutes, depending on the material used. All the company's two-component FST adhesives are REACH-compliant. Typical applications include bonding inserts to honeycomb panels, panel-to-panel bonding (ability to bond multi-material substrates), composite potting and fillet seals.
www.llproducts.com

Luna Innovations (Roanoke, VA, US) will present a paper on Thursday, Oct. 29 at 8:00 a.m., titled "In-Situ SHM of Composite-Overwrapped Pressure Vessels." It will demonstrate how Luna's High-Definition Fiber Optic Sensing (HD-FOS) system is used to monitor distributed strain in composite-overwrapped pressure vessels (COPVs) throughout the manufacturing process, subsequent qualification testing and periodically during a pressure vessel's service life. Luna's ODiSI product platform uses HD-FOS technology to turn ordinary, unaltered, single-mode fiber-optic cable into advanced strain or temperature sensors. Fiber-optic cables, when illuminated, have the equivalent of an optical fingerprint, which changes, in a predictable and repeatable way, in response to changes in strain and temperature. The fiber sensor, coupled with Luna's advanced HD-FOS technology, replicates a virtually continuous line of strain gages or temperature sensors with mere millimeter spacing between sensing points. At 150 microns in diameter, the fiber sensor also has the capability to be embedded within structures under test. For strain, this high-density sensing is suitable for measuring the non-linearity and high gradients associated with composite structures, as well as for finite element analysis (FEA) model validation of designs with complex geometries or that use new advanced materials. www.lunainc.com

MarkForged (Cambridge, MA, US) will return to CAMX with the Mark One Composite 3D Printer and an assortment of ultra-strong, fiber-reinforced 3D-printed parts and applications. MarkForged notes that using additive manufacturing to automate the composite layup process with thermoplastics eliminates the laborious tasks typically associated with hand layup. Manufacturers, says the company, are thus no longer limited to sheets of composite, long-lead time tooling, clamshell designs and manual labor. The Mark One can turn complex assemblies into a single printed part. As the world's first 3D printer capable of printing continuous-strand carbon fiber, Kevlar, and fiberglass, the Mark One uses a patented Continuous Filament Fabrication (CFF) print head alongside a FFF (Fused Filament Fabrication) printhead to create tough and functional parts. The company says the system enables designers and engineers to 3D-print reinforced plastic parts that are up to 30 times stronger and 30 times stiffer than conventional 3D-printed parts made from ABS plastic. **www.markforged.com**

Matrix Composites (Rockledge, FL, US) is emphasizing its Hot Isostatic Resin Pressure Molding (HiRPM) process, an out-of-autoclave system designed for composite mold and composite part fabrication. HiRPM, says Matrix, offers ±0.003-inch dimensional repeatability, eliminates shimming processes in bonded assemblies, provides precise IML and OML profile controls, eliminates debulking, is compatible with qualified materials, and produces laminates with validated void content of less than 0.5%. It's suitable for integrating multiple parts into a single assembly, offers minimal post-mold machining, is easily customized and is well-suited for fabrication of radomes, spars, aerocontrol surfaces, complex geometries and critical edges. **www.matrixcomp.com** »

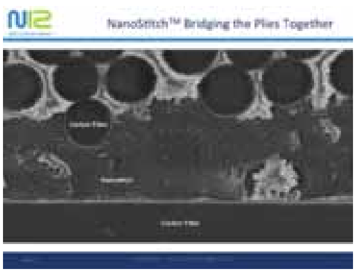
Maverick Corp. (Blue Ash, OH, US) will feature its family of non-MDA polyimides in a co-exhibit with **Renegade Materials Corp.** (Springboro, OH, US). The products they'll have on display are currently in production and qualification at aerospace primes. All of Maverick's polyimide products are available in prepreg and adhesive form from Renegade. Two of Maverick's featured polyimides will be MVK-14 Freeform and RM-1100. MVK-14 Freeform is now flying on commercial engine and aircraft platforms. MVK-14 Freeform and RM-1100 are in the qualification process at various aerospace primes and are under evaluation as primary structure for new, advanced military engines. Maverick also will showcase its high-temperature polyimide resin transfer molding (RTM) resins, including MVK-10 and J1, as well as its line of aerospace-qualified, fully certified compression-molded parts and components. www.maverickcorp.com | www.renegadematerials.com

The McLube Division of McGee Industries Inc. (Aston, PA, US) is featuring its line of release agents for high-performance composites fabrication processes. These new coatings, says McLube, address key concerns within the industry, including gloss, reduced VOC emissions, improved part appearance, abrasion-resistance and multiple pulls per application. McLube's products include water- and solvent-based releases and anti-tack coatings, plus a full line of oils, greases and dry film lubricants. www.mclube.com

Mokon (Buffalo, NY, US) is emphasizing the redesign of its Duratherm MAX line of high-performance water systems, with temperatures up to 193°C and system pressures up to 20.7 bar. Each incorporates a top air discharge to direct waste heat away from personnel, features increased mechanical compartment ventilation, and offers greater access to components for maintenance and improved overall performance of the system. The basic unit is designed for restrictive processes and high-temperature water applications. It features a stainless steel heater vessel designed and tested to ASME standards. It also uses nonferrous and stainless steel materials of construction and a seal-less magnetic drive turbine pump fitted with a stainless steel impeller. The Duratherm MAX incorporates a fan-cooled heat exchanger that provides safe, dependable process fluid cooling and eliminates thermal shock, flashing to steam, mineral buildup and expansion noise. **www.mokon.com**

Web tension control specialist **Montalvo** (Gorham, ME, US) will showcase its new Modular Automated Tensioner (MAT) and Automated Tensioning Stand (ATS) units. Designed for applications that run multiple strands (via creels, rovings, etc.) of composite materials, the MAT and ATS systems are drop-in units for existing and new applications that create a high-performance and, reportedly, cost-effective tension zone prior to the material being processed. This new tension zone allows every strand of composite material to be precisely tensioned, automatically and continuously, throughout a production run, ensuring reduced waste and a higher-quality end product. Applications include hand layup, filament winding, pultrusion and prepreg processes. **www.montalvo.com**

Nanotechnology specialist **N12 Technologies Inc.** (Cambridge, MA, US) has commercialized a Massachusetts Institute of Technology (MIT)-licensed technology, called NanoStitch, to become the world's first manufacturer capable of industrialized, continuous vertically aligned carbon nanotube (VACNT) production (also see "CW Trends," p. 22). N12 will feature



this patented z-axis mechanical enhancement technology at CAMX. Via NanoStitch, nano-sized fibers can be "grown" perpendicular to and on the surface of a carbon fiber prepreg, conveying to the prepreg surface a z-direction bonding point that substantially increases interlaminar shear strength (see photo, p. 59). N12 says shear, fracture, compression and fatigue performance of composite materials can be significantly enhanced by NanoStitch. N12 is scaling manufacturing capacity, testing materials for multiple OEM programs and collaborating with the world's leading prepreg composite suppliers to develop a full range of certified NanoStitch-enhanced fiber/resin systems. The company also is developing NanoStitch-enhanced products compatible with resin infusion techniques, thermoplastics and adhesives. N12 says it has more than 100 OEMs globally exploring and testing its technology and have now committed the capital through 2018 and beyond to build industrial-scale NanoStitch manufacturing capacity. **www.n12technologies.com**

NDT Systems Inc. (Huntington Beach, CA, US) will feature its line of advanced ultrasonic testing equipment to the nondestructive testing (NDT) marketplace. These products include a variety of ultrasonic thickness gages, bond testers, portable flaw detectors and a range of precision ultrasonic transducers and manual and automated scanners for the inspection of almost all materials, from advanced composite materials and plastics to ceramics and metals. The bond tester allows for rapid inspection of bond line integrity; imaging flaw detectors give the advantage of area scanning with C-scan displays in an easy-to-use package. Customized solutions, including fully automated inspection solutions and specialized transducers, also are available. **www.ndtsystems.com**

PPG Industries' (Pittsburgh, PA, US) fiberglass business is introducing at CAMX its HYBON 2052 direct draw roving, designed for high- and low-pressure epoxy pipe applications and pressure vessels. It is compatible with amine- and anhydride-cured epoxy resin systems. HYBON 2052 is available in E-glass and E-CR glass compositions. PPG says the tailored chemistry, which uses an alkyl phenol ethoxylate (APE)-free sizing system, offers excellent fiber/matrix interfacial hydrolysis resistance and strength retention. These products are currently produced in the US and are globally available in various TEX/YIELD options in filament diameters ranging from 16 to 23 microns. **www.ppgfiberglass.com**

Reichhold (Durham, NC, US) will launch its new ADVALITE vinyl hybrid resins, available in styrene-free liquid and monomer-free hot-melt prepreg versions. Both versions reportedly exhibit excellent mechanical properties with a rapid cure rate to reduce production cycle times. ADVALITE vinyl hybrid resins can be used in resin transfer molding (RTM), infusion, filament winding, liquid molding and pultrusion processes, directly coated or adhesive filmed for fiber impregnation.

During the CAMX conference, Reichhold's James A. Bono will present "Vinyl Hybrid Snap Cure Resin Applications in Filament Winding, RTM and Prepreg Processes"; Samuel Freeman will present "Studies on the Effect of Degree of Crosslinking of Vinyl/Acrylate Networks"; Anthony Skrobacki will present "Mechanical and Thermal Analysis of Toughened Rubber-Modified Vinyl Ester"; and Hildeberto Nava will present, "Studies on the Reactivity of 1, 2-Vinyl Containing Liquid Rubbers in a Rubber Modified Vinyl Ester." **www.reichhold.com**

Sunstrand (Louisville, KY, US), a manufacturer of natural fibers for polymer composite reinforcement and plastic fillers, says all Sunstrand products and processes have been designed to deliver consistent, high-quality fibers that are compatible with typical composite manufacturing processes. The Sunstrand team has developed architectures to service a variety of industries, including automotive, sporting goods, building materials, consumer products, and marine. CEO and founder of Sunstrand, Dr. Trey Riddle, also will be leading an educational session at CAMX, titled "Assessment of Composite Properties Utilizing Short Discontinuous Natural Fibers," on Tuesday, Oct. 27, at 2:00 p.m. **www.sunstrands.com**

TE Wire & Cable LLC (Saddle Brook, NJ, US), a thermocouple and specialty wire and cable manufacturer, will exhibit a variety of high-accuracy thermocouple products. Featured will be the company's AccuClave autoclave thermocouple assemblies, designed to improve the accuracy, reliability and efficiency of aviation and space program autoclave applications, including a new solution especially for tooling departments. Unveiled will be prototypes of the company's new bayonet-style thermocouple sensor for measuring Invar tool temperature. This new addition to the AccuClave can be configured to handle ambient temperatures of 200°C-870°C. The product is available in Type J and K calibrations with fixed and adjustable spring-loaded fittings. Also featured will be AccuClave reusable, pre-made thermocouple assemblies; AccuClave-X thermocouple extension cables for faster autoclave loading; the AccuConnect multi-circuit interconnect system; and AccuFlex, for composite repairs with minimal mark-off. **www.tewire.com**

Teijin Aramid USA (Conyers, GA, US) will feature its aramid fiber reinforcements under the Twaron and Technora brand names for use in automotive, aerospace, ballistic protection, civil engineering, composites, heat- and cut-protective clothing and optical-fiber cables. Twaron and Technora aramid fibers, says Teijin, offer high strength and stiffness in combination with low density. In powder form, they reportedly can reduce wear and improve durability in engineering plastics, even when operating under high speeds and temperatures. Twaron aramid short-cut fibers now offer improved dosing and processing behavior. **www.teijinaramid.com**

TenCate Advanced Composites (Morgan Hill, CA, US) will highlight several technologies. TenCate TC275-1 is an out-of-autoclave (OOA) epoxy prepreg that features good moisture resistance and good hot/wet strength retention. This product has a dry T_g of 183°C and a 136°C wet T_g after saturation. It has an extensive database on a variety of fibers, including HexTow HM63, IM-7 and Grafil's TR50S 15K fiber. TC275-1 is in several active qualification programs and is already in use in large-volume applications.

TenCate Cetex TC1320 PEKK-based uni-tapes will be featured. These have a relatively low processing temperatures, but reportedly retain excellent mechanical performance at 121°C with good impact and FST properties. Developed to serve commercial aircraft structural » applications, they are optimized for automated tape laying (ATL) applications, as well as for oven processing.

TenCate Composite Molded Billet Stock is being offered in 25.4-mm to 76.2-mm thick molded and machined billet stock from thermoset bulk molding compounds (BMC). Billet stock is offered in plates up to 356 mm wide by 711 mm long. Billet stock has the tensile strength of aluminum with 40% weight savings. Billet stock also may be used for hard-point attachments and saves layup costs of thick laminate fabrication.

TenCate's TC890 polyimide high-temperature prepregs, using polyimide resin from PROOF Research's (Columbia Falls, MT, US) P2SI, will be highlighted. PROOF Research's P2SI's 900HT resin is a high-temperature, non-MDA replacement for PMR 15 applications. A US Air Force-funded design allowables database on 900HT is being finalized. The prepreg made with this resin is on T650-35/8HS fabric. The design allowables database will be made available to interested parties. Further, a complete P2SI 900HT toolkit is being developed under Integrated Computational Methods for Composite Materials (ICM2) activities, which includes integration into the commercial process modeling and simulation software COMPRO and RAVEN (Convergent Manufacturing Technologies). www.tencateadvancedcomposites.com

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Thermwood Corp. (Dale, IN, US), a manufacturer of 3- and 5-axis CNC routers, will emphasize its new program to develop a 3D additive manufacturing system capable of making large "carbon graphite"-reinforced thermoplastic composite components. Thermwood's system uses a "near net-shape" approach where a relatively large extruder, mounted to the machine, is used to heat, melt and deposit, or "print," the carbon graphite-filled thermoplastic material to quickly create a structure that is almost, but not quite, the final shape. That structure, when it cools and hardens, is then 5-axis machined to net shape. These new systems will be based on Thermwood's Model 77, semi-enclosed, high-wall gantry machine structures, which are currently offered in sizes up to 18.3m long. For the plastic extruder, Thermwood turned to **American Kuhne** (Ashaway, RI, US), a provider of engineered solutions for plastic, rubber and silicone extrusion, which developed a custom system that integrates closely with Thermwood's CNC machine. With the addition of a second gantry, the additive and subtractive processes can be performed on the same machine. A second subtractive gantry will be offered as an option. Thermwood's system will feature a full 6-axis articulated additive deposition head, allowing it to build layered structures on a horizontal plane as well as planes canted in any direction up to 90° from horizontal. Thermwood's initial development machine, which is nearing completion, can make parts up to 3m long by 3m wide by 1.52m high, is equipped with a 20-hp, 44.5-mm diameter, 24:1 L/D extruder and support equipment capable of processing more than 45.4 kg/hr of material. www.thermwood.com | www.americankuhne.com

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Vectorply Corp. (Phenix City, AL, US) is introducing at CAMX VectorLam Cirrus 2.0, the latest edition of Vectorply's proprietary laminate analysis software. Version 2.0 provides a cloud-based, multi-platform-compatible approach to classical laminate theory and provides a suite of services across diversified market segments. This upgrade from the Excel-based version of VectorLam allows users to build and access laminates on nearly any Internet-connected device. VectorLam Cirrus 2.0 is designed to help users achieve goals of stiffness, strength, weight and cost by enabling them to design a specific laminate for their application. The 2.0 program is free to all users and will be accessible through Vectorply's Web site.

Vectorply's director of composites engineering, Trevor Gundberg, will present his technical paper at CAMX titled, "E-Glass/Polypropylene Woven & Stitch-Bonded Biaxial Fabrics — Static & Dynamic Composite Property Characterization." The paper covers the mechanical property testing — static and dynamic — done on Vectorply's ThermoPly E-glass/polypropylene commingled fabrics. Gundberg will compare this data with other types of thermoplastic composites, including LFRT and similar thermoset composites. **www.vectorply.com**

Victrex (Thornton Clevelys, UK) is featuring its hybrid molding technology that allows engineers to overmold a PAEK-based composite with fiber-reinforced PEEK injection molding materials. This polymeric advancement enables the design of stronger, lower cost components that are up to 60% lighter than typical metal and thermoset systems. Victrex and Tri-Mack Plastics Manufacturing Corp. (Bristol, RI, US) have cooperated to engineer an aerospace bracket using this new polymer and technique with the demanding performance requirements of loaded applications in mind. The bracket will be available for viewing in the Victrex booth. **www.victrex.com**

Virtek (Waterloo, ON, Canada), a subsidiary of **Gerber Technology** (Tolland, CT, US), will feature Virtek Projection Data Creator (PDC) software to quickly and accurately visualize, generate and edit projection data from CAD models in a virtual 3D environment. Virtek says PDC supports a number of formats and quickly generates projection files in a virtual 3D environment. Virtek PDC supports CAD files in IGES, STEP, CATIA V4/5/6, Siemens NX, Solidworks, DXF, CREO, Parasolid and Autodesk Inventor file formats. It also supports Virtek LaserEdge and the Iris Spatial Positioning System, particularly in the creation of datum and verification points. Virtek PDC, which replaces the Virtek Planner software, supports documentation, such as queries, labels or graphics. **www.virtek.ca**

Wisconsin Oven Corp. (East Troy, WI, US) will feature its line of electrically heated, gas-fired and indirect gas-fired batch ovens for curing composites. Features include data acquisition instruments, vacuum piping, pumps and transducers. All equipment is designed for combination airflow arrangement, which ensures even and uniform heat distribution throughout the work chamber and provides quicker heating rates and recovery times. Wisconsin Oven's composite curing ovens are typically guaranteed and certified for ±10° at 350°F temperature uniformity. Tighter tolerances and certification at other temperatures are available. Equipment is completely tested prior to shipment and must pass a 154-point quality inspection prior to shipment. Wisconsin Oven also supplies ovens for a variety of other applications, including finishing, heat-treating and solution-treating. **www.wisoven.com**

Reforming the technological foundations

CFK-Valley Stade technical conferences historically have lacked little in terms of technical excellence. That said, CEO Gunnar Merz opened the 2015 proceedings by predicting an historic shift in manufacturing, under the collective name "Industry 4.0." From there, attendees knew they were in for something extra, and many Convention sessions, indeed, were sounding boards for what many called a coming revolution.

Source (left) | Michael Hensel / Source (below) | CFK-Valley Stade Convention

CFK-Valley Stade Convention 2015 report

The composites industry in Germany proclaims the coming 4th Industrial Revolution.

By Bob Griffiths / Contributing Writer

» Previous CFK-Valley Stade technical conferences have lacked nothing in the way of excellence. Papers have unfailingly revealed the latest technology from academic institutions and reported the most forward-looking automated production techniques from German industry. But two new features made the 2015 event stand apart. The first was the new concept of Partner Countries. This year's partner was Belgium, with a surprise benefit that I will come to later. The second was announced in the conference title: "Industry 4.0 for Composites." New to many in the audience, particularly those outside Germany, the term "Industry 4.0" was coined in 2011 and refers to the integration of the supply chain based on three concepts: cyber-physical systems, the Internet of Things and the Internet of Services, a combination which is expected to lead to what proponents call truly "Smart Industries."

Opening day

CFK-Valley Stade CEO Gunnar Merz opened proceedings by introducing Industry 4.0 — shorthand for the Fourth Industrial Revolution, the follow-on to the first, based on the steam engine; the second, on the use of electrical systems to power Ford's assembly lines; and the third, powered by today's computer-controlled machines and local networking. Merz's description, however, went beyond the concept of a smart factory to include all interfacing organizations in a Smart Complex, with a target date of 2040.

After Merz set the conference theme in perspective, two keynote speakers took turns at the podium.

The first, Eva Brockhous of ptJ (Jűlich, Germany), addressed the all-important subject of funding for R&D. In Europe, the European Union's (EU) Framework series of programs will finish with the currently ongoing 7th Framework and will be replaced by Horizon 2020. To encourage participation, the German government was enabling companies to obtain advice from ptJ, free of charge. There were strict rules for how teams of companies could be formed to be eligible for funding. The minimum requirement was a team of three legal entities from three EU member states.

The second keynoter, Prof. Berend Denkena, head of IFW at Leibniz Universität Hannover (Hanover, Germany), picked up the Industry 4.0 theme. Denkena explained that what began as a German concept is gaining recognition globally and, although some details aren't yet defined, 4.0 involves a cloud-based system that could enable an entire industrial complex to communicate via smart devices: A smart machine tool, for example, might measure excessive deflection of a cutter, draw a conclusion as to the cause, then take corrective action, which might include placing the order for a replacement cutter from the supplier.

Wilhelm Rupertsberger, of Fill Gesellschaft mbH (Gurten, Austria), gave a wide-ranging presentation on Fill's automated production systems. Examples were given of its applications in

FIG. 1 Fully automated production

Fill Gesellschaft (Gurten, Austria) showcased the automated production cells supplied for the BMW *i3*, which include layup lines, ultrasonic joining, preform cells, RTM cells, 3D cutting and braiding cells like those pictured above.

Source | Fills Gesellschaft

the automotive and aerospace industries (see Fig. 1, above). Also shown were a wide range of NDT cells, many including robots. Further, integrated and automatic data handling systems were shown to provide high-quality data to ensure transparent, highly efficient machine operations.

Dr. Nikos Pantelelis, of Synthesites Innovation Technologies (Piraeus, Greece), reported that an intelligent monitoring system has been developed for the monitoring of composites curing, providing real-time T_g indication. A module has been added that also checks the degree of cure in real time by means of measurements of the electrical resistance and temperatures. This module is specific for each type of resin.

Dr. Carsten Schmidt, an engineering researcher at the University of Hannover + IFW (Stade), has *redesigned* the design process so that manufacturing planners are involved earlier and detailed design happens later. He outlined an innovative design for a fuselage panel that was fulfilled by this process, which yielded a 2.3% lighter panel with bigger windows *and* increased manufacturability. The double-curvature of the new design produced a few quality issues for the automated fiber placement (AFP) machine, such as gaps between placed tows, but work was undertaken to show that this was predictable and within acceptable tolerances.

Dr. Yves-Simon Gloy, head of the Textile Machinery/Production Technologies division at RWTH Aachen University, ITA (Aachen, Germany) returned to the conference theme, raising the question in his presentation title, "Will Industry 4.0 bring an evolution or a [R]evolution to automating composites?" He provided many examples where networked data were used to automate both textile machines and composite processing. His conclusion was that it would, indeed, bring a revolution to the composites industry.

In his interesting and detailed review of current carbon fiber manufacturing capacities, costs and methods, Dr. Henry Shin, head of the ICC lab at the Korea Institute of Carbon Convergence Technology (KCTECH, Jeonju, Republic of Korea), showed that the precursor contributes more than half of fiber cost and that, in most fiber manufacturing scenarios, it is made using a wet-spinning process, which is slow and expensive. He proposed replacing this with *melt* spinning. It is possible, he claimed, to exceed the Ford Motor Co. (Dearborn, MI, US) specification for T300 carbon fiber, in strength and modulus, using a precursor made by melt spinning. He was able to offer a large range of fiber diameters, from 28 to 43 μm.

Dr. Johannes Treiber, development engineer/project manager for Coriolis Composites GmbH (Augsburg, Germany), presented "Automated Manufacture of Mass Production and Low-cost Materials." The paper demonstrated how complex parts for aerospace and automotive applications can be made by AFP, followed by press forming.

Frank Wunder, Hufschmied Spanungssysytem GmbH (Bobingen, Germany), talked about the high-speed cutting of carbon fiber-reinforced polymers (CFRP). The paper reviewed the current options and their weaknesses: ultrasonic-assisted drilling (high tool wear); CO_2 laser and waterjet (both high-cost systems). The recommended solution was ultra high-speed machining at 60,000 rpm, with examples of what could be done with such a high-speed system.

Darmstadt-based Evonik Industries AG's marketing expert Uwe Lang announced two solutions that address a previous processing weakness for the company's ROHACELL foam: the need to machine or very slowly thermoform the foam to simple shapes. The latter process involves a preheating period of nearly an hour due to the foam's excellent insulation properties. Lang says a new way has been found to heat the foam by using a selected infrared frequency, which penetrates the material, reducing heat-up times to a few minutes, as the first stage for what has been renamed a "thermoshaping" process, called the In Mould Forming (IMF) method. Secondly, Evonik has a new version of ROHACELL, named Triple F, that can be *molded* into *complex* shapes see Fig. 2, below). »

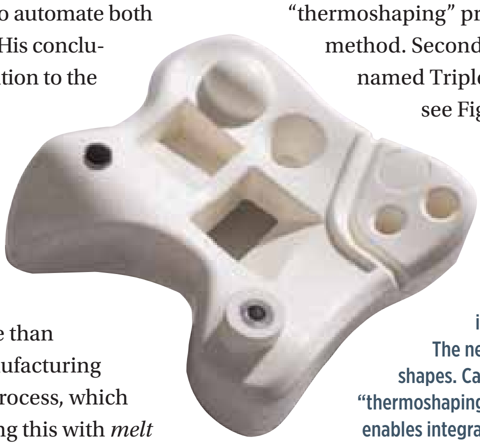

FIG. 2 Foam forms complex shapes, accepts inserts

Darmstadt, Germany-based Evonik Industries AG introduced a new version of ROHACELL, called Triple F. The new foam formulation can be molded into very complex shapes. Called the In Mould Forming (IMF) process, a companion "thermoshaping" process enables not only complex contours but also enables integration of metal inserts. Source | Evonik Resource Efficiency GmbH

Dr. Felix Kruse, head of the Department of Composite Process Technology at the Institute of Composite Structures and Adaptive Systems, German Aerospace Center (DLR) at Stade, explained how he has developed a machine that lays dry tows in a wide band through a laying head. Judging from the slides shown, the positioning of the tows was so precise that the band of material deposited looked more like a wide tape of UD prepreg. It was reported that the fibers were dry and had no binder. The process, Automated Direct Fiber Placement, was developed to enable a new design for wind turbine blades.

Belgium's keynoter, Julie Leroy, introduced the two Belgium organizations that will be involved with CFK. First is AGORIA (Brussels), for which she is business group leader. AGORIA brings together members from the technology sector, most of whom are involved with composites. Second is Brussels-based *sirris*, a collective that connects clients with testing, consulting and technology marketing expertise. The concepts of Industry 4.0, she noted, have been taken up by Belgian industry, under the banner, "Made Different."

Dr. Eli Voet introduced work on composite structures with sensors embedded in or on the laminate. His company, Com&Sens (Zwijnaarde, Belgium), of which he is a managing associate, applies Fiber Bragg Gratings in a variety of applications, such as marine turbines. Beyond the obvious operational uses, measuring in-service strains on structures, examples were given of additional use in monitoring production processes, such as filament winding and thermoplastic tape laying.

Day two

The second day began a keynote from Hermann Rosen, founder of the Rosen Group (Karlsruhe, Germany), about the use of an integrated system to run a truly global company. Although the company at issue was in the service side of the oil industry, it was a good vision of where the composite industry needs to aim.

Marcus Kleinberg, from the DLR portal at Braunschweig, showed a new approach to composite molding process control. Applicable equally to open and closed mold processes, his premise was based on the fact that raw materials and production processes have tolerances that are in the production specification. Today, the typical way of solving this problem is defining a conservative, and invariable, production corridor. His proposal is to use sensors, typically of the ultrasonic type, to monitor the ongoing processes and to adjust production parameters during the process — or at least correct the parameter settings for the next shot. He believes this will improve repeatability and perhaps reduce production cycle times and scrap rates.

Dr. Christian Weimer, head of operations at Airbus Group Innovations (Stade), reported on a program to automate the inspection of laminates laid by AFP machines in parallel with the layup process. Program targets are ambitious: Reduce inspection times by 95%, nonconformities by 50% and total inspection time, including NDT, by 50%.

Dr. Fabian Schreiber, a board member at ark industrie AG in Aachen, showed how many elements necessary for implementing Industry 4.0 in the composite industry are available today. These range from ways of communicating with operators (Google Glass) to the use of the cloud. Textile machines, such as braiders, could incorporate RFID chips in each bobbin, to control material supply, and stress sensors in each braided structure for health monitoring, allowing the safe use of lighter structures.

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Alexander Schönberg, FFT Produktionssysteme GmbH & Co. (Fulda-Rodges, Germany), described a system FFT developed to locate the stringers on the Airbus A350 wingskins. A circumferential and longitudinal tolerance of about ±1 mm after curing is required. Therefore, the stringers must be positioned by robots with 0.3 mm accuracy. The end-effector is moved by four robots located on each side of the tool. The accuracy requires that the position is checked by laser trackers that send signals to the robots together with data from a force sensor. The FTT technology is called absolute robot positioning (Ab.Ro.Pos) and uses an Emscon-client to manage laser trackers (Leica AT901-XR with a T-Mac) and an ATI Omega 160 force/torque sensor on each of the end-effectors.

Dr. John Klintworth, director of strategy at Dassault Systèmes (Woking, UK), wrapped up the conference by uniting the convention's composites and Industry 4.0 themes. He talked about using a single data model that could transform the efficiency of using composites by modeling and simulating *all* the processes, from design through to manufacturing. What was new was the plan to include an integrated cost model in the system, so that designers could quickly compare the cost of different options.

Welcome change

We live in a time when the overall manufacturing industry is about to go through one of its occasional "revolutions." The composites industry will not be exempt. In fact, the complexity of the products made from composites and the associated intricacies of composite designs indicate that our industry will have the *most to gain*. So let us all welcome the changes that are approaching! CW

ABOUT THE AUTHOR

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■ Composites promote conservation

To encourage the return of catfish to the Chicago River, representatives of conservation group Friends of the Chicago River, the Illinois Department of Natural Resources, Urban Habitat Chicago, Ozinga RMC, students representing several other Chicago non-profits, and Asimow Landscaping gathered to produce 50 demonstrator fish habitat and spawning units (FHSUs). Source | Ozinga RMC Inc.

Composite rebar strengthens riverbed "catfish houses"

Basalt-reinforced polyester rebar extends useful life of concrete habitat units in Chicago River environmental restoration effort.

By Peggy Malnati / Contributing Writer

» More than a century of engineering effort has made the Chicago River — a 251-km long system of rivers and canals that snakes through urban Chicago, IL, US — into what the American Society of Civil Engineers (ASCE, Reston, VA, US) today considers a "civil engineering monument of the millennium." One result? Water quality has improved dramatically in the past 30 years, according to Margaret Frisbie, executive director of the Chicago-based conservation group Friends of the Chicago River (Friends). A downside, however, is that in many areas of the system, the downed trees and natural riverbanks that created good fish habitat and would ordinarily be present have been replaced with concrete seawalls, thus preventing the return of healthy fish populations to the now improved river environment. To address the loss of fish habitat and encourage healthy repopulation, Friends worked with the Illinois Department of Natural Resources (IDNR) to design nesting cavities for channel catfish, a native species that surveys had shown should be more abundant in the system. The simple cavity design mimicked an underwater hollow log. It was designed using 31-cm-diameter PVC pipe cut to 81-cm lengths and attached by steel cables to concrete blocks to weigh the pipes down and keep them on the bottom of the river. The plan was to install 400 fish habitat and spawning units (FHSUs), introduce 100,000 baby channel catfish, donated by IDNR, that would mature in the river and, ultimately, see them use the FHSUs as nesting cavities.

Before FHSU production began, Friends had an opportunity to consult with Brian Lutey, VP – sustainability at Ozinga Green Building, a division of Ozinga Bros. Inc., a Chicago-based builder and concrete supplier. He examined the initial FHSU design and suggested that there was a better way to make them.

Lutey is active on the board of another non-profit called Urban Habitat Chicago (UHC, Chicago). The group's mission is to demonstrate the viability of green infrastructure, urban agriculture and materials reuse/recycling, and to work with disadvantaged and at-risk youth. He knew a microbiologist and fish expert from that board, so they met to discuss the needs of catfish and the possibility of using Ozinga's Filtercrete "pervious" concrete in FHSUs.

Pervious concrete is fairly *porous*. Thanks to use of the chunky aggregate that creates *pores* in its finished structure, it's often used in parking lots of green buildings to encourage rainwater to infiltrate soils rather than run off to overloaded storm drains. The biologist already knew that pervious concrete's pores help to clean water by trapping large particles (mechanical filtration) and by providing habitat for microbes and invertebrate colonies, which eat organic matter (chemical filtration) and, in turn, are eaten by fish fry (baby fish) and larger vertebrates. The pores also would help reduce the structure's mass.

Because the FHSUs were intended as permanent installations, that's where composites entered the picture. In an aquatic environment, steel rebar would quickly rust and contribute to premature unit failure, but Lutey knew composite rebar would resist corrosion and withstand long-term underwater exposure to freeze/thaw cycles. To find a source of composite rebar, Lutey turned to Dr. Mohsen Issa, Ph.D., P.E., S.E., professor of structural and civil engineering at the University of Illinois – Chicago, who is well known for his work on high-performance concrete and rapid bridge replacement. Issa put Lutey in touch with RockWerk Systems Inc. (Naperville, IL, US), which was working with composites consultancy Allied Composite Technologies LLC (ACT, Rochester Hills, MI, US) to develop North American-produced basalt-reinforced composite rebar.

"We've been working with Dr. Issa for about 10 years on different types of basalt rebar," explains RockWerks partner, Jack Rigsby. "I brought the first composite rebar over from Russia 12 years ago when I was head of R&D at Dukane Precast [Naperville, IL, US]. Dukane built the first building in the US I'm aware of that was reinforced in key sections with basalt rebar for Argonne National Laboratory [Lemont, IL, US]. They needed a building free of steel because their equipment created magnetic fields around »

Rebar reinforced with basalt fiber

The FHSUs, affectionately called "catfish houses," were formed by Urban Habitat Chicago crews using Ozinga's Filtercrete pervious concrete reinforced with composite rebar (unsaturated polyester resin reinforced with basalt rovings supplied by RockWerk Systems Inc.). The project also helped at-risk and disadvantaged Chicago youth gain useful and interesting real-world experience while helping improve the health of the Chicago River. Source | Ozinga RMC Inc.

Generational improvements continue

Generation 1 FHSUs (below) featured an integral concrete "foot" designed to keep the end farthest from the stream bank off the bottom of the riverbed so it didn't fill up with sediment. Rebar was allowed to protrude through these feet to anchor them into the riverbank, preventing units from moving once installed. Those heavy units, however, proved difficult to move and handle. A second-generation design, built this spring, used lighter aggregate, eliminated the concrete foot, and paired 2 FHSUs with wooden risers banded to wooden pallets (at left). Significantly lighter, the new design also had its issues and likely will be modified. **Source | Ozinga RMC Inc.**

anything ferrous, which affected their readings. When we tested basalt rebar, we found it was three times stronger than steel, easy to install and didn't rust, so we asked ourselves 'why aren't we using it here?'"

Tony Celucci, another RockWerk partner adds, "We've had Dr. Issa test basalt rebar from many manufacturers to check product consistency, quality and fiber content across various sizes of rebar. We found they varied dramatically — from 60% to 83% fiber in some cases. Since there didn't seem to be any established standard for quality control, we decided to partner and establish a strategic supply chain where we could control everything from rock to finished product." In addition to ACT, RockWerk currently is partnered with basalt rovings producer Mafic SA (Kells, Ireland), resin supplier Ashland Inc. (Columbus, OH, US) and an unnamed pultruder. RockWerk arranged to supply #3 (10-mm diameter) basalt-reinforced unsaturated polyester rebar to Lutey for the project.

Generation 1 into the water

After evaluating nine FHSU prototypes, the team was ready to make its first production batch in fall 2014. Ozinga supplied pervious concrete, and labor was provided by UHC staff plus youth from two other Chicago-based non-profits: Empowerment through Education & Exposure (EEE), which exposes underprivileged youth to educational opportunities and activities that build knowledge and skills; and BUILD Chicago Inc., which works with at-risk and gang-involved youth to develop alternative lifestyles. Additionally, UHC president, Larry Asimow, owner of Larry Asimow Landscaping Inc., a local landscape contractor, agreed to provide extra labor and construction equipment.

Because one of UHC's missions is to promote materials reuse/recycling, the team used a lot of "found" materials to produce the FHSUs. Donated 208L plastic drums became the outer "mold" (form) for the concrete and cardboard concrete forms formed the hollow center. The latter didn't prove durable enough, so the team switched to PVC pipe that was split lengthwise to allow a wooden strip to be inserted. A plastic ball sealed off the top of the pipe so concrete didn't get into the center opening when it was poured into the barrel. During the forming process, polymer-based rope loops were pushed through the structure's walls to form anchors for fans of geotextile "kelp," which also was bonded in place with plastic sealer and foam.

Each FHSU used four lengths of composite rebar and featured a separate concrete "foot" designed to keep the end farthest from the stream bank up off the riverbed so it wouldn't fill with sediment. A soybean-based sealer/curing/release agent for the pervious concrete (The Bean, C2 Products Inc., Arcadia, IN, US) was used, and each unit was wrapped in a plastic bag to help speed cure by ensuring the concrete didn't dry out.

When the concrete was fully cured, the wooden strip was removed, which provided space to pull out the PVC pipe. The first units weighed 163-181 kg and measured 0.91m long, with an outside diameter of 46 cm, an inside diameter of 34 cm and 5.1 to 6.4-cm-thick walls. Lutey reports they achieved an extremely robust cure. "You could hit the FHSUs with a hammer and the concrete wouldn't break," he recalls.

The first 50 units were trucked to preselected sites, lifted by boom onto a barge, and set onto the river bottom by a team from Friends and IDNR just before the river froze. By that time, Friends and IDNR had already released 55,000 channel catfish fry into the river.

Lighter Generation 2 deployed

This May, IDNR and Friends surveyed the pilot site via underwater camera and found that the FHSUs hadn't moved or sunk into the riverbed, so the team moved forward with plans to make another 350 units this spring and summer. Since then, 100 units have been produced and installed, but with design changes to improve handling and stability. The geotextile kelp was eliminated and the concrete foot was replaced by wooden risers. To reduce weight so FHSUs were easier to transport, the concrete was modified with a lighter aggregate, reducing unit mass to about 100 kg. This time, FHSUs were lashed, several feet apart, to wooden pallets in pairs before they were placed into the river. The thinking was this would keep the fish houses from sinking into the silt should the riverbed erode. (The pallet wasn't expected to rot very quickly since the water is fairly anaerobic.) However, this design also proved challenging because the pallets tended to flip over in the water, and banding that held the FHSUs to pallets could loosen. "This is an evolving project," concedes Lutey. "The design is still changing."

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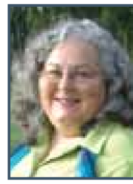
Friends and IDNR have since released the remaining 45,000 catfish fry plus an additional 100,000 to help build a strong population. Frisbie notes that the IDNR does fish surveys across the state on a rotating basis and will check progress in areas where FHSUs have been placed in about three years. "It'll be a little while before we find out how the catfish are doing, but hopefully, the FHSUs turn out to play a strong role in their return." CW



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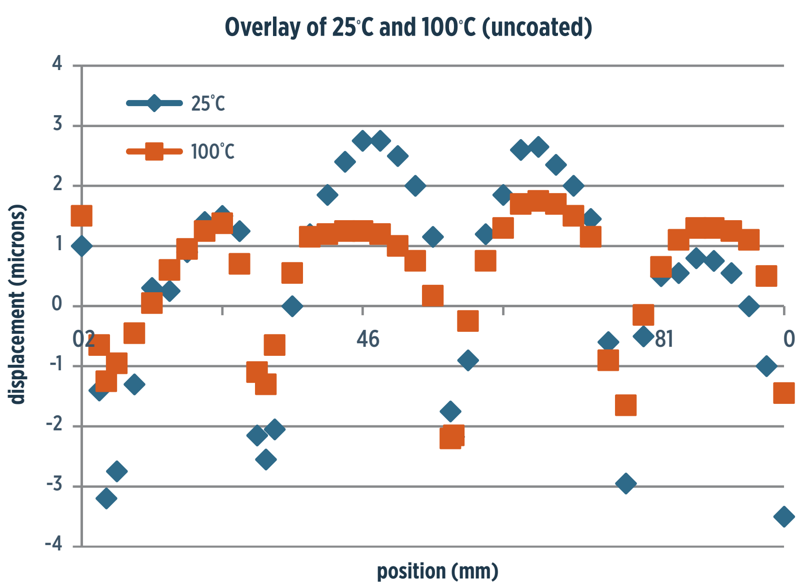
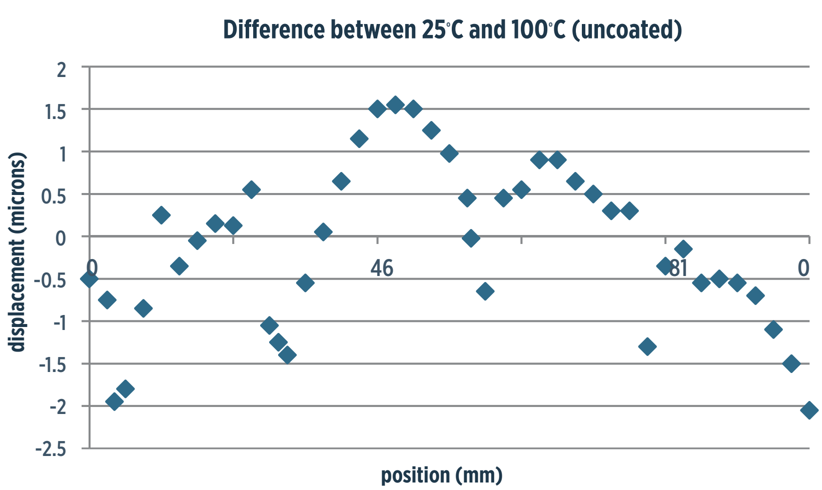
Carbon fiber auto body panels: Class A paint?

As tougher emissions standards loom, one supplier's study sheds light on the challenges of applying flaw-free primer and paint to production CFRP exterior body panels.

By Michael LeGault / Contributing Writer





»Automakers and their suppliers have been painting glass fiber-reinforced composite exterior body panels, including those made from sheet molding compound (SMC), for many years. SMC painting, in particular, came in for its share of problems (see "Learn More," p. 76) but today, can be integrated into OEM production and assembly processes. But painting and decorating carbon fiber composites has a shorter history, and almost none in connection with volume production. Carbon body panels are typically limited to very low-volume sports cars, and here, OEMs are often content to play up the natural look of carbon fiber weave by applying a clearcoat.

By 2025, however, when new US corporate average fuel economy (CAFÉ) requirements and European CO_2 emissions limits kick in, carbon fiber could be in the auto industry mainstream as engineers seek to tap the material's high strength- and stiffness-to-weight ratios as a partial solution to the conundrum of nearly doubling the average number of miles a vehicle can travel on a given volume of fuel. With respect to weight reduction,

FIG. 1

Textured grooves that kept appearing on the painted panels at room temperature prompted researchers at BASF to measure the topography of the unpainted carbon fiber substrate with an optical profilometer. Scans of cross sections of the unfinished panels at room temperature revealed grooves on the surface approximately 5 microns deep. The grooves aligned with the weave of the fiber mat. As the carbon fiber substrate was heated to 100°C, the grooves became less pronounced, shrinking to about 2.5 microns. The periodicity of the grooves aligned with the grooves of the painted panels, meaning the texture could be explained by differential expansion/contraction in the substrate. Source | BASF carbon fiber body panels are among the remaining "low-hanging fruit" in terms of effective impact, yet ever out of reach for a variety of logistical, marketing, cost and technical reasons.

Many people in the composites industry point to the Chevy *Corvette* hood as proof that carbon fiber composites are a viable, lightweight alternative to steel and aluminum in a commercial — albeit high-end — high-performance vehicle, capable of producing a Class A finish. But the *Corvette* hood is a relatively limited-run part by typical automotive measures (~40,000 units/yr) made by a technologically advanced process that entails multiple layers of prepreg, vacuum bagging and autoclave cure or a rapid out-of-autoclave method, yet still requires post-mold finishing. For carbon fiber to have a chance at competing for high-volume body-panel applications, it must be made by a short-cycle process capable of automation within tight tolerances to *minimize* post processing.

The obvious candidate process is resin transfer molding (RTM). In anticipation of the new CAFE requirements, BASF Coatings (Münster, Germany and Southfield, MI, US) conducted a study evaluating the paintability of carbon fiber test samples produced via RTM, comprising 48K tow carbon fiber fabric and epoxy resin.

Don Campbell, BASF's group leader, coating solutions, notes the company has a history of developing composites-specific paint systems for Class A automotive parts. In 2001, BASF was given a PACE award for its DynaSeal "dual cure" primer designed to seal porosity defects in SMC. These porosity defects usually arise from the protrusion of random fibers through the surface of the panel, leading to "pop" defects in the top coat if not properly sealed.

In one respect, the challenge in generating a Class A surface on a carbon fiber panel is similar to that encountered with glass-reinforced panels: Carbon, like glass, has texture that must be covered or filled before a clearcoat is applied. Unlike chopped glass-filled composites, such as SMC, the most weight-efficient carbon fiber composites are manufactured from continuous fiber, which can be woven, knitted or braided. Carbon fiber also has virtually no coefficient of thermal expansion (CTE), while glass has a fairly significant CTE. Both of these factors, Campbell and his team learned, have consequences when attempting to generate a painted Class A finish on a carbon fiber composite part molded via RTM.

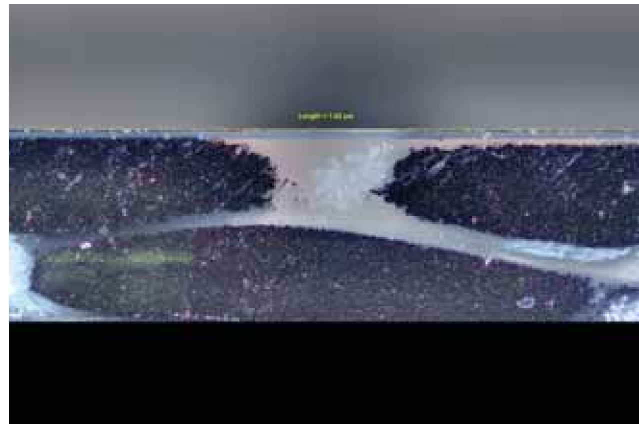
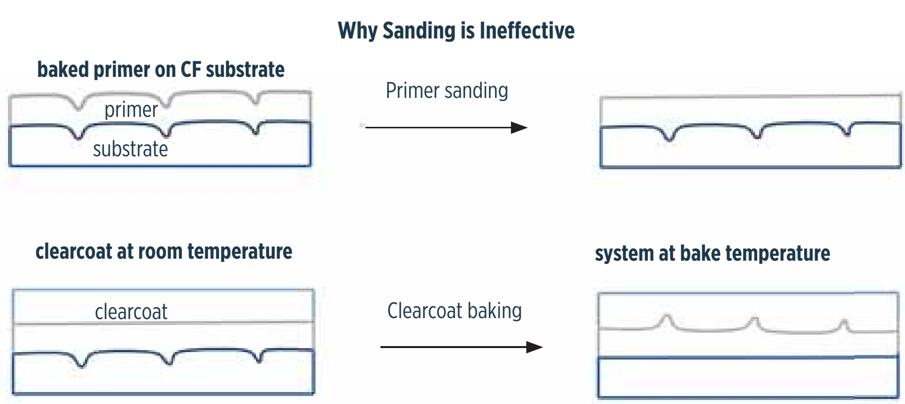


FIG. 2

The differential expansion of the substrate arises as a result of the resin-rich domains of epoxy laying between non-homogeneously distributed carbon fiber bundles at the substrate surface. The carbon exhibits little to no thermal expansion, whereas epoxy, with a CTE of 15 to 100 ppm/°C, differentially expands and contracts with changing temperature. Source | BASF

Campbell's team selected a set of primers and low-bake clearcoats that are specially formulated to flow and fill surface texture. After application and cure of the primer, one set of panels was sanded and another set was not. Both sets were then clearcoated and oven-baked at 100°C. When the panels were removed from the oven, both sets were, initially, texture- and defect-free. However, as the panels cooled to room temperature, texture appeared in the surfaces of panels in both groups. The unsanded panels showed surface grooves as wide as 2 mm; the sanded panels had smaller grooves, about 0.25 mm wide. »



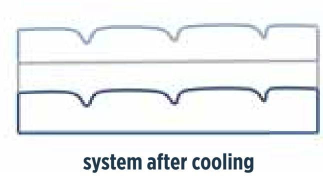


FIG. 3

Sanding of the primer did not eliminate texture in the clearcoat after panels cooled to room temperature. The diagrams here explain the phenomenon: The baked, primed substrate was removed from the oven and sanded smooth at room temperature (top sequence), but the substrate, with its characteristic textured surface, remained beneath the primer. As the clearcoat was applied and ramped up to bake temperature (middle images), the substrate expanded, causing ridges in the solidified primer layer. However, the still liquid clearcoat flowed to a smooth level over the ridges until it cured and set at the bake temperature. As the panel cooled again (bottom image), the substrate shrank, forming ridges, the ridges in the primer disappeared, but adhesion between the primer and clearcoat caused grooves in the clearcoat. Source | BASF

Follow-up trials with panels subjected to multiple coats of primer and multiple sanding (a technique currently used to reduce texture on the Corvette hood and glass-filled wind blades, for example) did *not* eliminate the texture once the panels cooled to room temperature. The finished panels, both sanded and unsanded, were then reheated to the bake temperature of 100°C. Immediately after removal from the oven, the unsanded panels were, again, texture-free; however, the sanded panels had reverse structure — that is, *the grooves were now ridges*. Once again, as the panels cooled, the groove-like texture reappeared.

"At this point, we were scratching our heads," Campbell admits. "We suspected what we were seeing could somehow be explained by differential cooling between the substrate, primer and clearcoat."

To better understand the results, the team obtained an optical profilometer**,** an instrument used to measure the roughness/smoothness of 3D surface topography. Optical images taken of the composite panel surface showed large carbon fiber bundles, 1.5-2 mm wide, embedded in resin-rich domains of epoxy as much as 0.25 mm wide and 0.25 mm deep. Scans of cross sections of the unfinished panels at room temperature also revealed grooves on the surface approximately 5 microns deep. The grooves aligned with the weave of the fabric. As the unfinished carbon fiber substrate was heated to 100°C, the grooves became less pronounced, shrinking to about 2.5 microns (Fig. 1, p. 72).

When graphs of the scan generated for the unsanded primer-plus-clearcoat panel at 25°C were overlaid with the scans for unfinished panels, the curves revealed the similar *periodicity*, meaning the texture in the clearcoat could be explained by cooling of the substrate between 100°C and 25°C. When the panel is reheated, the substrate expands and the grooves disappear, only to return as the panel cools. The differential expansion of the substrate arises as a result of the resin-rich domains of epoxy that lie between non-homogeneously distributed carbon fiber bundles at the substrate surface. The carbon exhibits little to no thermal expansion, whereas the epoxy, with a CTE of 15 to 100 ppm/°C, differentially expands and contracts with the changing temperature.

As for the sanded panel, the same explanation holds, with one difference. The baked primer is removed from the oven and sanded smooth at room temperature over the substrate, which also has cooled with its characteristic textured surface beneath the primer (Fig. 2, p. 73). After the clearcoat is applied and ramped to bake temperature, the substrate expands, causing ridges in the solidified primer layer above. However, the still-liquid clearcoat flows to a smooth level over the ridges until it cures and sets at the bake temperature. But as the panel cools, the substrate shrinks, the ridges in the primer disappear, and the adhesion between the primer and clearcoat causes grooves in the clearcoat. The same phenomenon reportedly explains why reverse texture »

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ridges appear when the sanded panel is reheated to bake temperature.

Campbell allows that further work and testing must be done to understand how carbon fiber fabrics can be developed for RTM to control and reduce texturing. He says carbon fiber composites with more uniform fiber distribution, which, in turn, reduce resin-rich domains at the surface, will mitigate the texturing effects.

"Meanwhile, the cost-performance trade-off between composite material in both structural and non-structural applications will continue to be evaluated, Campbell notes. While carbon provides high stiffness, most body panels are nonstructural. Glass, with a CTE similar to epoxy, might be better suited for Class A finish applications; however, the trade-off is negative from a weight perspective, given the higher density of glass fiber. Another alternative, he notes, is chopped carbon. "Chopped carbon poses its own challenges, but they are ones related to porosity that we understand."

Campbell reports that BASF's European division is researching in-mold gelcoats, including two-phase systems, for carbon fiber parts. The research is in early stages, but he says the coatings likely would have to be thicker than those typically used to coat glass-filled composites to defray surface stress and texture print-through.

Lastly, lightweighting cars and trucks by increasing the use of composites, including the possibility of composite body panels, will hinge on integrating them into the logistical flow of parts on the assembly line, a sticking point that previously raised thorny issues, including colormatching problems, for suppliers of parts made of neat plastics. Currently, because of the high-temperature E-coating process at the body-shop stage, most plastic parts are painted off line and assembled after the paint booth. Campbell believes the most feasible solution is to install most exterior composite parts between the E-coat and paint booths. Inherently corrosion-resistant, plastics and composites need no E-coating. To that end, BASF is developing a low-bake clearcoat that can be applied to both metal and plastics/composites. Lower temperatures also help alleviate differential expansion of the matrix and carbon fiber.

"It's an interesting challenge," Campbell concludes. Indeed, capitalizing on the opportunity to supply automakers with large-scale, volume composite exterior parts will require ongoing development by suppliers, fabricators and OEMs alike, and no doubt will be the subject of much additional research in the coming years. CW

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Predicting strength of fiber-filled components using Moldflow® and Helius PFA

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Short fiber reinforced plastic materials are commonly used for their strength and weight benefits, as well as their ability to be manufactured quickly. In order to complete an accurate structural simulation of a short fiber reinforced plastic part, the as-manufactured material properties need to be accounted for. Without including data such as fiber orientations and residual stresses/strains, the structural simulation results will not match the performance of the actual manufactured part. Learn how the as-manufactured material from Autodesk® Moldflow® can be used with Autodesk® Helius PFA to complete an accurate nonlinear structural simulation.

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Cost-competitive aerostructures from composites

As a globally recognized manufacturer of composite structures for commercial aircraft, including pivot bulkheads (top left) and door surrounds (lower left), Israel Aerospace Industries (Tel Aviv, Israel) must continually improve its production processes to maintain cost-competitiveness.

Source | Israel Aerospace Industries

Optimizing composite aerostructures production

Israel Aerospace Industries ramps production while reducing costs and improving quality, thanks to integrated optimization software.

By Ginger Gardiner / Senior Editor

» A globally recognized military and commercial aerospace and defense company, Israel Aerospace Industries (IAI, Tel Aviv, Israel) is simultaneously a Tier 2 supplier (e.g., to Alenia, for the Boeing 787 program) and a Tier 1 supplier to OEMs, such as Lockheed Martin, Boeing and Gulfstream. For the Boeing 787 program, IAI's Commercial Aircraft, Group Aero-Assemblies Div. produces a variety of carbon and glass fiber prepreg aerostructures.

Two years ago, as IAI prepared for Boeing's planned production ramp-up to 10 787 aircraft per month, the company was looking for ways to maintain favorable financial performance during an economic downturn and increase its competitive position in the global aerostructures market. Increasing output on the 787 program while reducing cost offered an excellent opportunity, but would also present a challenge.

"We looked everywhere for how to cut costs, and then we saw our waste and raw materials," recalls Avishay Hod, composite deputy director for IAI's Group Aero Assemblies Div. "We buy very expensive raw materials and then cut these to form composite aircraft structures, so there is a lot of waste."

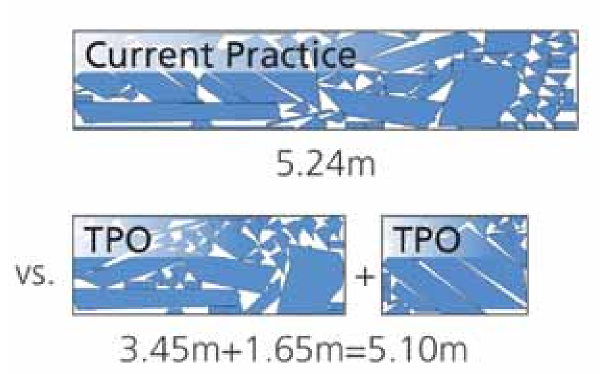
Already aware of Plataine Technologies' (Waltham, MA, US and Tel Aviv, Israel) composite cut-planning optimization software (see "Learn More," p. 81), IAI sought *more* than optimized nesting. Plataine suggested its Total Production Optimization (TPO) software, and the two companies began implementing a system that would, by early 2014, not only cut raw material consumption by 5% but also automate daily production plans for materials and cutting, greatly reducing manual tasks and improving materials utilization. Automation has freed up resources and reduced the risk of errors. That, in turn, has generated cost savings in terms of improved quality control.

Daily work plan in one click

On any given day, IAI Aero Assemblies makes multiple parts. Its CNC cutting machines require dozens of nests to process a wide inventory of materials. "Mostly, we are cutting glass and carbon fiber prepregs," says Hod, "but each part can use three or four different types." Like most other aerospace manufacturers, IAI already had in place manufacturing resource planning (MRP) software and computer aided design (CAD)/engineering programs, such as CATIA (Dassault Systèmes, Velizy-Villacoublay, France). "But there was nothing that bridged the gap between these systems," says Plataine president Avner Ben-Bassat, noting for example, "MRP would output the production schedule and materials inventory for each day, but the production design — specifically, what materials, shapes, tools, autoclaves and ovens were needed — was detailed in the engineering platform." Therefore, many manual operations were still required. "Production engineers would take the MRP printout and then go to the engineering office to pull each part's nest from a library," Hod recalls.

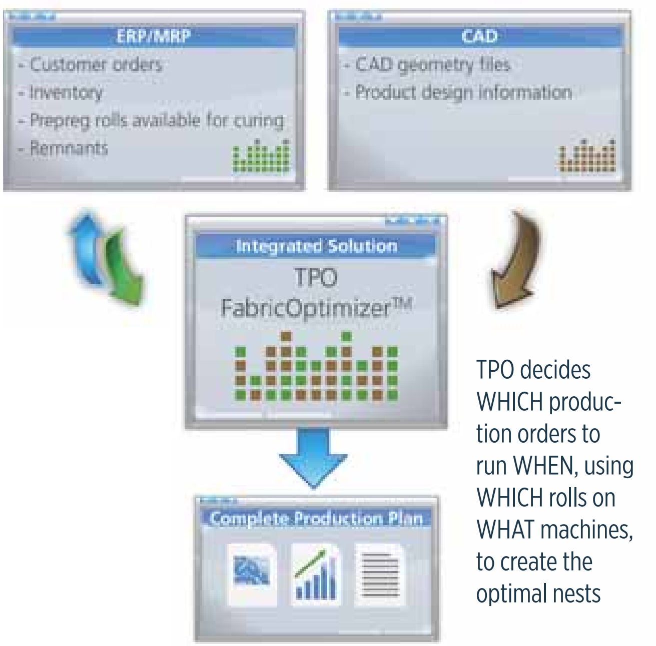
Ben-Bassat describes this library as static vs. dynamic: "There is typically one nest per kit and one or more kits per aerostructure." Thus, the production engineer would pull each of the nests required for that day's parts and send them to the CNC machining centers to be cut. "So these operations were tied to inventory and production schedule, but they were not integrated or optimized."

"What is good with TPO is that the daily work plan is now generated from the MRP through TPO with one click," says Hod. TPO »



Automated cut planning & inventory control

Previously, IAI's production engineer would pull each of the nests required for the parts to be made that day and send those to the CNC-machining centers to be cut. Now, Total Production Optimization (TPO) software from Plataine Technologies (Waltham, MA, US and Tel Aviv, Israel) performs these functions, checking inventory for remnants and generating the daily production plan while reducing materials waste. Source | Plataine



Waste reduction a key to cost control

By better using materials, Platiane's TPO has reduced IAI's raw material consumption by 5%, a significant help when aerospace industry efficiency in cutting raw materials is, generally, in the range of 65-70%. Source | Platiane

develops the plan, produces the optimized nest, chooses the materials *and* provides the optimized nest files for the operator. "All of the tracking the operator used to do is now done in a few minutes," Hod explains. "The operator's tasks are now reduced to getting the rolls of materials and starting the cutting machine. This reduces not only manual labor but also opportunities for error. It increases our efficiency *and* our process control, which improves quality."

Reduced waste, improved efficiency

When asked about the 5% savings in raw materials, Hod admits this does not *sound* like much, "but when you use hundreds of yards per day of hundreds of raw materials, it adds up." He also notes that in aerospace, the typical efficiency in cutting raw materials is usually only 65-70% — *30%* is waste. "So being able to reduce this also adds to the bottom line."

IAI has many material rolls of different lengths in cold storage. "Before, we didn't know when to best use the remnants," says Hod. "Would we have enough to make all of the parts for that run or that day?" Now, TPO does that analysis. "Before, looking at which rolls were closest to their expiration date and out-time limits was all done manually," says Hod. Now it is automated.

One final point also has an impact: "I am gaining material that I previously did not use but I am also freeing up operator and engineering resources." Hod explains, "When you have to increase your production rate, you have to spend more operator and engineering time because you are increasing the time machines are in use and the coordination of materials into products. But if you don't double your operator and engineering hours because of something like TPO, then this allows you to increase your production rate without increasing your overhead."

He notes one additional value due to TPO's integration in both the inventory and MRP systems: "I can make better decisions about how much materials to buy and when. This sometimes saves more money than the 5% raw materials reduction."

Implementation

IAI fully understood that integrating TPO into its production would require training. Ben-Bassat notes the process was made easier because "continuous improvement is in IAI's DNA, so there was no challenge in getting everyone's buy in." That said, Plataine's experienced integration team still had to answer a lot of questions and make sure IAI's needs would be met. "We had to make a lot of adjustments," says Ben-Bassat. "We then began testing the configuration." The team started with one nest on one product and performed validation tests to make sure IAI's team got the results it wanted. "Every day we would add more products, but we kept to static nests until week two." Plataine then began combining nests and adding products and functions until TPO was fully implemented across all parts in production. "It's no different from any enterprise-level software implementation," says Ben-Bassat, "you don't want to just flip the switch overnight. It took three to four months in all."

Staying competitive

IAI has not yet incorporated the RFID tracking available with TPO, but Hod says the company might do so in the future. "We are always looking to improve," he observes, explaining that all suppliers in the commercial aircraft industry are under pressure to reduce the price of their products. "Although the parts are very expensive, we are always looking at how to do this to meet our customers' needs," says Hod. "We must remain competitive." CW

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ABOUT THE AUTHOR

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Composites tackle concussions

The launch of the first commercial composite football helmet and new research thrusts show FRPs could play a critical role in mitigating head injuries.

By **Michael LeGault** / Contributing Writer

» It has become a familiar scene on Saturday and Sunday afternoons during the American football season: A lightning-fast play, a helmet-to-helmet hit and a player laid out, semi-conscious on the ground.

For many years, of course, composites have been incorporated into headgear and helmets used in military, industrial and recreational sports activities, such as those for skiing and whitewater kayaking. Composites also have recently moved into headgear used in wide-participation, mainstream sports: In 2013 Major League Baseball (MLB) and the MLB Players Assn. adopted the Rawlings Sporting Goods Co.'s (St. Louis, MO, US) S100 Pro Comp batting helmet, constructed of aerospace-grade carbon fiber composite, as the league standard. Rawlings says the helmet is 300% stiffer and 130 times stronger than the conventional ABS helmet it replaced, while providing enhanced protection for ball strikes of up to 100 mph.

Yet, despite being a sport that involves physical contact on every play, and despite growing alarm about the frequency and severity of head injuries, American football teams almost exclusively equip their players with a helmet consisting of a polycarbonate (PC) exterior shell with an interior lining of foam padding — a basic design that has gone unchanged for more than 30 years. "The innovation in football helmet design has basically been with respect to the interior padding and facemask, and very little to the shell," says Elizabeth Cates, VP of R&D at Innegra Technologies LLC (Greenville, SC, US).

American football: The last holdout

Although paddle sports, bicycling, professional hockey and major league baseball have converted to the use of composite protective headgear, football — a *full-contact* sport — still relies almost entirely on helmets like these, featuring unreinforced polycarbonate shells with interior foam padding. Concern over concussions has been a catalyst for change.

Source | University of Michigan, Athletic Department

Given the increasing role composites have and are playing in headgear and helmets of all types, it was only a matter of time before someone attempted to build a fiber-reinforced composite football helmet. That distinction fell to SG Helmets (Brownsburg, IN, US), the manufacturer of the SG helmet, introduced to the market in 2012. Short for Simpson and Ganassi (i.e., former race car drivers Bill and Chip), the SG is made of Kevlar aramid fiber (from DuPont Protection Technologies, Richmond, VA, US), carbon fiber and epoxy. Bill Simpson, the primary point person in the endeavor, spent 1.5 years on R&D and another 1.5 years on field testing. Testing was conducted at Purdue University (Lafayette, IN, US) where researchers found the SG helmet was at least 50% better at dissipating forces to the head than the traditional PC helmet. One of the key benefits of the helmet is that it is about half the weight of its predecessors (~0.91 kg).

After some initial product-launch issues, which included defects such as cracking, the SG is getting noticed in a market known for its conservatism: 40 to 50 players in the National Football League (NFL) have adopted the helmet, a metric that is noteworthy not only because of the short time the helmet has been on the market but also because the SG is targeted to *youth league* football, at the high school level and below, where one of the greatest benefits afforded by the switch to composites is the lighter weight of the shell. The weight reduction meshes well with the body sizes of the hundreds of thousands of kids playing pee-wee, Pop Warner and high school football, many of whom are wearing ABS/PC helmets built for people three times their size. “I’m not trying to sell to the NFL. My interest is in the kids,” says Simpson. (And the numbers indicate that’s also *good business*. See the Side Story titled “Football participation tops in high school” on p. 84.) Toward that end, SG Helmets reports that several high schools and youth leagues in Indiana have adopted the SG.

Notably, the SG was recently given a five-star rating, based on a safety and performance testing and rating system devised by the bioengineering department at Virginia Polytechnic Institute and State »

First composite football helmet to market

SG Helmets (Brownsburg, IN, US) recently introduced the first commercial composite football helmet, the SG Simpson, made of Kevlar aramid and carbon fibers and epoxy. Company co-founder Bill Simpson (pictured) says the SG is at least 50% better at dissipating forces to the head than the conventional unreinforced polycarbonate helmet at *half* the weight. Simpson is targeting youth football, but says 40 to 50 National Football League players also have adopted his helmet.

Source | SG Helmets

Value: Balancing performance and price

Virginia Tech’s (Blacksburg, VA, US) bioengineering department created a laboratory rating system for football helmets, called STAR, based on 120 different measurements. STAR gauges a helmet’s ability to absorb energy and reduce head acceleration, and assigns a helmet a rating from 1 (lowest) to 5. Of the 26 commercial football helmets tested thus far, 25 — including the Rawlings Tachyon model pictured here — are made with a polycarbonate or ABS shell. The sole commercial composite helmet, the SG Simpson, and the Tachyon both received Virginia Tech’s 5-Star rating, but the respective difference in price point, US$414 vs. US$299, is a stimulus for additional R&D inquiry.

Source | Rawlings Sporting Goods

Helmet R&D: Materials characterization

The first phase of testing, designed to characterize a selection of basic fiber-reinforced materials as potentially suitable for use in the shell of a football helmet, was conducted at Clemson's bioengineering lab. The test set up, conducted to the ASTM D 7136-12 standard, comprises a drop sled or "cushion tester," a high-speed camera and an analysis computer. Sensors measure velocity impact and sample displacement, while the camera records rebound velocity and contact time.

Source | Clemson Bioengineering

University (Virginia Tech, Blacksburg, VA, US). Researchers at the school took more than a decade's worth of head/helmet acceleration data collected on Virginia Tech football players and mapped it to a laboratory test system that collects more than 120 points of impact test data on each helmet, measuring its ability to absorb energy and reduce head acceleration. Results of the rating system, called the Virginia Tech Helmet Ratings, are posted at www.sbes.vt.edu/helmet.php. Thus far, the program has tested 26 commercial football helmets, 25 made with polycarbonate or ABS shells, and the composite-shelled SG Simpson.

Along with its five-star rating, however, the SG's posted result was accompanied by several warnings, including one about cracking in the internal padding — *not* the composite — and a caution to consumers about a stated lifetime for the SG of *two* years, when the expected lifetime of a PC helmet is typically 10 years. SG Helmets president Bill Simpson takes issue with both. "We built the first prototype of the helmet in 2010, and since that time we have continually been tinkering with the formula and the manufacturing process," he says, reporting the helmets are hand-layed, bagged and oven-cured at 140°C. "Cracking is not an issue for the current model." As for the two-year stated lifetime, Simpson says when SG Helmets started the helmet certification process with the National Operating Committee on Standards for Athletic Equipment (NOCSAE), he was required to give an expected lifespan and simply stated "two" without a clear understanding of the football helmet market or certification process. "Our helmet's expected lifespan," he says," is 10 years like every other helmet on the market."

The physics of concussions: The brain/shell interface

It's important to note that helmet design, here, is complicated by the fact that American football is, above all, a *contact sport*. Stefan Duma, the director of Virginia Tech's School of Biomedical Engineering and Sciences, says *two* major factors determine a helmet's performance and rating. "The highest-rated helmets," Duma says, "protect against high-impact hits, but they *also* protect against medium- to low-impact collisions, which players experience much more often." It's not just about the Big Hit.

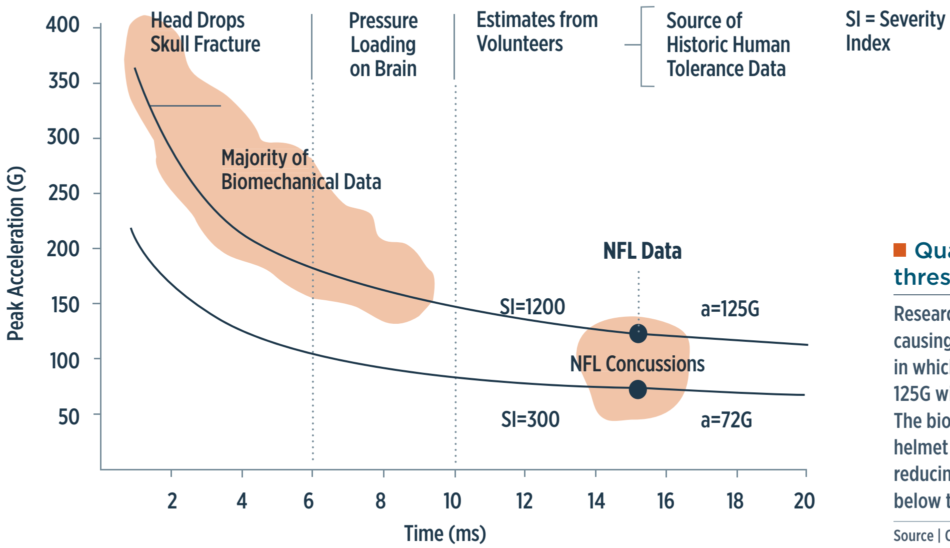
This "duality" related to the helmet shell's protective capabilities, the material impact resistance and toughness necessary to provide 10-year durability, and the need to compete on price point (the SG is about 20% more expensive than other top-rated brands), make designing and manufacturing a composite football helmet for mass-market use a challenging undertaking.

Innegra's Cates says her company was inspired recently to take a fresh, blank-slate approach to the challenge after seeing a "concussion simulator" developed by bio-engineering researchers at Clemson University (Clemson, SC, US) for the Roper Mountain Science Center in Greenville, SC. It consisted of a test dummy's head and upper torso, similar to the type used in Karate training. An accelerometer mounted in the head monitored the G-forces upon receiving a blow from a member of the audience, with a display screen indicating if a concussion threshold was reached.

SIDE STORY

Football participation tops in high school

Professional American football garners much of the media limelight, but thumbnail statistics published by *USA Football* illustrate the potential magnitude of the football helmet market *outside* the pro ranks. In 2010-2011, football led the way in terms of total number of participants among all high school sports, with 1,134,000 athletes playing the sport at freshman, junior varsity and varsity levels. College, of course, represents another tier of football participation. According to NCAA statistics, colleges with active football programs at the Division 1, 2 and 3 levels currently number 120, 149 and 236, respectively. Further, at most universities football is the major revenue source for funding of all other sports programs. In the 2012-2013 school term, average revenue among Division 1 schools was US$15.1 million per school.



Quantifying a range and threshold for concussions

Researchers who studied film of concussion-causing collisions in the NFL identified a range in which concussions occur, between 72G and 125G with a duration of 14-16 milliseconds. The bioengineering objective of a composite helmet is to increase the impact *duration*, thus reducing the acceleration of the head well below the threshold G-force value of 72G.

Source | Clemson Bioengineering

"When we saw the Clemson exhibit demonstrating the forces associated with head injuries," says Cates, "we naturally thought of the hot-button issue related to football and concussions." Innegra already supplies its Innegra S and H fibers to customers who manufacture helmets for whitewater kayaking and other extreme sports that present the potential for impacts equal to or greater than those in football, so it seemed plausible to Cates and her team that these same materials could provide benefits in the design of a football helmet. Soon thereafter, Innegra and Shelby, NC, US-based fiberglass supplier B & W Fiberglass (already a partner/supplier in the production of the Innegra H fiber), approached Clemson's bio-engineering department about the possibility of a partnership in a study to evaluate the properties and performance of composite materials and their suitability for a potential application in the outer shell of a football helmet.

The first phase of the project, a materials characterization study, was completed in 2014. About 25 materials were tested to ASTM D7136-12 "Standard Test Method for Measuring the Damage Resistance of a Fiber-Reinforced Polymer Matrix Composite to a Drop-Weight Impact Event." The basic test setup comprised a drop sled system called a "cushion tester," a high-speed camera and an analysis computer. A flat panel sample coupon of each material of interest is placed into a fixture at the base of the drop sled where it is subjected to impact by an object of a specified weight and shape. Sensors measure velocity of impact and sample displacement, while a high-speed camera records rebound velocity and contact time. These values, in turn, are used to calculate the *impact coefficient of restitution* and *energy absorption*. These are the key parameters for materials intended for use in applications subject to multiple and continual impacts. They provided the study with a baseline distinction between the various samples.

The initial materials tested were, by design, simple, consisting of a single reinforcement material and an off-the-shelf epoxy. Fibers tested included various types of glass and carbon as well as Innegra's olefin-based S-fiber, and also the company's H-fiber, a hybrid yarn, consisting of its S fiber combined with another high-modulus fiber, such as carbon, S-glass or basalt. "We deliberately tested simple systems because we wanted to specifically focus on fiber behavior in this phase," says Cates. Included in the initial round of testing were control flat-panel samples of neat PC and ABS. Although the project entailed evaluating elementary composite structures, the early findings are reportedly promising, pointing to significant differences in the performance of composites with respect to both controls.

"We've seen some remarkable results thus far with the various fibers we've tested, indicating composites could provide superior protection against the types of impacts and forces generated in football," says John DesJardins, who is the Hambright Leadership associate professor of bio-engineering at Clemson. DesJardins, who is collaborating closely on this project with Dr. Greg Batt, Clemson's assistant professor of Food and Packaging Science, notes that polycarbonate has high impact resistance but is not very good in terms of energy dissipation. This property makes both PC and ABS good at withstanding repeated impacts without breaking, but not so good at mitigating concussion-causing forces. »

SIDE STORY

Head safety initiative to fund research

Sponsored by the National Football League, GE (Fairfield, CT, US), the National Institute of Standards and Technology (Gaithersburg, MD, US) and sports apparel maker Under Armour (Baltimore, MD, US), the 2015 Head Health Challenge III will reward up to US$3 million to companies and organizations that deliver novel materials to address and mitigate concussion risks in football and other sports. Clemson University (Clemson, SC, US) associate professor of bioengineering John DesJardins says his team is currently conducting research on potential composite materials for football helmets (see main story) and will participate in the Challenge.

Helmet technology transfer

Shred Ready (Auburn, AL, US), a manufacturer of helmets and safety gear for whitewater paddling, has launched a new model this year called the OSK — Old School Kool — featuring a shell made entirely of Innegra Technologies LLC's (Greenville, SC, US) S- and H-fibers. Reportedly, a similar construction could be the "X-factor" for a football helmet that could meet all the necessary performance criteria *and* narrow the price premium between it and polycarbonate helmets. Source | Innegra

The design solution for energy dissipation has been to pad the interior of the shell with copious amounts of foam. Until now, the possibility that the shell could be a front line of defense against head injuries in football has been constrained by the notion that its first, and foremost, function is impact resistance. "We knew from high-energy impact applications, such as ballistics, that fiber-reinforced composites provide great advantages in dissipating forces laterally, rather than directly through the material," says Cates.

The second phase of testing, commencing this year, will evaluate a more complex set of fiber and resin laminate systems and layups, including toughened resin systems and different combinations of commingled yarns (Innegra's H-fiber) and woven fabrics. It also will employ a slightly modified test method that uses an impactor with a larger radius and geometry designed to more closely mimic the curvature of a football helmet. Desjardins reports that the same drop sled used in the first phase also will be used in the next, although the drop height will be lower due to the greater mass of the impactor.

Although basic fiber-reinforced materials demonstrated some significant potential performance enhancements with respect to the control materials in the first phase of testing, researchers expect the use of a wider impactor in the next round to change some of the energy dissipation characteristics. In short, "everything is on the table" on the materials side of the equation, says Cates. Further, she notes that greater cognizance of manufacturing cost and processing factors will be necessary as the project moves forward.

Helmet optimization: The performance/cost interface

That is a bridge already crossed by Shred Ready (Auburn, AL, US), a manufacturer of helmets and safety gear for whitewater paddlers. The company currently makes five all-composite whitewater helmet models, as well as less-expensive helmets made of injection molded ABS. One of the most common layups for a number of its composite models comprises two layers of glass on the inside ply and a layer of Kevlar as the outside ply. Shred Ready president and founder Tom Sherburne says the aramid fiber layer provides excellent energy dissipation properties, and enhances design features. "Composites, and in particular Kevlar, allows us to design a more form-fitting helmet and get the same impact absorption as a traditional injection molded ABS," he claims, reporting that comparable interior foam padding for a helmet with an ABS shell needs to be 3-4 mm thicker.

Shred Ready also has launched a new model this year called the OSK, for Old School Kool. The helmet features a shell made entirely of composites, reinforced with fibers supplied by Innegra. Manufactured "under high heat and pressure," the shell sports three inner layers of Innegra-S and an outer layer of Innegra-H carbon hybrid fiber. Sherburne says the hybrid fiber processes better than the purely hydrophobic olefin fiber and provides a better surface finish — important, because decorative details are applied to the helmet, post-cure.

"The Innegra S fiber is equal to Kevlar for impact absorption, and the carbon adds toughness," Sherburne contends, noting an overall gain in cost-effectiveness, compared to other material solutions.

A similar construction, involving either or both of the Innegra fibers, might be the "X-factor" in the design and manufacture of a football helmet that could meet all the necessary performance criteria *and* narrow the price premium between it and football helmets made of polycarbonate.

Success in building a next-generation football helmet will no doubt hinge on a similar amount of tweaking and trade-offs. In a study introducing a new head injury metric, called "the combined probability of concussion," Steve Rowson, research assistant professor, bio-medical engineering, Virginia Tech, writes, "part of the remaining burden of reducing concussion incidence relies on improvement of head protection," noting current football helmets are designed to prevent skull fractures, not to guard against concussion. "One of the challenges in designing helmets to account for concussive forces is accurately modeling concussion risk," he writes.

One of the original studies attempting to quantify the threshold forces associated with concussions was carried out by researchers at Wayne State University (Detroit, MI, US) in the 1960s (Gurdjian, ES, et. al.). This and subsequent studies have focused on concussions as a function of two factors: Impact magnitude (acceleration measured in G-force) and impact duration (in milliseconds or ms). Research has identified a range in which for concussion-producing impacts occur in the NFL: between 72G and 125G, with a duration of 14-16 ms. From this quantitative angle, the goal of a composite helmet would be to increase the duration of impact, thus dissipating some of the energy laterally, thereby decreasing the resulting acceleration and G-force to a value substantially below the threshold value of 72G (see the chart on p. 85).

But such a helmet must be able to withstand *repeated* impacts through the course of a game and season, and therein lies the rub. "When you look at the market for helmets, composites are widely accepted for motorcycles, bike racing, whitewater sports," Cates says. But she points out: "What distinguishes a motorcycle helmet from a football helmet is if you crash and damage your motorcycle helmet, you *replace* it." The standard a successful football helmet design must meet in the final phase of testing is to sustain more than *1,000* impacts, yet retain *all* its functional, protective characteristics. This, she says, implies a fundamental difference in the way one designs materials and develops a helmet.

The final phase of the Clemson-based research project will consist of testing full helmets attached to a dummy head to a standard established by NOCSAE, Doc (ND) 001-11m13, "Standard Test Method and Equipment Used in Evaluating the Performance of Protective Headgear/ Equipment." The researchers at Clemson will be building a new tower and drop carriage. In order for a helmet to pass the test, it must be able to withstand impact at an acceptable level, according to NOCSAE's Severity Index (SI) — a pass/fail threshold value for a helmet's ability to reduce impact force calculated in terms of acceleration and duration in 16 helmet locations. It also must meet all other damage and durability requirements of the specification.

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When development reaches this stage, the project team will need a helmet manufacturing partner, says Cates, and efforts are ongoing to secure one. Further, the research could have broader long-term commercial benefits. "We're sponsoring this research focused on helmets in contact sports, but impact is really a much wider issue in the composites world," she acknowledges. "So, in this sense, we're looking at this as a basis to understand impact better, more generally, and to allow us to make more nuanced materials suggestions and solutions to our customers."

A helmet on *every* at-risk head

First into the market, the SG helmet has proven the mettle of composites as a *superior* material for dissipating G-forces related to football head-to-head collisions and concussions. As with any new product, ongoing R&D efforts will fine-tune and enhance early designs, and address the realities of commercial cost in a highly competitive market. As the process plays out, prompting greater emphasis on safety in American football, delivering fundamental research insights with spin-off benefits for other applications in which head injuries are a risk, it promises to be a win-win for helmet manufacturers, football players of all ages and the parents and fans who cheer them on. CW

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Materials Sciences Corp.: *Multifunctional* composites

MSC draws on four decades of experience and computer modeling expertise to develop novel composite materials with the potential to make a big impact.

By Ginger Gardiner / Senior Editor

» Materials Sciences Corp. (MSC, Horsham, PA, US) was established in 1970 by a group of scientists who helped develop the constituent relations that describe the behavior of composites. Performing research for NASA, the Defense Advanced Research Projects Agency (DARPA) and the US Departments of Defense and Energy, MSC was an elite materials engineering company from the start.

Carbon/carbon was one of the first materials MSC analyzed. "It cost $30,000 to make one cubic inch," recalls MSC president Tom Cassin. "We had to convince the US Air Force that we had the constituent models that would accurately predict behavior without having to manufacture and test material samples." This ability to develop CAD software to model and simulate the micromechanics of materials has become a foundational expertise for MSC. It developed, for example, the MAT162 module for LS DYNA, a multiphysics simulation software platform produced by Livermore Software (Livermore, CA, US). "The original target was to simulate impact response," says Cassin, "but it is now used for a variety of dynamic load analyses."

MSC also developed two other commercially available software programs: TEXTLINK is one, written for textile analysis. "We can model angle interlock architectures and set their depth within the 3D textile," Cassin notes, "and also simulate z-pinning. So our understanding of these fabrics informs our ability to design and produce these for composites applications." The other, BONDMASTER, is for modelling adhesively bonded joints. MSC also has developed programs for thermal, acoustic and wave-propagation analysis as well.

"Complementary to all of these computer-aided design, engineering and prediction tools is our testing lab," says Cassin, where MSC can verify and validate (V&V) its models. "We have to manufacture parts using a specific manufacturing process and then test to confirm the properties we have predicted. We also verify batch-to-batch variation in fibers and matrices." Cassin explains that all of this provides the substantiation for B-basis

■ **It's what's *inside* that counts**

MSC's new Greenville, SC, operation's exterior reveals little and its 1,200m^2 workspace might seem unassuming, but the facility is the commercialization hub for new developments such as MSC's proprietary COUNTERVAIL vibration-canceling composites, which reduced fatigue for bicyclist Lars Boom (above) when incorporated in his Bianchi bike frame during the cobblestone-intensive fifth stage of the 2014 Tour de France.

Source | Materials Sciences Corp.

Source (bike photo) | Bianchi

allowables, a key part of the method currently required to certify composite structures for use in aircraft and military platforms.

But Cassin also sees this capability as strategic, because the industry is seeking ways to reduce the time and cost of design and certification. "Being able to characterize the composite material allows you to move away from conservative designs," he says, "and also reduce the amount of testing." Therefore, MSC has developed a unique repository of models and model-building knowledge that enables it to understand and simulate a composite from its chemistry to its fiber and resin constituents through to laminates and end-use structure behavior. Cassin maintains, "This is a powerful tool we are using to develop new material forms and solutions for the design and manufacture of advanced composite structures."

Since the '70s, MSC has moved far beyond composite materials research as a design services provider to perform design, analysis and prototyping projects for government and industry, and manufacture of commercial products as well. "Our mission is to develop advanced materials," says Cassin. "Product design and manufacturing are inherently part of that, especially for composites." He notes that now, when MSC works with a customer to develop new materials and/or structures, "we are often doing the qualification work."

An engineer himself, Cassin has been with MSC since 1987. About 15 years ago, MSC moved from R&D into applied engineering and began exploring how to transition the company's proprietary technologies into commercial applications. Since then, MSC has tripled in size, opening two additional US locations with dedicated staff and facilities to add significant in-house testing and manufacturing capabilities. The first, in Gulfport, MS, supports local customers and partners, including Seemann Composites, United States Marine Inc. (USMI) and large shipbuilding contractors. Its latest is in Greenville, SC.

"In South Carolina," Cassin points out, "our operations are all manufacturing." These include 3D weaving, fiber commingling, automated resin application, kit cutting, parts fabrication and advanced nondestructive inspection (NDI). *CW* recently toured the Greenville facility, with Cassin as guide, and caught a glimpse of MSC's new materials for multifunctional composites and how they will be manufactured for commercial applications.

Although the facility, at 1200m^2, is not large, it is filled with equipment and activity. Each stop along the way revealed another facet of MSC's mission. The tour began with COUNTERVAIL, an MSC technology that, because of its proprietary nature, is formed in a portion of the facility curtained from view. It was, however, possible to view rolls of the material as it was undergoing prepregging and was subsequently readied for shipment. Cassin did, however, reveal a good deal of detail about COUNTERVAIL's background.

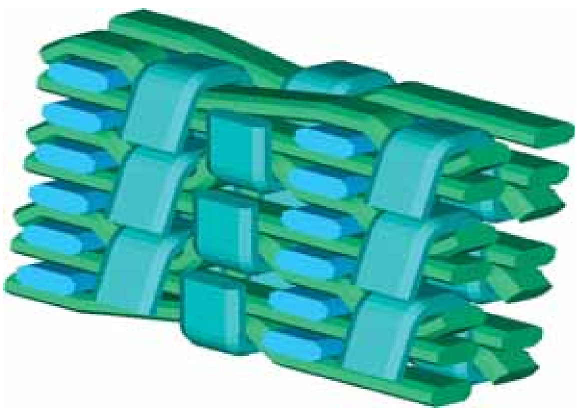
A sound challenge

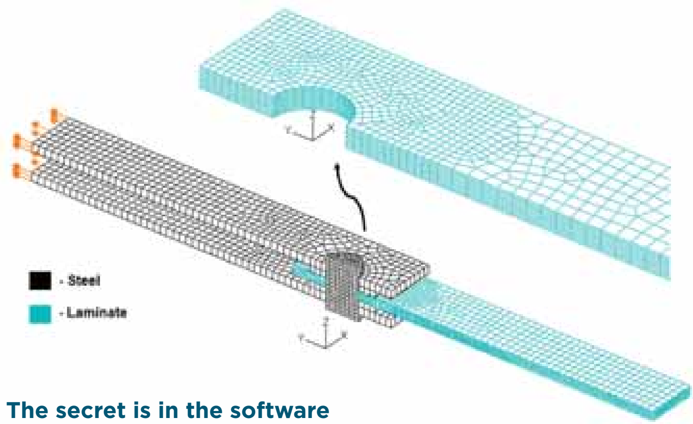
The technology dates back to an MSC Small Business Innovation Research (SBIR) grant to develop an improved, all-composite sonar acoustic window for naval vessels, aimed at increasing structural and sonar performance, while reducing weight and cost vs. existing versions. Cassin credits SBIRs with a great deal of MSC's growth: "There is a high risk to insert new technology into military vessels and aircraft. MSC uses SBIRs to develop the requisite technology and reduce risk," he says. "Once you have verified and validated it, you can now insert the technology into trial operations."

A sonar dome, he explains, is an underwater structure typically mounted to the bow of a vessel. It houses the sonar transducers, protects them from exterior loads and damage, and is flooded with seawater to acoustically couple them to the surrounding ocean. Sonar domes demand high structural properties to resist pounding from rough seas and potential impacts. The sonar window is the part of the dome through which sound passes on its way to and from the transducers, and it must disrupt this transmission as little as possible. "The challenge is to match the impedance, or speed, of sound through the material to that of the seawater," explains Cassin.

Notably, a sonar window is not a simple structure. Some can measure more than 10m^2 in area and require compound curvature. MSC's solution is a low-acoustical-insertion-loss composite, using proprietary fiber commingling technology. The latter blends acoustical and structural fibers into a tailored fabric and multilayer composite that enables the high-strength, protective sonar window to mimic the density and acoustical impedance of seawater, minimizing sound-wave scattering and reflection. The result is a clearer, more accurate signal.

MSC also had to reduce risk in the joint between the composite dome and the steel vessel. "Joining two dissimilar materials »





The secret is in the software

MSC has developed and licensed both standalone and third-party commercial software modules for material modeling and for predicting structural response, damage progression, and impact behavior of composites. Examples include TexLink (left) and ABAQUS: UMATs for damage progression prediction (right). Source | Materials Sciences Corp.

that have vastly different constituent properties is one of the most challenging issues when engineering composite structures," explains Cassin. "Our strength is understanding multi-phase materials. For example: fiber-to-matrix interfaces, commingled fibers and binding systems." MSC has developed a deep knowledge of organic polymers and metals, the latter not only as a matrix for composites but also as a bonding substrate. "The Achilles heel of composites is attachment to non-composites," he points out. "We have specialty software that models the mechanics of joining and helps understand how to test and inspect these joints."

MSC proved the durability of its joint design via full-scale tests, using a reconfigurable 445-kN modular test frame that simulates static and fatigue responses of full-scale ship bulkheads or girders.

Weaving fabrics in three dimensions

Standard and specially modified weaving looms produce a range of customized fabrics, including 3D weaves for ballistics and blast-resistance applications.

Source | Materials Sciences Corp.

Transitioning R&D into commercial products

Through this program, MSC developed a much better understanding of how to tailor a composite's sound-transmission properties. It also recognized an opportunity to optimize materials not for sound transmission, but for sound *disruption*. After significant development, MSC launched COUNTERVAIL, a composite material that can be integrated into a structure to significantly reduce vibration without adding parasitic weight. Appropriately named (*countervail* means to act against with equal force), its characteristics, including drapability, stiffness and damping coefficient, can be tailored to the application. COUNTERVAIL comprises a lightweight viscoelastic combined with a patented fiber preform, and can be made with any fiber or combination of fibers, including carbon, glass or aramid. The preform features a fiber pattern that maximizes the vibrational energy dissipation provided by the viscoelastic component.

One of MSC's first applications for COUNTERVAIL was in high-performance skis, with the goal to enhance the skier's speed and control. "You only ski fast when the ski is in contact with the snow," explains Cassin, "because the edge is actually melting the snow. If the ski chatters, it loses speed." MSC built a model to predict and optimize the performance of COUNTERVAIL in a ski. The material has been used in boutique skis, such as Wagner and Romp, and field trials are in progress at a major ski manufacturer.

Bianchi (Milan, Italy), a bicycle manufacturer often associated with Tour de France winners, saw MSC's demonstration of COUNTERVAIL in skis and began collaborating with MSC to apply it in a bike frame. MSC's computer modeling showed a potentially significant performance difference vs. Bianchi's standard carbon fiber composite frame. Bianchi then adopted COUNTERVAIL in its 2014 *Infinito CV* model, which was ridden by cyclist Lars Boom to win Stage 5 of the 2014 Tour de France, a stage known for its bike frame-chattering cobblestones.

"COUNTERVAIL does not interrupt the shock of hitting a cobblestone," Cassin explains, "but that impulse excites the bike frame structure to resonate at a natural frequency." He gives an example of striking a bell: "The ring is still there, but with COUNTERVAIL, it will not be there for very long. Similarly, you will still feel the impulse from going over a bump, but you won't be subjected to the vibratory envelope." Cassin adds that in addition to the vibrational frequencies you can feel, there are hundreds that

Fiber forms with acoustical & structural functions

A beam of commingled fibers is drawn into a weaving loom (left) to produce one of MSC's specialty fabrics (right) which blend acoustical and structural fibers into a tailored fabric that delivers lightweight, high-strength and tailored wave propagation and/or dielectric properties to the finished multilayer composite.

Source | Materials Sciences Corp.

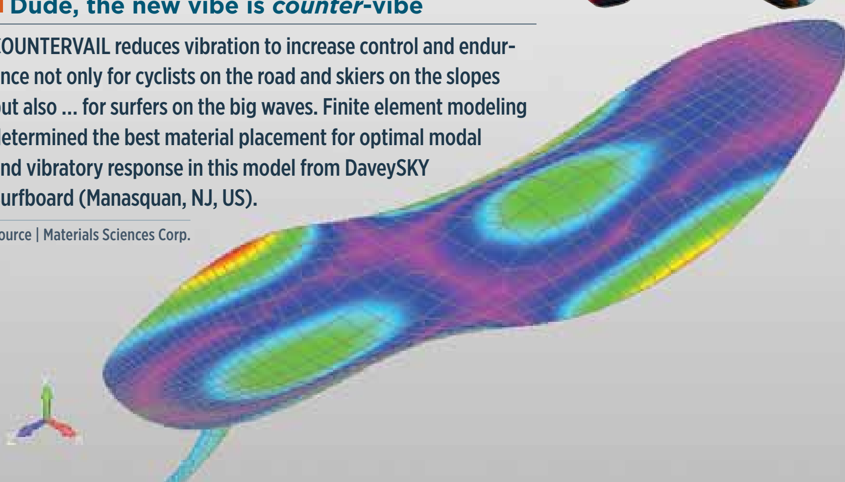
you cannot sense because the frequecies are too high. "Yet your body reacts to these, and you can calculate how much energy your body uses to counteract these vibrations." This reduction in energy consumption pays off in performance for the cyclist, whose goal is to transmit every ounce of energy into forward propulsion. "So now we are adding value to a laminate by making it multifunctional, offering not just lightweight structure but also vibration damping and the performance benefits that come with that."

"COUNTERVAIL is very unique, allowing you to use damping for structural vibration reduction and/or for shifting natural frequency and change resonant mode shapes," Cassin notes. Thus, the degree of vibration and/or noise reduction depends on how the material is used and the engineering goal for the final structure. That flexibility has already resulted in varied implementation. COUNTERVAIL reportedly has not only achieved a 50-70% vibration reduction in specific carbon composite bike frames, but a fivefold reduction for a composite spar. It also has reduced peak noise transmission by roughly 30% without increasing weight in a noise isolation interior panel for a Bell 403 helicopter. Cassin also showed a prototype camera boom for a UAV that was being prepared for testing during *CW's* visit. "Vibration in these gimbals and armatures makes it harder for the camera to lock onto the GPS signal," he pointed out. "This continuous searching can render the device useless, similar to a cellphone exhausting its battery from nonstop searching for a GPS or Bluetooth signal."

Cassin envisions a range of potential applications for COUNTERVAIL, including wind blades, aircraft interiors, boat hulls, prosthetics and automotive structures. "Radiated noise is a whole category of application for this technology," he adds. "Traditionally, the best way to damp noise has been to *add* mass — like lead blankets — but these add a significant amount of weight." Although Cassin sees the technology as far-reaching, he says MSC is pursuing a controlled rollout, targeting low-hanging fruit first.

Fiber forms for a multifunctional future

Along the right side of the facility's open production area, a variety of weaving looms produce standard fabrics from commingled fibers followed by specially modified looms from American Iwer Corp. (Greenville, SC, US) and other suppliers for producing 3D weaves used in ballistics and blast-resistance applications. Down the center of the space are beaming and »



Dude, the new vibe is *counter*-vibe

COUNTERVAIL reduces vibration to increase control and endurance not only for cyclists on the road and skiers on the slopes but also ... for surfers on the big waves. Finite element modeling determined the best material placement for optimal modal and vibratory response in this model from DaveySKY Surfboard (Manasquan, NJ, US).

Source | Materials Sciences Corp.

■ Cutting & kitting complete the package

MSC uses computer-controlled ply cutters to transform its specialty textiles into labeled preform kits. Source | Materials Sciences Corp.

stitching machines, the former enabling the warp fibers to be readied in-house for hybrid fabric production, and the latter for attaching lightweight veils and mats to custom fabrics for infusion. Along the left side of the building, several machines are used to prepreg fabric. They apply resin to MSC's tailored fabrics and are capable of processing thermosets, thermoplastics and high-temperature resins. Preform kits are prepared using computer-controlled ply cutters near the building's front side.

Along the far wall are the commingled fiber machines. These feed in strands of two or more different fiber types, intermingling them to produce an integrated yarn, which then can be used in MSC's weaving machines. Examples of commingled fibers could include glass with nylon or other thermoplastic fiber, but MSC's versions often tend toward unusual tailored combinations, specially developed for customers who prefer to keep their systems under close wraps.

Fiber commingling is not new technology. But thanks to MSC's long history of materials and applications development, it sees commingling as a means for entirely new multifunctional composites. One example harkens back to the sonar window work. "We take fibers that have structural properties, and then add acoustical performance, like low insertion loss," Cassin explains. "The fibers that give the best through-transmission have low structural properties. Our ability to combine these fibers provides a tailored solution."

Cassin adds that MSC can customize the electrical, thermal and dielectric properties of such fibers. "We have commingled thermoplastic fibers, such as polypropylene and PEEK, with carbon fibers, and also analyzed the process parameters," he says. "From our modeling capabilities, we can synthesize thousands of materials to produce totally novel, custom composites." Asked how realistic this is for near-term applications, Cassin responds, "The structural low-insertion-loss materials are being developed now as our next commercial products." The technology is made possible, he adds, by two things: Development of constituent theories (e.g., partial differential equations that describe the physical behavior of each component material) and the advancement of computer power. "We can now run very complex models in a matter of minutes. These new multifunctional composite materials are achievable today."

South Carolina and beyond

Technology growth — realized and potential — made another facility inevitable. But why South Carolina? Cassin begins with the practical. "This facility belonged to a supplier with whom we developed our 3D weaving capabilities," Cassin replies. "The building became available and it was the right timing for us." But he also credits the business climate in Greenville: "It offers very unique access to businesses that we want to be working with, like GE, Lockheed, Boeing, BMW and Milliken." The South Carolina Research Authority (SCRA, Columbia, SC, US) also plays a role. MSC is a member of SCRA's composites consortium (TCC) and has completed several projects through the Composites Manufacturing Technology Center of Excellence (CMTC, Anderson, SC), which applies composites technologies to US Navy systems.

"There is also real support here from the county and the state," Cassin adds. "The Greenville Area Development Corp. was also very helpful, introducing us to suppliers and potential customers. Whenever we had a need, they did their best to connect us to resources."

Cassin says this type of networking and connection to resources is vital for small businesses. "We tend to work with engineers, but they often are not the decision makers. You need a way to bridge that gap, and the folks in South Carolina understand this well, offering real help toward commercializing new products and processes."

That, indeed, is MSC's main priority with the Greenville facility. "Developing new material forms is a great business for MSC," says Cassin, "but for us it is only the first step. The real payoff is seeing these materials used in defense, industrial or commercial applications. The ability to make a product perform in a completely different and better way is our focus." CW

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Read more about COUNTERVAIL online in the *CW Blog* titled "Vibration-canceling composite technology" | short.compositesworld.com/MSCVibBlog

Fokker Aerostructures: Hoogeveen, The Netherlands

This Dutch aerospace supplier leverages its founder's pioneering spirit from a century ago to lead the way, today, in thermoplastic aerocomposites.

By Jeff Sloan / Editor-in-Chief & **Sara Black** / Technical Editor

» The Fokker name enjoys a long and storied history in aviation. It harkens back to the earliest days of manned flight, when Dutchman Anthony Fokker first flew his *Spider* aircraft over the city of Haarlem, in 1911. After founding a Dutch aviation company, Fokker set up Fokker Aviatik GmbH in Germany in 1912 to supply the German army. Throughout the 1920s and 1930s, Fokker was, arguably, the best-known and most successful aircraft manufacturer in the world. In full flight in the aerospace industry by the 1950s, his company launched, in 1958, the F-27, a two-engine, single-aisle passenger plane that became the company's signature aircraft. But by 1996, market forces had overcome Fokker Aviatik. The aircraft builder declared bankruptcy and ultimately ceased operations.

But the Fokker name did not die. It lives on in business units spun off before bankruptcy. Three — Landing Gear, Electrical Systems, Services — make parts and perform maintenance and repair work, and carry on under the name Fokker Technologies. The fourth and most notable is Fokker Aerostructures. Headquartered in Papendrecht, The Netherlands, this developer and fabricator of thermoplastic composite structures for aerospace applications — the subject of this *CW* Plant Tour — is adding a significant chapter to the history of its storied name.

Turning the page: Thermoplastics

Fokker Aerostructures started its thermoplastics activity 25 years ago by creating a small R&D team that cooperated closely with

Fig. 1 ***Autoclaved* thermoplastic composites**

Although Fokker is famous for its thermoplastics expertise, the company still relies on the autoclave to consolidate many parts as they cool after forming because it remains the best tool for meeting porosity specifications.

Source (all photos) | CW / Photos /Jeff Sloan & Sara Black

material supplier TenCate (Nijverdal, the Netherlands) and with prospective customers. Initial customers were the owner, Fokker Aircraft company, Dornier (Friedrichshafen, Germany) and Airbus (Toulouse, France). Thus, an ever-growing range of products was developed and taken into production. This ranged from initial applications, such as brackets, ribs, wing panels and floor panels, to fully assembled structures, including wing leading edges, rudders and elevators. A key player on the team proved to be gifted R&D engineer John Teunissen, who created and developed several new manufacturing technologies and product concepts. In 1995, a breakthrough was the development of *Gulfstream 5* floor boards, which included primary structure pressure bulkheads. This led to a move towards fabrication of thermoplastic composite primary structure, with corresponding engineering and manufacturing knowledge.

Our hosts during our plant tour are Richard Cobben, VP technology, and Arnt Offringa, director, R&D. Well-known in the composites community for his thermoplastic composite expertise, Offringa guides us on the tour of Fokker's large facility in Hoogeveen. Before the tour, Cobben presents the different Fokker companies. Then, in advance of leading us to the production floor, Offringa reviews some of the parts and structures that Fokker manufactures at the plant, most notably the rudder/elevator for the *Gulfstream G650* business jet (see "Learn More"), elevators and floorboards for the *Gulfstream 5* business jet, rudder and elevators for the Dassault *Falcon 5X*, the wing leading edge for the Airbus A380 superjumbo passenger plane, and all of the access doors for all of the variants of the F-35 *Lightning II* fighter jet. With the exception of the F-35, each of these applications relies on thermoplastics and it's thermoplastic composites on which the Fokker name now stands.

A strong proponent of thermoplastics, Offringa believes they will see only increased use and application in the aerospace market. The material, he notes, offers a toughness — as opposed to brittleness — that thermosets can't match, making them suitable for use in structural and semi-structural applications.

"New designs can, therefore, be lighter in weight because the amount of composite plies can be reduced," he contends. "Welded thermoplastic rudders and elevators are 10% lighter than their thermoset composite predecessors because of the so-called 'post-buckled' design" (discussed below). That said, thermoplastic composites fabrication at Fokker is not, as some thermoplastics proponents claim, an out-of-autoclave process. Indeed, the company still relies heavily on the autoclave to ensure that its products meet porosity goals (Fig. 1, 94). "I know we like to think of thermoplastics as not needing autoclave cure, but for large parts, »

Fig. 2 **Themoplastics enable innovative rudder/elevator combo**

These thermoplastic spars are for the *Gulfstream G650* rudder/elevator and feature a design that, because of the material's high toughness, allows for in-flight buckling, without damage or failure.

Fig. 3 **In-house equipment development**

Much of the thermoplastic composites innovation that comes out of Fokker is a product of the company's research and development lab, which features this automated fiber placement (AFP) machine, equipped with a Fokker-developed end-effector.

Fig. 4 Wing leading edges awaiting welding

Molded of glass fiber/PPS, the Airbus A380 wing leading-edge skins on these racks soon will be integrated with ribs and spars via welding in Fokker's large Tool Jig Room.

we see it as the best way to achieve the compaction and consolidation pressure required, to drive out any volatiles," Offringa notes. "And for an aerospace structure, that is critical."

Good buckling, R&D

One of the first parts we see on entering the Hoogeveen facility are the just-molded spars for the *Gulfstream G650* rudder/elevator (Fig. 2, p. 95). They're fabricated in lengths of 4m and 6m at thicknesses of just less than 1 mm to several millimeters. They're consolidated in an autoclave and feature integrated ribs with regional thicknesses (from weldments). The material is TenCate Cetex carbon fiber/PPS.

These parts, says Offringa, are exemplary of the tough/not brittle attributes that make thermoplastics so appealing to aerospace fabricators and OEMs. They are designed, says Offringa, to buckle slightly during service, without breaking or cracking. "A thermoplastic rudder consists of thin skins welded onto a stiff internal skeleton of ribs and spars. When the rudder is used, it is loaded in torsion and the skins are allowed to buckle at 70% of limit load (the load that occurs once in the lifetime of an aircraft). This allows for thinner skins than otherwise, resulting in a weight reduction as compared to conventional composites." Fokker's thermoplastic composite parts are tested and certified at 1.5 times limit load.

Much of what Fokker has learned about thermoplastic composites fabrication, assembly and performance is fueled by the company's significant research and development (R&D) work, which is guided by Offringa. Fokker's R&D lab employs 10 people and has equipment for environmental simulation, 3-D printing (provided by Leap Frog, Alphen aan den Rijn, The Netherlands),

Fig. 5 Compression molding of rib components

A380 wing leading-edge ribs are compression molded, using materials cut from TenCate's Cetex preconsolidated glass fiber/PPS sheets, on this massive press supplied by automated machinery manufacturer Pinette Emidecau (Chalon Sur Saone, France).

Fig. 6 "Meshing" leading edges ribs and skins

Molded ribs for the A380 wing leading edge are bonded to the skins by means of resistance welding, in which a metal mesh strip coated with PPS is attached to the edge of the rib. A current is applied to the mesh, which softens the PPS and bonds the rib to the skin. The metal mesh becomes part of the bond.

autoclave curing (from Italmatic, Cassina de Pecchi, Italy) and automated fiber placement (AFP, Fig. 3, p. 95). The latter features a Fanuc (Minamitsuru-gun, Japan) robot, a Fokker-developed end-effector that features 35,000-Hz ultrasonic heating capability, and CGTech (Irvine, CA, US) control software.

It's here in the R&D lab that Fokker has worked with Airbus and other partners on the Europe-based Thermoplastic Affordable Primary Aircraft Structure (TAPAS I and TAPAS II) projects (see "Learn More") to evaluate the performance of thermoplastic composites in aerostructures. Fokker also is involved with the European Clean Sky Joint Technology Initiative, part of which is comparing autoclave energy use between thermoset and thermoplastic materials. At the time of *CW's* visit, a large fuselage panel demonstrator was being readied for display at a composites trade show.

> Fabrication is only half the Fokker story, for the company invests just as heavily in assembly ....

Big assembly for the A380

Fabrication, however, is only half of the Fokker Aerostructures story, for the company invests just as heavily in assembly, which, when it came to thermoplastics, opened the door to welding methods. And it's in development of thermoplastic welding technologies that Fokker has truly excelled. Fokker's contract to manufacture the wing leading edges on the massive Airbus A380 from »

Fig. 8 Robotically automated welding

All welding of the A380 wing leading edge is done with robotic equipment, which measures the distance traveled along the skin to recognize which rib it's welding.

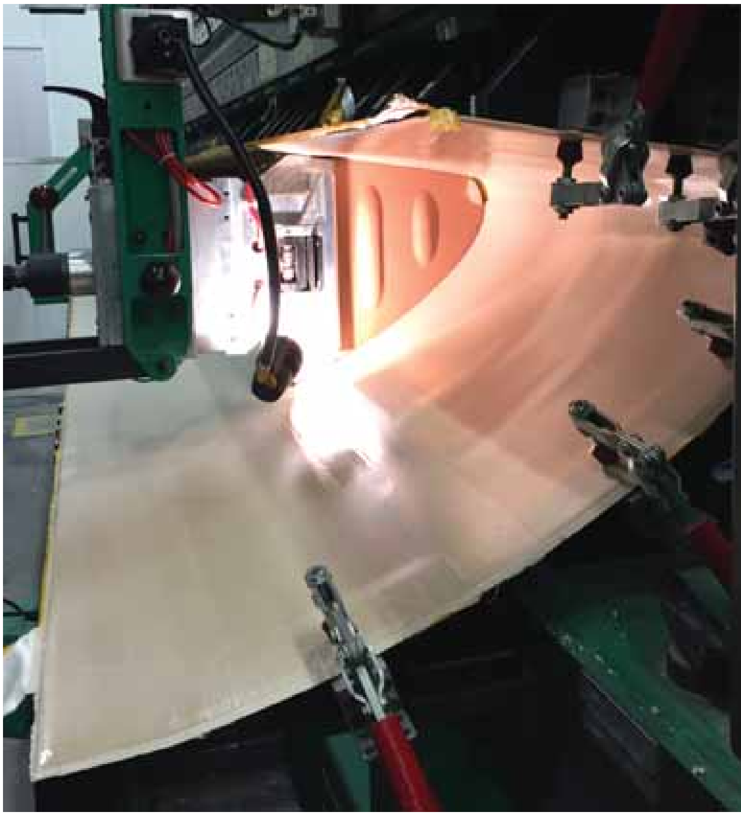

Fig. 7 Section-by-section assembly

An A380 wing leading edge skin and its ribs, spar and stiffeners, mounted in an assembly jig, is shown here during resistance welding. Each jig holds one 3.5m section of wingskin. Each wing leading edge comprises eight 3.5m sections, for a total length of 26m.

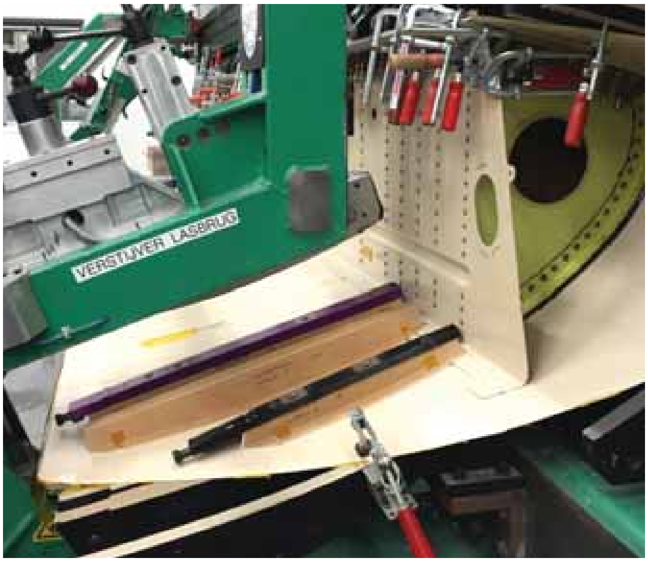

Fig. 9 Welding's future: Toward "lights out" technology

For the Dassault *Falcon 5X* elevator, Fokker employs next-generation *induction* welding technology that, unlike resistance welding, allows direct thermoplastic-to-thermoplastic bonding and obviates the need for a metal mesh strip. This assembly jig holds all of the spars and ribs for the elevator; during the night shift, robotically guided induction coils are inserted into the jig to bond the parts together.

thermoplastic composites was one of the composites industry's biggest news stories in the first decade of the 21st Century. That program also consumes the biggest space at the Hoogeveen plant. The work is done in the plant's Tool Jig Room, so named because it is dominated by eight two-sided jigs — one side for the left wing, the other side for the right wing — in which Fokker welds the thermoplastic leading edge skin and spar with a series of reinforcing ribs. Each jig accommodates a 3.5m length of leading-edge skin. Each wing leading edge comprises eight 3.5m sections, for a total leading-edge length of 26m, spanning from each wing's inboard engine to its wingtip.

The welding of the thermoplastic skins and thermoplastic ribs is important because this assembly technology creates what is, in effect, a unified thermoplastic composite structure. The benefit is significant because it relieves the manufacturer of what would otherwise be a costly additional step necessary for aircraft certification: Adhesively bonded skins and ribs would require the redundant use of mechanical fasteners. But *welded* skins and ribs do not. However, this makes the consistency and repeatability of the welding process critical.

The leading edge skin (Fig. 4, p. 96) and spar are fabricated via hand layup, using a glass fiber/PPS semipreg provided by TenCate Advanced Composites under the Cetex brand. The skin and spar are layed up using single plies of the semipreg, which are cut on Gerber Technology (Tolland, CT, US) flatbed cutting tables. Ply positioning guidance is provided by Virtek Vision International's (Waterloo, ON, Canada) laser projection systems. The parts are bagged and then consolidated in an autoclave at 320°C, with a total cycle time of 3 hours — 6-9 hours is typical for thermoset composites. Ribs and stiffeners (Fig. 5, p. 96) are compression molded on a Pinette Emidecau (Chalon Sur Saone, France) press using the same Cetex material, but supplied by TenCate as preconsolidated sheets. The Cetex sheets are first softened in an infrared heater and then quickly transferred to the press, which offers a 0.5-second closed cycle, says Offringa. Stiffeners for the wing leading edge, fabricated from glass/PPS, are robotically machined and drilled near the Pinette press by a Panasonic VR-016 robotic system.

All of the wing leading edge parts — skin, spar, ribs, reinforcements — eventually come together in the Tool Jig Room for assembly and welding. Fokker has experimented over the years with a variety of welding technologies, but for A380 wing leading edge assembly, it settled on resistance welding. For that method, a metal mesh strip coated with PPS is attached to the contact edge of each rib (Fig. 6, p. 96). The rib is then inserted into the jig, secured by a rib holder rail. The welder then moves from rib to rib, and a current is applied to each for 1 minute at one end of the metal mesh. This is followed by a 1-minute hold and a 1-minute cool-down. The current melts » the PPS around the mesh and creates a bond with the skin. The mesh remains in place and becomes a permanent part of the weldment. After all ribs are bonded, the spar is attached and held in place with stiffeners, which also are welded (Fig. 7, p. 97).

Much of this assembly, says Offringa, is automated, but some manual labor is required to attach holding fixtures. The welding itself, however, relies on automation for both speed and consistency. "An electronic ruler on each jig tells the machine which rib it's on," says Offringa (Fig. 8, p. 97).

Advancements in induction welding

Although the resistance welding regimen employed on the A380 wing leading edge assembly is an effective and now relatively mature Fokker technology, the assembly of parts for the *Gulfstream 6* and Dassault *Falcon 5X* via induction welding represents the very latest developmental step that is already delivering on its very great promise. This work is done at the next stop on *CW*'s tour, the Marconi Street Building, a short drive from Fokker's main facility in Hoogeveen. Here, we see a jig design and automated process that has evolved beyond that used for the A380 wing leading edge configuration.

The advantage of induction over resistance welding, says Offringa, is that it does not require use of a metal strip or other conductor, thus there is no weight penalty for the weldment. Fokker's induction method was developed and provided by KVE Composites Group (The Hague, The Netherlands). Dubbed Induct, it generates eddy currents in the electrically conductive carbon fiber reinforcement within the thermoplastic laminate. The currents are generated by moving an induction coil over the weld line; the eddy currents it generates then heat the laminate from the inside. The parts that are being welded must be positioned, says KVE, in a proprietary tooling material (steel, with a "special" ingredient) that is transparent to the electromagnetic field and has good thermal conductivity. The coil motion at Fokker is actuated robotically.

Offringa first shows *CW* the assembly jig for the *Gulfstream 6* rudder, which consists of two spars with supporting ribs. All are fabricated from carbon fiber/PPS via compression molding. As with the A380 wing leading edge assembly, the *Gulfstream 6* rudder jigs (there are six, total) are oriented horizontally and elevated about waist high. A jig is 4 to 6m long and features horizontal slots to hold the spars and vertical slots to position the ribs against the spars. With all parts in place, a robot equipped with a KVE induction coil moves into various slots along the jig, welding each rib to the spars.

For the Dassault *Falcon 5X* elevator, Fokker has three jigs, similar to the *Gulfstream* jig system but improved in the sense that the six jigs are now replaced by only three, using the same induction technology (see Fig. 9, p. 97). On these jigs, day shift labor is used to load composite parts into the jig, and then a robot works overnight to induction weld the resulting assembly, a process that takes about six hours.

A new chapter

Offringa sums up his company's wholehearted focus on thermoplastics, and the philosophy Fokker refers to as "aircrafting": "When we began our work with thermoplastics, the supposed advantages had yet to prove themselves. After a certain time they become clear, and then new, unpredictable advantages revealed themselves, such as the benefits of post-buckling design, fewer production steps and greater design freedom, compared to thermosets." The material and design innovations represent aircrafting, which reflects the Fokker commitment to and appreciation for all the details that go into designing, assembling and then maintaining a modern aircraft.

Now, yet another chapter in the company's century of experience is beginning. Fokker Technologies announced on July 28 that it will be acquired by GKN plc (Isle of Wight, UK). Hans Büthker, Fokker Technologies' CEO, has said that Fokker can benefit greatly from the scale, innovation and financial power of GKN, and the combined entity will lead to new opportunities for Fokker employees who will be participating in some of the world's largest and most challenging aerospace projects.

"A strong focus on a limited number of unique technologies," Offringa says, in conclusion, "has proven a successful way to create new business opportunities." CW

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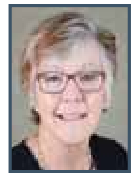

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Composites Events

Oct. 4-6, 2015 — Charleston, SC, US
Thermoplastic Resin Formulators Assn. (TRFA) Annual Meeting
www.trfa.org/meeting/2015/index.aspx

Oct. 5-7, 2015 — Orlando, FL, US
2015 Polyurethanes Technical Conference
www.polyurethane.americanchemistry.com/Polyurethanes-Technical-Conference

Oct. 5-8, 2015 — Wichita, KS, US
CMH-17 PMC Coordination Meeting
www.cmh17.org/meetings.aspx

Oct. 6-7, 2015 — Los Angeles, CA, US
SpeedNews 20th Annual Business & General Aviation Industry Suppliers Conference
www.speednews.com/business-and-general-aviation-industry-suppliers-conference

Oct. 20-21, 2015 — Knoxville, TN, US
Additive Manufacturing 2015
www.additivemanufacturinginsight.com/conferences/am-workshop

Oct. 20-22, 2015 — Singapore
JEC Asia 2015
www.jeccomposites.com/events/jec-asia-2015

Oct. 26-29, 2015 — Dallas, TX, US
CAMX – The Composites and Advanced Materials Expo
www.thecamx.org

Nov. 2-4, 2015 — Berlin, Germany
Composite Pressure Vessel Symposium 2015
www.cpvsymposium.com

Nov. 4-5, 2015 — Birmingham, UK
Advanced Engineering UK 2015
www.advancedengineeringuk.com

Nov. 4-7, 2015 — Sao Paulo, Brazil
Compocity 2015
www.almaco.org.br/compocity/2015

Nov. 12-14, 2015 — Istanbul, Turkey
PUTECH Eurasia/Eurasian Composites Show
www.eurasiancomposites.com

Nov. 17-19, 2015 — Seville, Spain
2nd Aerospace Structural Impact Dynamics Int'l Conference
www.asidiconference.org

Nov. 24-25, 2015 — Stuttgart, Germany
INC 2015 (Industrial Nanocomposites Conference)
www.industrialnanocomposites.com

Dec. 6-9, 2015 — Ishikawa, Japan
14th Japan International SAMPE Symposium & Exhibition (JISSE-14)
www.sampe.nuae.nagoya-u.ac.jp/jisse14

Dec. 8-10, 2015 — Knoxville, TN, US
Carbon Fiber 2015
www.compositesworld.com/conferences/compositesworlds-2015-carbon-fiber-conference

Jan. 25-28, 2016 — Palm Springs, CA, US
36th High Temple Workshops
www.hightemple.udri.udayton.edu/Pages/default.aspx

March 6-10, 2016 — Vancouver, BC, Canada
NACE Corrosion 2016
www.nacecorrosion.org

March 8-10, 2016 — Paris-Nord Villepinte, France
JEC World 2016
www.jeccomposites.com

March 20-24, 2016 — Grapevine, TX, US
2016 No-Dig Show
www.nodigshow.com

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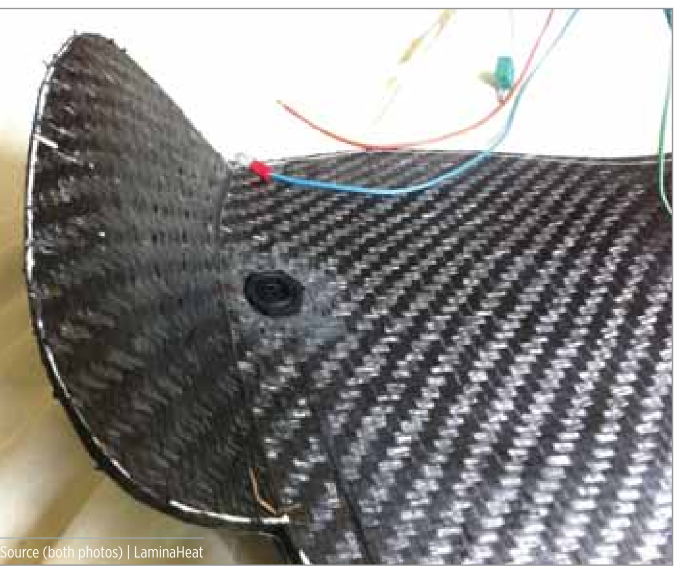
REFORMABLE COMPOSITE EQUESTRIAN SADDLE

Carbon fiber/PET saddle tree features intralaminate heating element



Source (both photos) | LaminaHeat

The effectiveness of **LaminaHeat LLC's** (Greenville, SC, US and Dorset, UK) PowerFilm and PowerFabric materials in heated composite tooling and structures was recently demonstrated in a very big way, via an 18m long carbon fiber (CF) composite tool used by Norco GRP Ltd. (Poole, Dorset, UK) to cure the tips of Blade Dynamics' (Southampton, UK) 75m long composite blades for 6-MW offshore wind turbines (see "Learn More").

PowerFilm, a thin (100 microns thick) layer of randomly oriented carbon fiber insulated with a polymer and incorporating copper contacts, converts electricity into heat so efficiently that it can generate up to 10 KW/m^2 — roughly the same heat as three gas fires — from only 1m^2 of material. In fact, PowerFilm converts with 99% efficiency vs. 80% for gas flame, according to technology developer Peter Sajic. But before its prowess was demonstrated in processing turbine blades, PowerFilm was trialed in carbon fiber/polyethylene terephthalate (PET) composite structures for *equestrian saddles*, providing a solution that could have far-reaching applications, from sporting goods to medical devices.

Sajic had friends involved in horse training and was aware of their issues with fitting saddles. "One of the biggest problems ... is that the shape of the horse changes as it grows and matures, just like in people," he explains. The saddle must be sent back to the saddlemaker, who adjusts its shape to better fit the horse, to prevent chafing, discomfort and potential injury. This must be done at least *twice annually* at a cost of roughly £350 (US$550) *each time*. Sajic says the saddlemaker must first send someone out to measure the horse with a special gauge. The saddle is then disassembled and a hydraulic ram is used to open the width of the *saddle tree*, or frame structure, principally in the neck area. "Though the gauge measurement is used to guide the widening," says Sajic, "it is still, typically, a trial-and-error process."

Sajic proposed a PowerFilm-enhanced composite alternative that enables a saddle to "grow with the horse." "With our system," Sajic explains, "you have the saddle on the horse and simply connect a power source via a plug at the rear of the CF/PET saddle tree." The latter heats up to 120°C-140°C (the leather acts as an insulator, so the horse feels about 25°C). A saddlejack is used to widen the neck area of the now-pliable laminate until it matches the horse's shape.

"We designed the PowerFilm to hit 120°C in 2 minutes," explains Sajic. "It uses a 24-volt DC power source, so it's very safe."

The CF/PET saddle tree is made using 12K CF tow commingled with linear PET (LPET) fiber. The latter enables lower processing temperatures vs. normal PET. The commingled tows are woven into fabric by **Carr Reinforcements** (Worsthorne, UK). The dry fabric is then hand layed onto a metal tool, with the PowerFilm and electric wiring to the power socket embedded within. The layup is then vacuum bagged, heated to 190-200°C and cured under vacuum for 20-30 minutes. After demolding, it's trimmed to size and ready to form the structure for the saddle.

The PowerFilm is an efficient solution. "It supplies 10 kW/m^2 from a 0.004m^2 piece of film that is 200-250 microns thick and needed only at the neck," says Sajic. He notes there are 200 shapes that can be used to customize saddle trees, "but with our system, you only need, maybe, five or six generic shapes, and then simply heat them to tailor and match the horse you're riding."

LaminaHeat's other PowerFilm applications include de-icing of wind blades. Sajic notes, "We've demonstrated a proactive system that prevents ice from forming, using a very low-mass insert [20 g/m^2] embedded into the glass laminate."

"There are companies spending millions on carbon nanotubes," says LaminaHeat's VP sales and marketing for North America Marc Anderson, "but we have a low-cost, efficient solution that works now." CW

LEARN MORE

Read more about the 6-MW blade tips online in "Heated Composites" | short.compositesworld.com/HeatComp

SUPER "SKINNY" WATER SKIFF

Shaving weight and boosting toughness of flatboat for shallow waters


Source | Hell's Bay Boatworks

Known for superlight flatboats built for "skinny" waters, Hell's Bay Boatworks' (Titusville, FL, US) previous best was its 5.8m long *Glades Skiff*, which weighs in at 172 kg fully loaded (engines and fuel) and maneuvers easily, with a draft of 1.2m. But a recent custom project demanded a craft with a draft of only 0.6m.

"This customer fishes in very shallow waters in Texas," says Hell's Bay president/owner, Chris Peterson, "so we were already looking at waterjet engines to meet the minimal draft." But that would only solve part of the problem. "When you run in shallow water, you are more likely to hit things," he explains. So, more impact resistance would be needed, but *at less weight.* "Every 8 lb of weight displaces another gallon of water," he says, "so less weight equals less draft." Sportfishing often requires pushing the boat quietly with a pole. "We needed to have a hull and deck that could handle ... potential impacts but also float well for easy poling. We needed to have a reinforcement and resin system that could do *both.*"

Peterson teamed with **Vectorply** (Phenix City, AL, US), **Innegra Technologies** (Greenville, SC, US) and **Scott Bader ATC** (Stow, OH, US). "Vectorply came up with a special carbon fiber weave that gives a lot of stiffness with thin laminates," he says. That noncrimp fabric combines carbon, E-glass and Innegra's S fibers, and integrates a carbon fiber veil as a flow medium. "Vectorply helped to design the laminate architecture as well, so that we used the fewest layers to meet mechanical property and impact requirements," adds Peterson, in a sandwich construction, with a single-layer, multiaxial faceskin on either side of Corecell foam core (**Gurit**, Newport, Isle of Wight, UK).

"We weren't sure how the Innegra hybrid fabric would work with the Scott Bader infusion resin," concedes Peterson. "So we tested it and it worked great." The Crestapol 1250LV low-viscosity urethane acrylate's cured molecular weight is 80% that of epoxy or vinyl ester, one reason the boat came out 24% lighter than the company's standard craft. "The boat also sat higher in the water," says Peterson, "which is what we wanted." CW

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Composite pontoons undergird update of 1820s-vintage floating bridge

Modular composite flotation system triples potential lifespan of New England town's signature single-lane auto/pedestrian timber bridge.

By Johanna Knapschaefer / Contributing Writer

» In the central Vermont town of Brookfield (pop. 1,292), the world's first floating fiber-reinforced polymer (FRP) bridge has replaced a 1978 version that carried state Route 65 traffic over Sunset Lake. Designed by T.Y. Lin International (San Francisco, CA, US), it is the eighth version of a floating log bridge built in 1820 after a resident fell through winter ice and drowned while crossing the lake nearly two centuries ago. It has since been the focal point of the town's life. Construction of the new 97m long, 6.7m wide, US$2.4-million single-lane Brookfield Bridge began in April 2014 and was complete before its opening, Memorial Day weekend 2015.

Preserving the past for the next century

Reportedly the world's first floating fiber-reinforced polymer vehicle bridge, the Brookfield Bridge preserves the character of the timber structure it replaces, but undergirds it with a buoyancy system designed to last for a century. (See more photos of the new bridge and some vintage shots of the 1978 structure it replaced in the online version of this article noted in "Learn More.") Source | Brookfield

Replacement became necessary when 380 of the 50-gal barrels that kept it afloat began to leak. "The plastic styrofoam-filled barrels were becoming saturated and deteriorating," says Jennifer Fitch, project manager at the Vermont Agency of Transportation (VTrans). As the barrels lost flotation and the timber got saturated, the bridge gradually sank and was finally closed in 2008. Its use had been seasonal, recalls John Benson, chair of the Brookfield Selectboard and a registered civil engineer, so "there were no plans for quick replacement, since only 110 cars cross the bridge daily in summer."

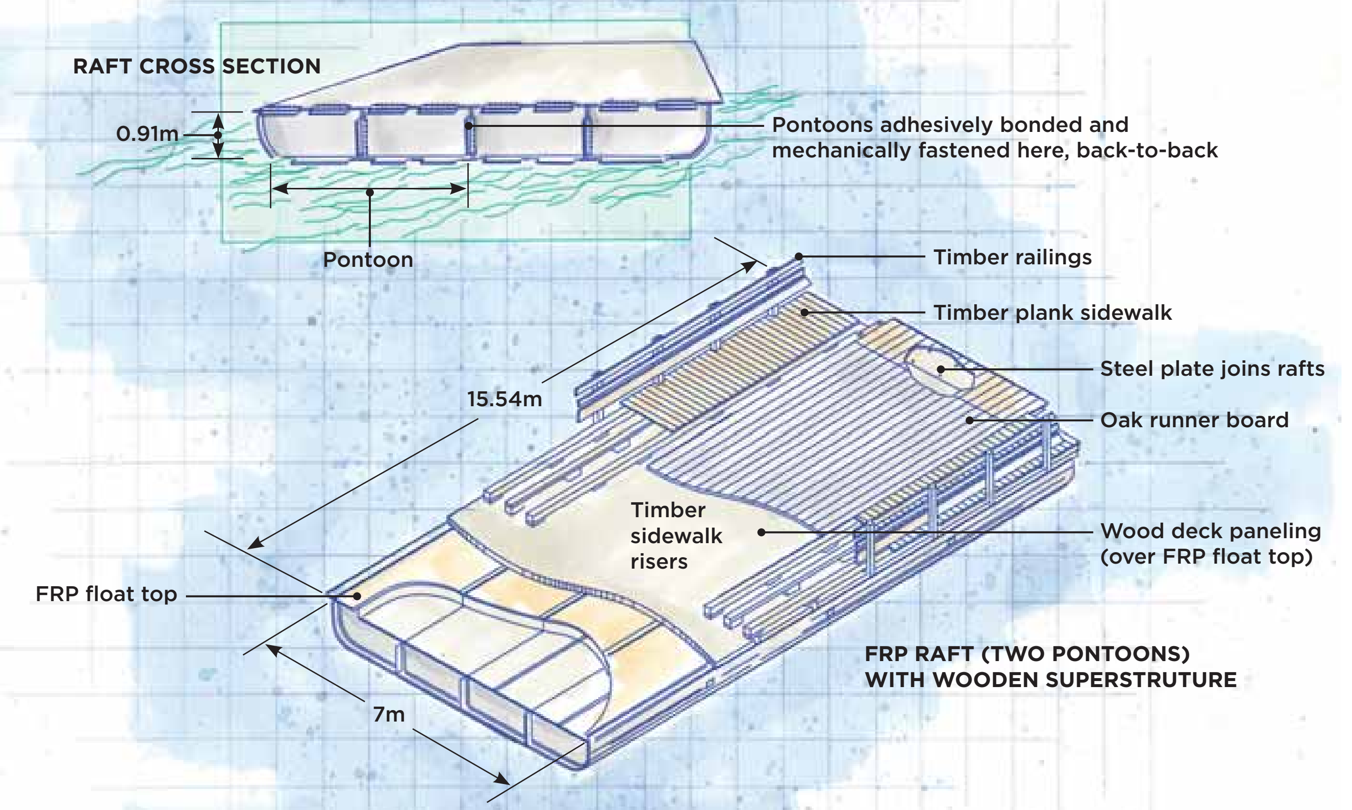
But two years later, increasing awareness of the bridge as a community landmark and a contributing element to Brookfield's listing on the National Historic Register spurred formation of a floating bridge committee. Its members — including representatives of the town, VTrans and the US Federal Highway Admin. (FHWA) — identified the need for a state-of-the-art flotation system with a 100-year life, says Fitch.

Design evolution

VTrans structures program manager Wayne Symonds first toyed with using FRP for the bridge while at the Maine Composites Showcase at the University of Maine (UMaine, Orono). He visited some of Maine's first bridge-in-a-backpack structures (designed at UMaine, see "Learn More") and the manufacturing facilities at Kenway Corp. (Augusta, ME), and Brunswick, ME-based Harbor Technologies. The latter was building floating docks for cruise ships. Symonds recalls thinking, "If .... cruise ships can bump into them, but they rebound without damage from impact, then a refined version of this technology could work for Brookfield with the traffic and ice loading."

The initial ideas for a *pontoon*-based buoyancy design came from research engineers Olivia and Xenia Rofes at UMaine's Advanced Structures and Composites Center (ASCC). "UMaine came up with the initial cross-sectional shape and helped us out as material property experts as we moved forward with final design," says Josh Olund, bridge engineer at T.Y. Lin's Falmouth, ME, office.

Although *concrete* pontoons were considered, concrete was ruled out because it would have required dredging along the shore to accommodate what would have been *3m-deep* pontoons. Specialized trucks and cranes also would have been necessary for transport and installation. "We managed everything inside the right-of-way with minimal environmental impacts," Fitch says of



DESIGN RESULTS / Kenway Composite Pontoons for Floating Bridge

- Replacement of foam-filled plastic barrel flotation system by more substantial composite pontoons extends bridge service life to 100 years.
- Modular assembly via mechanically fastened "rafts" permits maintenance/repair without removal of entire bridge from water.
- Selection of composites over concrete for pontoon material avoided expensive lake bottom dredging step.

Illustration / **Karl Reque**

the more manageable FRP, adding, "Had we gone with concrete, it would have taken longer to complete the design phase."

"FRP was a top pick since few materials have the ability to provide such longevity," Fitch sums up. "It doesn't crack easily; it can handle ice pressures; and with the addition of UV-9, an inhibitor chemical, it should not degrade easily."

The greatest design challenge was working with *unknowns*, Olund says. Because design codes for FRP bridges do not exist, the team worked with VTrans and UMaine to examine available guidance and research papers and developed its own set of criteria, using those guides as a foundation. "Every single step of the way, we had to reinvent how to approach design," he recalls.

T.Y. Lin also determined bridge loading conditions, including ice pressures, live-load configurations (pedestrian and vehicle) and buoyant-service capacity. During the winter of 2012-2013, ASCC's Sanchez set up sensors at the bridge site to record the pressure developed by the ice on the lake's surface against the existing flotation system's vertical surfaces. And as FHWA required for the new bridge, the design team increased the load capacity of the structure, designing for the larger of a single 12-ton truck or 384 lb/linear ft for cars crossing the bridge, Olund explains. "Historically, the bridge had been posted for 3 tons, but it's unclear if this was truly its design capacity."

To make construction, transport and installation practical, the FRP portion of the bridge structure was designed in five separate but identical 15.54m long by 7.01m wide sections called *rafts* (see drawing, above) each formed from two buoyant FRP pontoon structures, assembled back-to-back. Assembled rafts then would be bolted together, end-to-end, using steel splice-plates designed by T.Y. Lin, to form a monolith, undergirding the entire length of the wooden bridge. "It actually acts as one long beam, with timber on top — this is new for a bridge application," adds Olund.

To prevent water overflow that had degraded the lifespan of the previous bridge's timber decking and made it slippery for auto traffic, the team designed rotating on/off ramps with unique bearings and joints to permit the bridge to rise and fall with the lake's natural 1.7m level fluctuations.

To enable the most cost-effective solution possible, the design team elected not to dictate specific materials or substantially high material properties. "This allowed the fabricators to have flexibility in meeting project goals with materials and practices they were comfortable with," Olund explains. »

CNC-accurate tool design

Plywood stations cut with a CNC router are pieced together and decked with more plywood to form the first half of the pontoon hull mold. A rotary laser level is used to ensure the 15.54m mold is straight and level to within 1.75 mm. Source | Kenway / Photo | Jake Marquis

Pontoon tool surface prep

The plywood mold is covered with fiberglass, which then will be sanded and buffed to a glossy surface. Molded pontoons will be capped on the ends and enclosed on top, reinforced inside and filled with foam. Source | Kenway / Photo | Jake Marquis

Rafts in the water and ready

Here, the five 15.54m long by 7.01m wide rafts — each formed from two buoyant FRP pontoon structures, assembled back-to-back — are in the water and assembled, ready for connection to land and wooden superstructure. Source | Miller Construction

Pontoon fabrication

During pontoon fabrication, Kenway Corp. applied techniques it had used previously for "marine camels" — giant floating fenders that protect piers in submarine berths (see "Learn More"). "The same fiberglass, vinyl ester resin and flotation foam were used as on camel fenders," says Kenway senior project engineer Jake Marquis. After design completion, the Kenway team had to calculate the number of internal members necessary to meet stiffness and strength requirements in the pontoon sections, and then determine the pontoon shell thickness.

Kenway molded 10 identical pontoons, using a hollow mold constructed of CNC-machined plywood frames (see photos, top left and center). First, the bottom and sides of the hull were molded by laying in dry fiberglass, supplied by T.E.A.M. Inc. (Bristol, RI, US), and vacuum-infusing the layup with vinyl ester resin from Interplastic Corp. (St. Paul, MN, US). After cure, separately infused interior bulkheads were bonded into position using two-part Plexus methacrylate adhesive (ITW Plexus, Danvers, MA, US) to form a grid that was subsequently filled with flotation foam before an infused fiberglass top was bonded to the pontoon hull.

During fabrication, ASCC ran tests to verify the material properties of the composite laminates produced at Kenway for construction of the pontoons, and a series of tests to evaluate the pin-bearing strength of the composite flanges that connect the sections of the bridge. "These results were used to verify that the flanges had the strength to perform as required for the bolted joints," says Tom Snape, ASCC research engineer.

"After fabricating the pontoons, the Kenway crew staged them in their yard, matching up the [splice-]plates and drilling more than 1,000 bolt holes before delivering them to the bridge site," Marquis says. The estimated weight of a single *raft* (two pontoons), including foam filling, but no attachment hardware, is 11,570 kg.

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Read more about UMaine's "bridge in a backpack" online in "Bridge cost cut with inflatable arches" | short.compositesworld.com/DwM3fIIT

Read more about Kenway's submarine "camels" online in "Composite submarine camels win with long-term durability" | short.compositesworld.com/fU1KgKnR

Bridge installation

At the bridge site, before pontoons began to arrive, crews removed the old bridge structure and installed cofferdams before constructing new concrete abutments. "Putting a cofferdam on a ledge [at one end] was challenging, but we overcame it," says Paul Holloway, project manager at Miller Construction (Windsor, VT, US).

Beginning in August 2014, Miller Construction began joining pontoons and launching rafts, as they arrived. Pontoons were delivered to the bridge site two at a time, as they were molded and finished, over a four-month period, Holloway says.

"We made a fabrication table out of steel girders and when the pontoons showed up on the flatbed truck, we unloaded them with a crane and put them on the fabrication table where they were bonded together," Holloway says, using Plexus methacrylate adhesive.

"Three tension rods passed through both pontoons, with a nut on each end to squeeze them together while they are glued," explains Marquis. "Crews spliced them together and installed the last raft in early December just before the lake froze," Holloway recalls. Although the pontoons are expected to last for 100 years, the modular raft design of the Brookfield Bridge will permit relatively easy maintenance or replacement of pontoon sections in the event of damage without pulling the entire bridge out of the water.

"Our project created design criteria and specifications for FRP pontoon construction that could be used as a basis for future projects with similar characteristics," Olund says. But he predicts the most direct technology transfer for the floating pontoon system likely will be in the marine industry, for floating docks, wharfs, barges, pedestrian bridges and temporary military bridges. CW

ABOUT THE AUTHOR

Johanna Knapschaefer, a bilingual (English/Japanese) writer based on Boston's North Shore, writes about design and construction of buildings and infrastructure as a correspondent for *Engineering News-Record*, *McGraw-Hill Construction*, *Architectural Record* and other publications.